RESEARCH PAPER | Agriculture | Volume : 3 | Issue : 12 | Dec 2013 | ISSN - 2249-555X

Spatial evolution of the physico-chemical characteristics of water of the Oubéira lake imposed by the severs conditions in drought period (Extreme NE algerian)

Evolution spatiale des caractéristiques physico-chimiques des eaux du lac Oubéira imposée par les conditions sévères de la sécheresse (Extrême NE algerien)

KEYWORDS: Lake, Oubeira, Transect, Bathymetry, Hydrochemistry, drought period

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ABSTRACT *The Oubeira endoreic lake, vast lake located in Algeria (36°51' N-8°23' E), at an altitude of 23 m, is subject to severe natural and anthropic constraints during the dry season, which generally begins in April and is completed in October. Due to its geometrical configuration and wind exposure, the water of the lake is well brewed within the entire water column. The first results, covering all the shallow water level, show the average mineralisation of hot moderate water, which releases CO2 in the atmosphere, an alkaline pH, higher than 8, related to intense evaporation and biological activity, in particular photosynthesis and calcite precipitation. Physicochemical measurements brought a considerable contribution to identify the individualization of two distinct water masses, one in the East and the other in the West, and the absence of limnologic layers. The conditions of the environment make organic particles degraded in the water column. Conservation of organic remains in the reducing environment, represented by the mud, is much reduced. Almost circular, the Oubeira lake has a flat bottom, generally covered with greyish mud, due to the presence of reduced iron, less than 2 m thick. The thickness of the water blade hardly exceeds 1.50 m and the maximum depth, between the surface of the lake and the substratum is about 3.50 m, in drought period.*

Resumé
Le lac endoréique Oubeira, vaste plan d'eau situé au NE algérien (36°51'N-8°23'E), a une altitude de 23 m, est soumis à des contraintes naturelle et anthropique sévères, pendant la saison sèche qui débute généralement en Avril et s'achève en Octobre. Sa configuration géométrique et son exposition aux vents font que ses eaux sont bien brassées sur toute la colonne d'eau. Les premiers résultats qui couvrent tout le plan d'eau, peu profond, montrent la minéralisation moyenne des eaux tempérées chaudes, qui libèrent du CO_2 dans l'atmosphère, un pH alcalin, supérieur à 8, lié à l'évaporation intense et à l'activité biologique, notamment la photosynthèse et à la précipitation de calcite. Les mesures physico-chimiques se sont révélées d'un apport considérable pour identifier l'individualisation de deux masses d'eau distinctes, l'une à l'Est et l'autre à l'Ouest et l'absence de couches limnologiques. Les conditions du milieu font que les particules organiques sont dégradées dans la colonne d'eau. La conservation de débris organiques dans le milieu réducteur représenté par la vase est très réduite. De forme presque circulaire, le lac Oubeira a un fond plat, recouvert généralement de vases grisâtres, en raison de la présence de fer réduit, d'une épaisseur n'excédant pas les 2 m. L'épaisseur de la lame d'eau ne dépasse guère ~~les~~ 1.50 m et la profondeur maximale, entre la surface du lac et le substratum dure est de l'ordre de 3.50 m, en période de sécheresse.

Mots-clés : Lac, Oubeira, transects, bathymétrie, hydrochimie, sécheresse,

1. Introduction

The lakes of the Mediterranean circumference, and more particularly those of North Africa, show a qualitative and quantitative degradation, resulting from natural constraints (precipitations, flows) and anthropic (surveys, wastes). This degradation had consequences on the economic development of certain areas.

The Oubeira lake being the subject of this study is located in Algeria (fig. 1). This lake of a surface of 21.73 Km2, receives water wastes from small localities and in dry season some of this water is used for irrigation. These actions have for the moment few effects on the physico-chemical characteristics of water (temperature, conductivity, dissolved oxygen...). The contributions of the dry season of the tributaries are usually weak and incompetents to bring intense disturbances to the aquatic mass. Because of its situation in the african northern zone, subjected to the mediterranean climate, the area is marked by very strong evaporation losses.

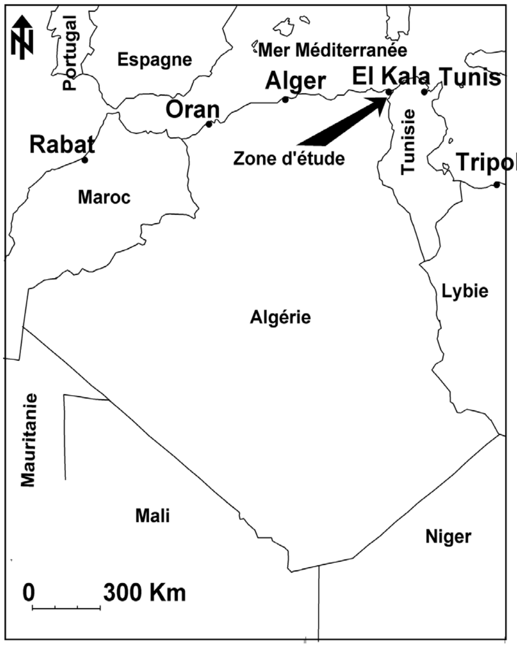

Fig. 1 : Location map of the study area

The endoreic lake of Oubeira is permanent because of the equilibrium between an evaporation of approximately 1500 mm/an and a rain supply of approximately 850 mm/an (Alayat, 1991). The dimension of the catchment area and the considerable contribution of the aquifers in the dry season, make it possible to compensate these important losses and to leave a permanent flow of the lake. The inequilibrium between the supplies and evaporation, at that time of the year, due to the anthropic surveys, with a high insolation and high temperatures, generates each year a temporary reduction of the lake extension (Anonymous, 2001). Water is withdrawn on 100 to 200 m and sometimes more, in particular towards the Western North and North.

