Moroccan Journal of Chemistry
ISSN: 2351-812X
http://revues.imist.ma/?journal=morjchem&page=login
Fadlaoui & al. / Mor. J. Chem. 8 N°1 (2020) 280-292

CONTRIBUTION TO THE EVALUATION OF THE PHYSICOCHEMICAL QUALITY OF THE SUPERFICIAL WATERS OF OUED ZEGZEL (NORTHEAST OF MOROCCO)

Soufiane FADLAOUI*, Mustapha BOUTERFAS, Ouahid EL ASRI, Hassan EL HALOUANI, Mohammed MELHAOUI

Mohamed First University, Faculty of sciences, Department of Biology, Laboratory of Water, Environment, and Sustainable Development, P.B. 717, Oujda city, Morocco.

* *Corresponding author:* soufiane.fadlaoui@gmail.com

Received 10 Oct 2019, Revised 08 Feb 2020, Accepted 12 March 2020.

Abstract

Data on water quality of Oued Zegzel and the characteristics of the sources of degradation are few and far between. In this context, this study concerns the analysis of 18 physicochemical parameters (SF, T°, pH, O_2, SM, EC, TDS, Sal, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, TH, NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}, Oxid) of the waters of this Oued in order to establish a diagnosis of the state of pollution of the surface waters of this river. Thus, water samples were taken from six stations during one year from October 2017 to September 2018 to allow a comparison between the low-water period and the flood period. The analysis results show that the waters of the stations are bicarbonated with calcium and magnesium, reflecting the geological and pedological nature of the terrain crossed by this watercourse. The values of most of the parameters analyzed generally indicate that the waters of Oued Zegzel are good to excellent quality according to the Moroccan surface water standards. Thus, the results of the Principal Component Analysis (PCA) revealed two gradients. The first reflects the degree of organic pollution, while the second describes the mineralization of water. In addition, this PCA made it possible to discriminate between stations according to their physicochemical data.

Keywords: Water quality, Physicochemical, Moulouya, Oued Zegzel, PCA.

1.Introduction

Renewable fresh water is an essential resource for life. It deserves particular attention, as it is very altered and seriously threatened by human activities. Indeed, population growth accompanied by rapid urbanization, which causes numerous disruptions to natural environments [1], industrialization, the irrational use of fertilizers and pesticides and the lack of public awareness of environmental protection, lead to an imbalance in the ecosystem and generate pollutants that can affect the physical, chemical and biological quality of receiving aquatic environments [2], but also to alter water uses (water abstraction, swimming, etc.) [3]. Indeed, rational water management requires a good knowledge of the functioning of freshwater ecosystems. It is essential to consider aquatic environments like chemical, physical and biological ecosystems more or less distant from their equilibrium states and for which the parameters that describe them, considered at a given moment, are linked to each other by relationships that evolve with their states [4]. The physicochemical characteristics of water determine those of aquatic biocenoses from a structural and functional point of view. Thus, discharges related to human activities, by modifying the chemical characteristics of water, can also modify the living communities of the receiving aquatic environment. The pressure exerted by this anthropogenic disturbance will depend on certain characteristics (concentration, amplitude, duration, frequency). The response of biocenoses will result in changes in their development dynamics [5], biomass [6] and biodiversity [7]. In Morocco, surface runoff is dependent on rainfall and has a high spatial variability [8]. In general, Morocco's water resources are limited and subject to extreme cyclical variations [9]. Similarly, the water quality situation is far from satisfactory [10]. At the scale of the province of Berkane, located in the administrative region of Oriental, Oued Moulouya is the main drain of the hydrographic network of the region. Indeed, the surface hydrographic network that collects rainwater to discharge into this Oued is essentially composed of the Oueds: Bouroulou, Jaara, Chabrane, Lakhmiss, Elouddah, Bourdim, Benbouchta, Bouhria, tizià and Zegzel (artery of Oued Cherraa). Oued Zegzel was the subject of various scientific research [11-19]. The Zegzel valley is located at the level of the Beni Snassen mountains. It is partially bordered by the road that connects the city of Berkane to the village of Tafoughalt through the village of Tazaghine. Like many Moroccan tourist communities, the communities of Zegzel is confronted with major sources of dysfunction. These dysfunctions are linked in particular to agricultural activities (the diversion of water from the Oued, the irrational use of fertilizers and phytosanitary products) and pollution linked to tourist activities. The interest in this watercourse mainly lies in the fact that the waters of this Oued are used for irrigation, swimming, livestock watering and domestic activities of the surrounding population. This state of place can generate a serious imbalance in this aquatic ecosystem and cause nuisances for the human population and fauna and flora. A diagnosis of the current pollution situation and rigorous spatio-temporal monitoring of its evolution are of great importance for the protection of this ecosystem.