This lake which is maintained since the quaternary age, was drained completely at the end of the summer 1990, following the important pumpings intended for the AEP and for a sequence of dry years. Consequently, the hydrous potential even if it is sufficient is not inexhaustible. Knowing the quality of water makes it possible to guide the choice of the projects of development, in particular in the agricultural and aquicultural lands and in the long term to avoid a serious destabilization of this medium.

The objective of this preliminary work consists in determining the impact of the dryness, in-situ in the Mediterranean area, the physico-chemical parameters of water and to realize for the first time bathymetric maps, starting from a tight grid. The surveys were carried out at the end of the low water level, right before the first rains of autumn, in October 2006. This period coincides to the low level of the lake water of the year (evaporation and over-irrigation).

2. Contexte Géologique

The many geological investigations in Algeria had for main goal to improve knowledge in order to facilitate the identification and the localization of the specific sites such as subsoil waters, mining, oil.... According to many studies which exist (Joleaud, 1936; Kieken, 1961; Durand Delga, 1969; Raoult, 1974; Vila, 1980;...) the geology of the area is very complex because of many overlapping and fault surfaces that have perturbed the primarily sedimentary formations during the alpine phases.

The numidian (Oligocene to Burdigalian age) appears in the catchment of the Oubeira lake. It is represented by a sandstone formation that comports at its base and top, numidian clay and clays associated with supra-numidian marl (fig. 2). The Pleistocene is visible in the Est of the lake. It is composed of sand that has been mumbled from the numidian sandstone under the influence of the hydromorphy. The realized pedologic profiles at the bank have shown a saturation during the whole year (perched aquifer) and the presence of reduced gley.

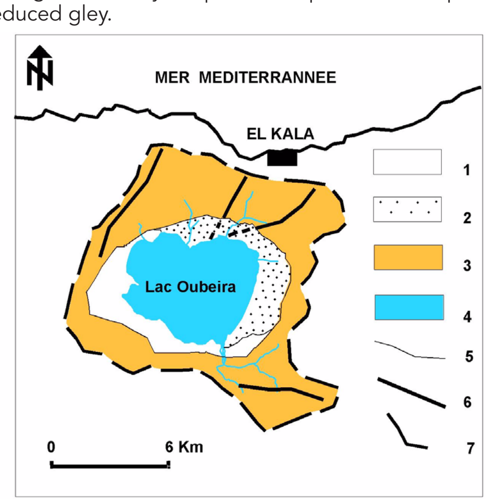

Fig. 2 : Carte géologique simplifiée de la région (vila 1980)

1 : Quaternaire ; 2 : Pléistocène ; 3 : Flysch non différencié (surtout grès numidiens et argiles de base) ; 4 : étendues d'eau ; 5 : Contacts géologiques ; 6 : Failles ;

7 : Limites du bassin versant

The marks of oxydo-reduction in the ground are often intense because of the seasonal fluctuations of the underground water. The quaternary is generally clayey-silty formation. It is associated with conglomerates in its western extension. The visible faults are very few in the catchment. They are sometimes associated with the hydrographic network.

3. Material and methods

Five parallel transects were carried out in the Oubeira lake (fig. 3). Measurements were taken on verticals according to water runoff. A point of measurement in the middle of the vertical for water blade of less than one meter and two points of measurements (one near the bottom and the other near the surface) for a water blade of more than one meter. Around fifty of measured points were thus carried out in the lake, in order to better determine bathymetry, the silting and the space evolution of the physico-chemical parameters.

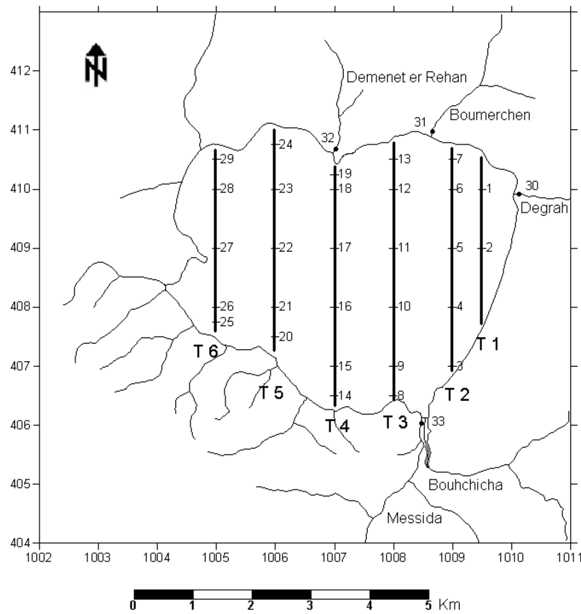

Fig. 3 : the bathymetric transects map

3.1. Measurements

Measurements realized in-situ are: - localization of the sampling sites using a GPS Garmin 72

- the height of the water blade with a ballast profiled at the end of a tick-marked line
- the thickness of the vase with a graduated pole
- electric conductivity, TDS and the temperature of water with a Heach conductimeter
- the pH with a pH device type Heach
- the oxygen dissolved with an oxymeter WTW

  the surveys intended for the physico-chemical analyses (realized at the laboratory of the UMR 8110) allowed the determination of the concentrations:
- chlorides, sulphates, nitrates and fluorine by ionic chromatography
- major cations by ICP-AES
- element traces by ICP-MS

4. Presentation and discussion of results

4.1 Bathymetry

The objective of the bathymetry is to obtain a map of the bottom of the lake using isobaths, whose study allows to

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identify the topographic anomalies (Hinschberger F and Al, 2003).. The bathymetric profiles carried in October 2006, represent the state of the bottom of the Oubeira lake at this time. The geomorphology of the lake deduced from the isobaths shows a stability of the bottom, with an increase in the depth of the banks towards the center and the absence of high bottom or low bottom (fig. 4). The maximum depth observed is 1.50 m.

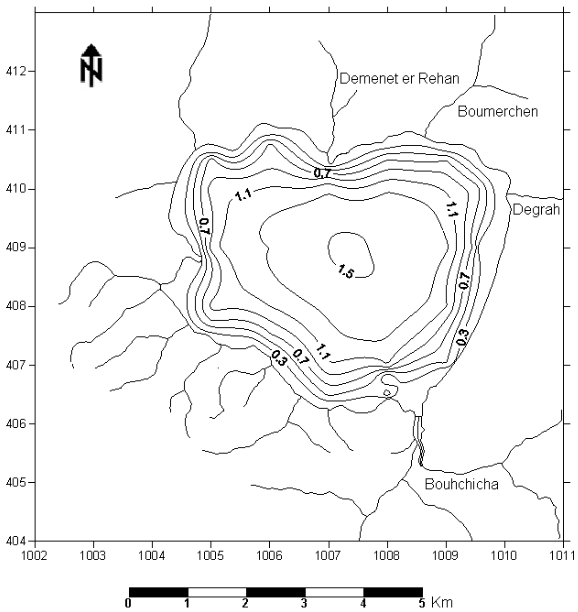

Fig. 4: Isobathic map of the lake Oubeira

The isopaque map of the Oubeira lake shows that the bottom of the lake is covered with a thick cover of vase, which reaches its maximum capacity in the center (fig. 5). The distribution of the vase coincides with that of the bathymetry. This silting could in the long term involve a serious destabilization of this medium which is an extremely precious environmental witness (Babaullt J and Al). The low slope confers to the lake a flat bottom.

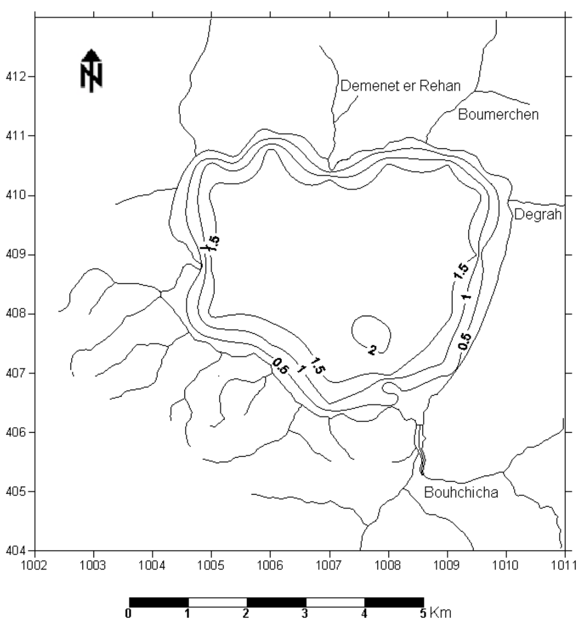

Fig. 5 : Iso-thickness vase map of the lake Oubeira

4.2 The temperature

The thermal recording is essential to understand the biological, chemical and mineralogical processes that happen in a lake. At the beginning of the dry season, the surface water is heated under the influence of the solar radiation and heat is propagated in-depth. The vertical thermal profiles carried out underline sometimes light disparities between surface and the bottom. At the end of the dry season, the temperature of the water at the bottom is generally higher than that of surface, about 0.5 to 1°C. This difference is explained by the slowness of the phenomena of reheating and/or cooling, which proceed in the water column (Dandelot S. and al, 2005; Constant P. and Al, 2005).

The confrontation of the temperature of the lake to that of the air, measured under shelters, shows a difference of about 3 to 7°C. A the end of the dry season the distribution of the isotherms in the stations on lake surface shows that the depth coincide perfectly with the bathymetric profile of the lake (fig. 6).