2. MATERIAL AND METHODS

Study area and sampling station

Oued Zegzel is an artery of Oued Cherraa, the main tributary of Moulouya downstream of the Mechraa Homadi dam; its watershed lies entirely within the Beni Snassen Massif, which is practically the largest mountain in the northeastern region of Morocco (fig. 1). The Zegzel-Cherraa basin, with an area of about 280 km², has a subrectangular, elongated east-west shape. It lies between latitudes 34°16' N and 34°22' N and longitudes 5°00' W and 5°30'W. Taking into account the various activities identified in the study area (agricultural and tourist activities), six sampling stations distributed along Oued Zegzel (fig. 2) were selected in such a way that they are accessible and reflect the actual characteristics of the surface waters of Oued Zegzel at the study area level:

Station 1 (Amont Zegzel): Located at the following coordinates (34°50'18.93" N 002°21'53.87" O) at 440 m altitude. The water is spread in a small natural basin 6 m long and 3.5 to 4 m wide. Temperatures are much more s**Table** at 22.5 °C than downstream. Water flows at a moderate to nil speed over a heterogeneous substrate made up of blocks, pebbles, gravel, sand and silt. Depths can reach less than 15 cm in some places and more than 80 cm in others.

Station 2: Located at the following coordinates (34°50'24.63" N 002°21'21.74" O) at 430 m altitude. It is known by a very important tourist influx especially, in the spring and summer periods. Temperatures are of the order of 19.3 °C. Depths can reach less than 10 cm in some places and more than 70 cm in others and the width of the stream does not exceed 5 meters. The substrate consists of slabs, pebble and sand.

Station 3: Located at the following coordinates (34°50'50.36" N 002°21'34.62" O) at 352 m altitude. Temperatures are of the order of 18.5 °C. The depths can reach less than 15 cm in some places and more than 50 cm in others and the width of this section oscillates between 5 to 7m. The substrate consists of slabs covered with a few emerged and semi-emerged blocks, pebbles, stones, and pebbles with mud on the banks.

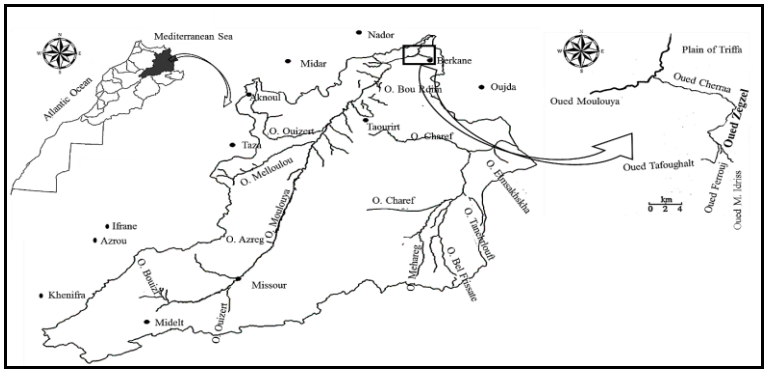


Figure 1. Localization of the study area, Oued Zegzel, Morocco

Station 4: Located at the following coordinates (34°51'11.76" N 002°21'41.79" O) at 336 m altitude. In this shaded stream, temperatures are much more s**Table** 18.5 °C than downstream. Water flows at a moderate speed. Depths can reach less than 20 cm in some places and more than 1 m in others. The substrate is heterogeneous and consists of large semi-emerged blocks, pebbles, stones, pebbles and sand and silt.

Station 5: Located at the following coordinates (34°51'52.74" N 002°22'09.10" O) at 292 m altitude. Temperatures are of the order of 17.5 °C. The bed is very wide, it oscillates between 8 to 12m. Depths can reach less than 20 cm in some places and more than 40 cm in others. The water flows on a substrate composed of pebbles covered with resting on a muddy bottom.

Station 6 (Aval Zegzel): Located at the following coordinates (34°52'22.32" N 002°21'49.08" O) at 267 m altitude. The temperatures are of the order of 18.5 ° C. The slope is lower, the width of the major bed is of the order of 4.5 to 6 m. The bottom is dominated by pebbles covered with filamentous algae and periphyton, with blocks and accumulations of sand and mud.