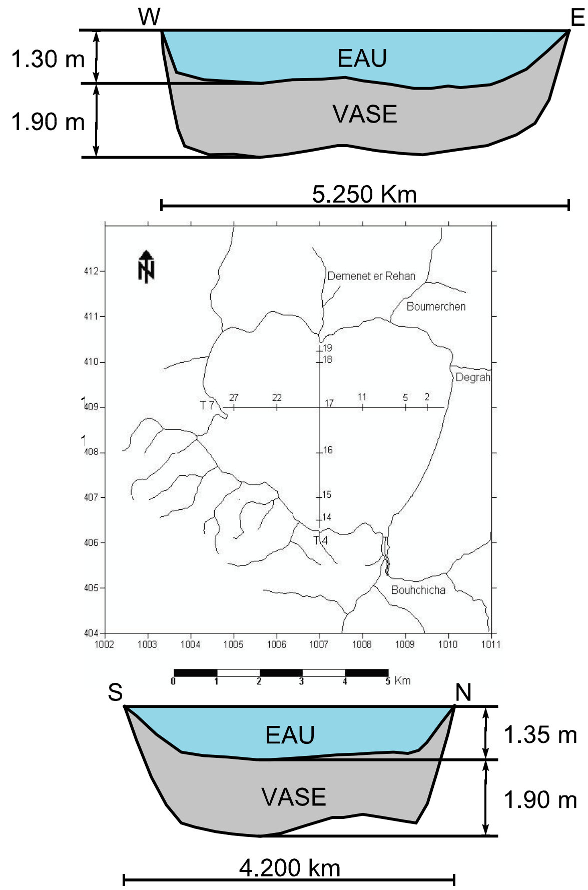

Fig. 6 : Isothermal map of the lake Oubeira

4.3 The dissolved oxygen concentration

The dissolved oxygen depends primarily on the breathing and the photosynthesis of the planktonic populations and the mineralization of the biomass. The oxygen content dissolved in water is closely related to the temperature pattern of the lake (Villeneuve V and Al). The high temperature of the season generates a proliferation and consequently, a strong increase in the dissolved oxygen concentration. The East bank is well oxygenated because of its exposure. The isopleth of concentration 10 mg/l delimits on the surface of the lake and in-depth two distinct aquatic masses. One impoverished of dissolved oxygen and the other supersaturated. The super-saturations in Oxygen can reach concentrations of 16 mg /l (fig. 7).

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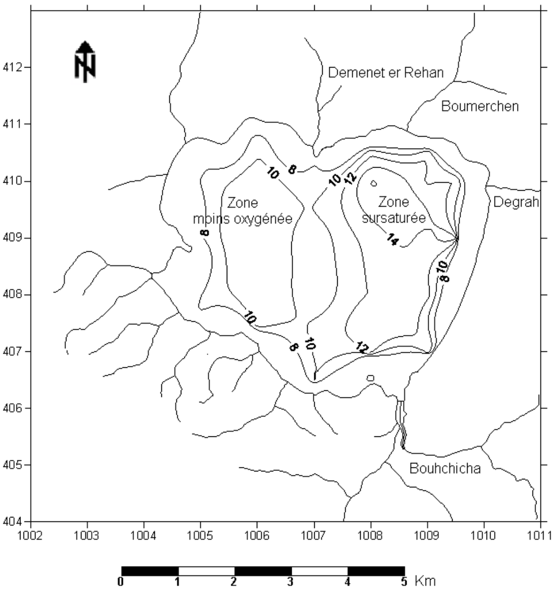

Fig. 7 : Isopleth map of the dissolved oxygen concentration of the lake Oubeira

The lake also undergoes in this season, a push of zooplancton which consumes the population algaire of the summer and involves the disappearance of the supersaturated layer in oxygen in its Western part. A bad homogenisation can be partly at the origin of this situation. Dissolved oxygen is well correlated with the temperature (Tabl. I).

	T	pH	CE	O_2	Ca	Mg	Na	K	Cl	SO_4	HCO_3	NO_3
T	1,00											
pH	-28,1	1,00										
CE	5,6	13,5	1,00									
O_2	-72,8	21,3	-5,3	1,00								
Ca	-18,4	15,3	-7,3	30,6	1,00							
Mg	5,0	-25,9	7,7	-5,8	-30,0	1,00						
Na	-6,0	-1,1	9,2	11,1	34,4	35,9	1,00					
K	-11,1	-4,3	-9,0	33,4	14,6	64,6	45,2	1,00				
Cl	-6,4	8,8	7,1	3,8	4,7	21,8	37,6	14,1	1,00			
SO_4	4,6	8,5	-4,2	-3,9	-13,8	13,6	16,2	-2,7	88,6	1.00		
HCO_3	-3,6	-31,4	0,7	4,6	-28,8	36,7	4,6	19,8	-2,6	6,6	1,00	
NO_3	17,5	-15,4	3,4	-0,6	-31,1	43,7	6,8	16,5	25,7	51,3	27,6	1,00

Tabl. I: Matrix of the correlations

4.4 The pH

The pH of the water surface depends on the concentration of CO_2. Photosynthesis algaire consumes more CO_2 and thus causes a notable increase in the pH of water. Breathing, on the contrary, contributes to its lowering by production of carbon dioxide. In the same way during the mineralization of the organic matter, the production of CO_2 involves a fall of the pH (Alayat, 2006). Finally, the carbonate precipitation induces an alkalisation and their dissolution and acidification.

The alcalimetric disparities are not ascribable, with the contributions of more acide river flows or rains of the season. The stations located at the West show a low pH, approaching tha value of 8, on the other hand in the East the pH is almost 9. This difference is explained by the mineralization of the organic matter, creating a reduction in the pH towards the Western bank of the lake and by the activity of the zooplanctonic populations. The alkalinity of the Oubeira lake is due to the phytoplanctonic populations and partly to the precipitation of carbonates, in particular of calcite, starting from bicarbonates. However, the vertical profiles show that the pH remains constant in all the water column.

The spatial evolution of the pH represented by the maps of isopleth related to pH results in a desalcalinisation of the aquatic mass, on the surface and at the bottom, from the Est to the West, parallel to the reduction in the concentration of dissolved oxygen (fig. 8).

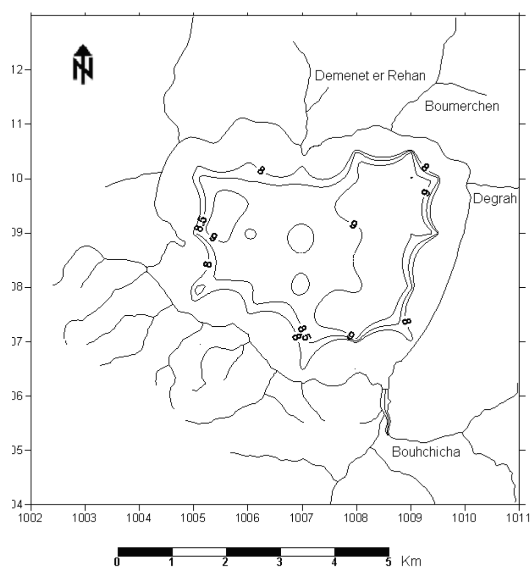

Fig. 8 : Map iso-pH of the surface of the lake Oubeira

4.5 Electric conductivity

The Measurements of the electric conductivity (noted EC) of water translate the content of the dissolved salts. The interest of measurements of the EC appears especially in their space

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evolution (Stournaras G. et al., 1989). The isopleth of the EC show the increase in the mineralisation of water as soon as one moves away from banks, in particular towards the SE and the SW (Fig. 9). Contrasts of EC do not make it possible to highlight pollution, zones of mixtures or drainance. Indeed the weak contributions of end of dry season of the affluents cannot be at the origin of the variation of the EC of water of the lake.

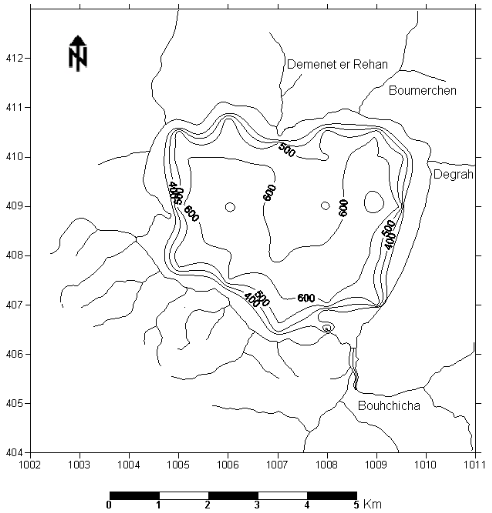

Fig. 9 : Carte iso-CE de la surface du lac oubeira
Fig. 9 : Map iso-CE of the surface of the lake Oubeira

In the Oubeira lake, the EC varies little or according to the depth. The transverse profile E-W, shows disparities of significant electric conductivities between the stations which are not ascribable with the wastes nor with measurements, which were checked in situ and done twice. They could be possibly explained by the planktonic successions of families.

4.6 Major cations and anions

The contents of Ca+Mg, Na+K, HCO3+CO3 and Cl+SO4 of water in the lake and the tributaries (Fig. 10), show that the principal radical acid is chlorine and the principal radical basic element is sodium (tabl. I and II). The nitrate contents of the lake are very low of about 10 with 500µg/l. This water also has relatively average contents of calcium (35 to 45 mg/l) and magnesium (13 to 15 mg/l) compared to the total mineralization (Stournaras G and al, 1989). These values plead in favour of an absence of pollution by the tributaries and the traditional seasonal agricultural activity (culture of groundnut).

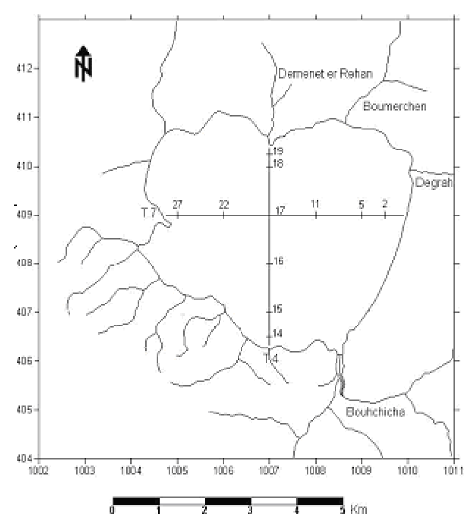

Fig. 10 : Bathymetric cuts NS and E-W

Stations	Ca+Mg meq/l	Ca+Mg %	Na+K meq/l	Na+K %	HCO3+CO3 meq/l	HCO3+CO3 %	Cl+SO4 meq/l	Cl+SO4 %
V2	3.13	45.04	3.82	54.96	2.44	34.13	4.71	65.87
V5/1	3.07	44.43	3.84	55.57	2.32	32.77	4.76	67.23
V5/2	3.15	44.81	3.88	55.19	2.24	30.52	5.10	69.48
V11/1	3.12	45.15	3.79	54.85	2.68	35.64	4.84	64.36
V11/2	3.10	46.13	3.62	53.87	2.64	35.97	4.70	64.03
V17/1	3.07	44.43	3.84	55.57	2.56	33.55	5.07	66.45
V17/2	3.08	45.43	3.70	54.57	2.40	33.06	4.86	66.94
V22/1	2.96	43.92	3.78	56.08	2.68	35.97	4.77	64.03
V22/2	3.08	44.96	3.77	55.04	2.52	34.47	4.79	65.53
V27/1	3.07	44.49	3.83	55.51	2.12	32.17	4.47	71.47
V27/2	3.06	44.35	3.84	55.65	2.20	31.47	4.79	68.53
Pluie	0.87	52.78	0.78	47.22	0.93	62.00	0.57	38.00
Demenet er Rehan	0.87	38.67	1.38	61.33	0.57	26.39	1.59	73.61
Boumer-chen	1.17	46.61	1.34	53.39	0.80	32.79	1.64	67.21
Bouhchi-cha	3.6	46.51	4.14	53.49	3.26	40.85	4.72	59.15
Degrah	3.03	43.85	3.88	56.15	0.82	11.80	6.13	88.20

Tabl. I: Cations content and anions of the waters of the transverse transect, the wadis and the Rain

Stations	Ca+Mg meq/l	Ca+Mg %	Na+K meq/l	Na+K %	HCO3+CO3 meq/l	HCO3+CO3 %	Cl+SO4 meq/l	Cl+SO4 %
V2	3.13	45.04	3.82	54.96	2.44	34.13	4.71	65.87
V5/1	3.07	44.43	3.84	55.57	2.32	32.77	4.76	67.23
V5/2	3.15	44.81	3.88	55.19	2.24	30.52	5.10	69.48
V11/1	3.12	45.15	3.79	54.85	2.68	35.64	4.84	64.36
V11/2	3.10	46.13	3.62	53.87	2.64	35.97	4.70	64.03
V17/1	3.07	44.43	3.84	55.57	2.56	33.55	5.07	66.45
V17/2	3.08	45.43	3.70	54.57	2.40	33.06	4.86	66.94
V22/1	2.96	43.92	3.78	56.08	2.68	35.97	4.77	64.03
V22/2	3.08	44.96	3.77	55.04	2.52	34.47	4.79	65.53
V27/1	3.07	44.49	3.83	55.51	2.12	32.17	4.47	71.47
V27/2	3.06	44.35	3.84	55.65	2.20	31.47	4.79	68.53
Pluie	0.87	52.78	0.78	47.22	0.93	62.00	0.57	38.00
Demenet er Rehan	0.87	38.67	1.38	61.33	0.57	26.39	1.59	73.61
Boumer-chen	1.17	46.61	1.34	53.39	0.80	32.79	1.64	67.21
Bouhchicha	3.6	46.51	4.14	53.49	3.26	40.85	4.72	59.15
Degrah	3.03	43.85	3.88	56.15	0.82	11.80	6.13	88.20

Tabl. II: Cations content and anions of the waters of the longitudinal transect, the wadis and

The rain

At that time of the year, the Demenet er Rehan, Boumerchen, Degrah and Bouhchicha tributaries which receive water wastes present at their mouth water just a little more mineralized than that of the lake, (fig. 15). This is explained by the self-purification, the low flow (some litres/secondes) and the effect of filter that sands offer to their outlet system.

The highest nitrate content of the tributaries is observed in the oulet of the wadi Boumerchen (either 2 mg/l).

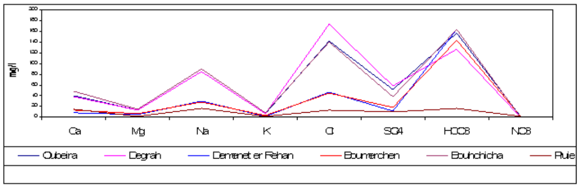

Fig. 11 : Chemical composition of water of the lake Oubeira, the rain and the wadis degrah, Demenet er Rehan, Boumerchen and Bouhchicha

The contents in Ca+Mg, Na+K, HCO3+CO3 and Cl+SO4 of the rainwater show that the principal radical acid is calcium and the principal radical basic element is bicarbonate. This water has very low contents of calcium (about 14 mg/l) and magnesium (about 2 mg/l). The nitrates remain low but exceed the contents observed in the water level to reach more than 1 mg/l. They come from the oxidation of ammoniacal nitrogen. The mineralization of this water is very low (EC = 204 µS/cm).

In the surface water of the area, the nitrates come mainly from the spreading of nitrate fertilizers (chemical or organic) and from the natural biological cycle, either by decomposition of the organic matter, or by active production of certain plants, in a saturated zone as in unsaturated zone (Travi, 1997; Le Borgne, 2006). In our case, nitrates in negligible quantity are induced from the rains. We did not make observations where water undergoes the effects of the anthropic activities. Our observations reflect a natural denitrification of water during various reactions of organic or inorganic reduction of ion NO_3^-.

4.7 Turbidity

The measurement of turbidity makes permitted to specify visual information on water. It translates the presence of suspended particles in water (microscopic organic debris, clays, organizations...). the taken measurements show that the turbidity of the aquatic mass varies very little in space, about 18 to 25 NTU (nephelometric turbidity unit). According to the classification of the French network on water and the cleansing (noted, RéFEA), which counts 4 of them class, the water of the Oubeira lake is slightly turbid (5 <classe 2<30NTU. The low variations of opacity can be explained by the reduction of the algaire proliferation, after the diminution of the nutritive supplies, the zoologic development, and absence of the thermic stratification and the violent winds.

4.9 Diagram of Piper

The plot of results from analyses of the transversal and longitudinal transects on a triangular diagram show the superposition and the regrouping of the studied stations in cluster, because of the low variability of the concentrations from a station to an another (fig. 12 and 13). The figurative points of the wadis Demenet er Rehane, Boumerchen and Bouhchicha are associated with those of the lake. Only the points representing the Degrah wadi and the rain deviate to a significant degree. It follows that water of the lake and the tributaries are chlorinated sodic but water from the rain is rather bicarbonated calcium and magnesium. In spite of low variations in concentration of the major elements observed in the lake, the diagram of Piper provides the same chemical facies of water in the lake.

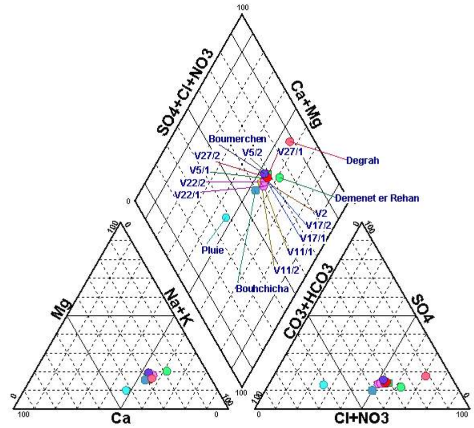

Fig. 12 : Faciès chimiques des eaux du profil transversal du lac Oubeira, des oueds Demeneter Rehan, Boumerchen, Degrah, Bouhchicha et de pluie

Fig. 12 : Chemical facies of water of the transerse profile of the lake Oubeira, the wadis Demenet er Rehan, Boumerchen, Degrah, Bouhchicha and of rain

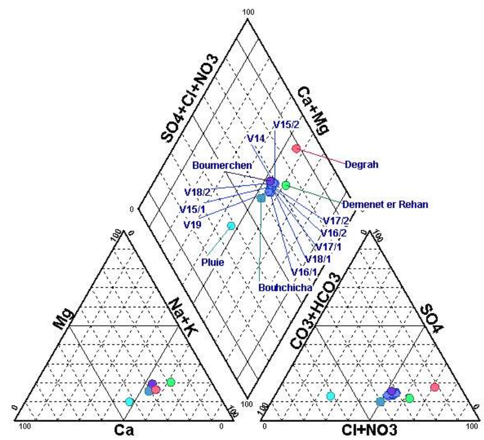

Fig. 13 : Faciès chimiques des eaux du profil longitudinal du lac Oubeira, des oueds Demeneter Rehan, Boumerchen, Degrah, Bouhchicha et de pluie

Fig. 13 : Chemical facies of water of the longitudinal profile of the lake Oubeira, the wadis Demenet er Rehan, Boumerchen, Degrah, Bouhchicha and of rain

The less to moderate mineralized water of the lake (390-760 µS/cm) is bicarbonated sodic of type Na-HCO_3. They are different from rainwater, bicarbonated calcium and magnesium, slightly mineralized (204 µS/cm of type Ca-Mg-HCO_3), and very close to those of the tributaries, which are fairly mineralized. The water of the lake has a mineralization comparable with that of the tributaries little influenced by the human activities.

The fine Quaternary sediments of the bottom of the lake are the products of weathering and erosion of the numidian clayey sandstone. They can transmit to the lake a part of the geochemical characteristics (Perroux, 2006). Moreover, the rainwater and the tributaries of wadis Demenet er Rehan and Boumerchen lose their principal characteristics in contact with water of the lake. The concentrations in major elements seem to grow according to the time sejourn of water. Water of the Degrah tributary is different from those of the lake by the low contents of HCO_3^- and fairly low contents of Cl^- and SO_4^{2-}. Water of the wadi Bouhchicha has higher contents of HCO_3^- and fairly low content of Cl^- (fig. 15). We observe here the result of cation exchanges on clayey minerals.

Volume : 3 | Issue : 12 | Dec 2013 | ISSN - 2249-555X

4. Conclusion

The Oubeira lake is an extremely precious environmental witness, which integrates many hydroclimatic parameters that react quickly. With the end of the dry season, the general behaviour of the temperature of the lake is almost identical. It does not present a thermal stratification. The lake stratification is disturbed by the direction and the intensity of the violent winds, able to re-establish a homogenisation in the water column. The bad weather generates a progressive mixing until the return of the homothermic of the aquatic mass of the lake. The thermal distribution is conditioned by topography characteristic of the lake. The thermal gain observed in the lake, is occurred by the low deepness of the bottom and in any way by the tributaries' supplies that are very low in this specific period of the year. The northern bank has water hotter than that of the southern bank because of the prevailing winds and the exposure.

The vertical evolution of dissolved oxygen appears in a comparable way on all the stations of the longitudinal and transverse profiles. The isopleths of concentration follow the thermal profile of the lake identifying two different aquatic masses; one super-saturated and the other less oxygenated. This zonation is explained partly by the microbiological behaviour and the exposure of the East bank to the dominant winds that lead to the mixing of water. Indeed, the mineralization of the organic particles involves the dissolved oxygen entrainement and the lowering of the pH. At the end of the dry season, the Western part of the lake undergoes a deoxygenation whose threshold drops around 7.4 mg/l.

The whole measurements of pH show that the mass of water at that time of the year is basic and that there are alcalimetric disparities between the eastern and the western banks of the Oubeira lake. They are not affected by exogenic supplies. The observed alkalinity of water is due primarily to the biological activity and incidentally to the precipitation of carbonates. The winds can be at the origin of the Western displacement of this aquatic basic and de-oxygenized mass.

If the vertical variations of the electric conductivity of water in the Oubeira lake are less sensitive at the end of the dry season, the spatial variations are important. Indeed, water is richer in dissolved salts inside the lake than in the edge and in particular towards the SE and the SW direction. However, the water of the lake remains soft. The variations of the electric conductivity are explained by the behaviour of the planktonic populations, the physico-chemical reactions and the time of sejourn of water in the lake. The possible underground water supply of the lake, at this time of the year, by more more mineralized water is an assumption to be checked in the south eastern part of the lake.

The self-purification activated by the continuous mixing of water gives a less content of nitrogen and phosphorus and shows the absence of particular degradation of the quality of the water which could have an origin defined as eutrophication. Because of the low power of the lake water column, the algae when decomposed do not affect the quantity of oxygen dissolved in water. Finally, the facies of water in the lake and that of the tributaries are on one hand chlorinated sodic and on the other hand the onesbelonging to the rainwater are bicarbonated calcicium and magnesium. The silting of the lake is a major problem which, in long terms, will involve the modification of the ecosystem. A dredging is essential!

Tabl. III: Extreme and average values of Fe, Al, Mn et F of water in the Oubeira lake

Valeurs	Fe mg/l	Al mg/l	Mn mg/l	F mg/l
Minimum	0,10	0,03	0,03	0.18
Moyenne	0,59	0,15	0,12	0.27
Maximum	3,23	0,88	0,49	0.45
Norme	0,2	0,2	0,05	**1,5**

Tabl. IV: Matrix of the correlations

	T	pH	CE	O_2	Ca	Mg	Na	K	Cl	SO_4	HCO_3	NO_3	Al	Fe	Mn	F
T	1,00															
pH	-28,1	1,00														
CE	5,6	13,5	1,00													
O_2	-72,8	21,3	-5,3	1,00												
Ca	-18,4	15,3	-7,3	30,6	1,00											
Mg	5,0	-25,9	7,7	-5,8	-30,0	1,00										
Na	-6,0	-1,1	9,2	11,1	34,4	35,9	1,00									
K	-11,1	-4,3	-9,0	33,4	14,6	64,6	45,2	1,00								
Cl	-6,4	8,8	7,1	3,8	4,7	21,8	37,6	14,1	1,00							
SO_4	4,6	8,5	-4,2	-3,9	-13,8	13,6	16,2	-2,7	88,6	1.00						
HCO_3	-3,6	-31,4	0,7	4,6	-28,8	36,7	4,6	19,8	-2,6	6,6	1,00					
NO_3	17,5	-15,4	3,4	-0,6	-31,1	43,7	6,8	16,5	25,7	51,3	27,6	1,00				
Al	-17,8	-27,8	14,6	13,1	20,8	6,0	3,7	-9,7	12,3	-2,1	9,7	-22,0	1,00			
Fe	18,5	-19,0	-13,0	-20,1	7,4	-2,0	-8,0	-11,4	-13,3	-16,2	-39,7	-3,3	8.0	1,00		
Mn	19,2	-20,8	-2,7	-27,1	6,4	-1,9	-4,1	-18,6	13,7	-14,7	-35,3	-2,5	9,7	94,5	1,00	
F	28,0	-20,4	-2,1	-28,4	-2,6	-0,1	-11,2	-16,9	-22,9	-20,8	-34,5	5,2	-1,9	84.9	***93,2***	1,00

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