<u>Water sampling and measurement of physicochemical parameters</u>

During our study cycle, our measurements *in situ* and our samples were taken monthly during the period from October 2017 to September 2018. At each sampling, the water temperature (T°), the electrical conductivity (EC), the salinity (Sal) and total dissolved solids (TDS) were measured in situ using a por**Table** multi-parameter (WTW 330i) while that of dissolved oxygen (O_2) is done using an oximeter (Orion Star A123) and the pH was measured using a pH meter (Jenco 6175). The water samples were taken in polyethylene bottles, previously rinsed with water from the station.

They were then stored at 4 °C during transport to the laboratory and analyzed within 24 hours. The methods of analysis are those recommended by Rodier standards (**Table** 1) [20].

Statistical Analysis (PCA)

This method has been widely used to interpret hydro chemical data of hydro systems [21-28, 7].

The PCA was performed using the SPSS software (version 23). A raw data matrix with 18 physicochemical variables was used. The variables selected for this statistical study are: Streamflow (SF), Temperature (T°), Hydrogen Potential (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity (Sal), Suspended Matter (SM), Dissolved Oxygen (O2), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Total Hardness (TH), Chlorides (Cl^-), Sulfates (SO_4^{2-}), Nitrogen compounds (NO_3^-, NO_2^- and NH_4^+), Orthophosphates (PO_4^{3-}) and Oxidability (Oxid).

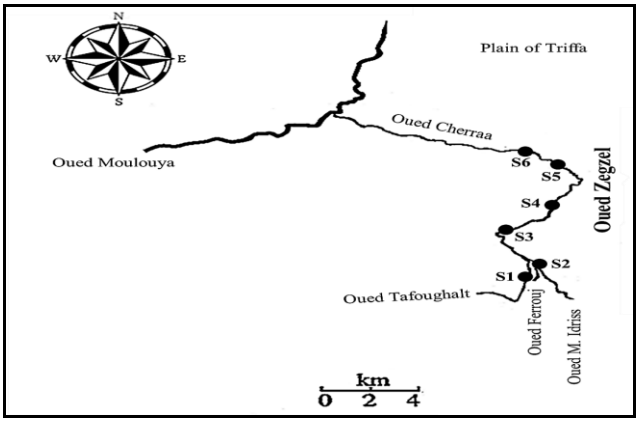


Figure 2. Localization of the sampling sites, Oued Zegzel, Morocco

Table 1. Methods of analysis of the different physicochemical parameters

Parameters analyzed	Unit	Methods of analysis
Suspended Matter	mg/l	Filtration on filter paper (Whatman)
Oxidability	mg/l	Determination by the Potassium Permanganate method
Sulfate	mg/l	Determination by the spectro-photometric method with chloridic acid and barium chloride reagents
Chloride	mg/l	Volumetric method using mercuric nitrate
Total Hardness	meq/l	Volumetric method with a complexing reagent EDTA
Calcium	mg/l	EDTA titrimetric method
Magnesium	mg/l	EDTA titrimetric method
Nitrate	mg/l	Determination by the spectrophotometric method with sodium salicylate reagent
Nitrite	mg/l	Determination by the spectrophotometric method with diazotization reagent
Ammonia	mg/l	Determination by spectrophotometric method with sodium phenol nitroprusside reagent
Orthophosphate	mg/l	Determination by the spectrophotometric method with ammonium molybdate reagent

3. RESULTS AND DISCUSSION

Physicochemical quality of water

Temperature (T°)

The temperature of the analyzed water oscillates between 11.6 °C and 24.70 °C (fig. 3). It should be noted that the temperature differences in this hydro system are related to the depths of the water (the more the depth decreases the more the water is hot) than to the absence of riparian rivers. Referring to the Moroccan standards of surface waters (MSSW) stipulated by SEEE [29], the waters of all the stations belong to the excellent class of water quality.

pH

In most natural waters, the pH is usually between 6 and 8.5. The average values observed in the Oued Zegzel indicate a slightly neutral to alkaline pH, both during the rainy period and in the dry period with an average of between 7.44 and 8.18 pH units (fig. 3). The small variation in pH throughout the study period is a good illustration of the water buffering effect at the study stations. This phenomenon can be explained by the combined effect of significant photosynthetic activity (as evidenced by the development of algae in the bed of the stream) and the lithological nature of the lands crossed by the waters (marno-dolomitic and limestone formations). It should be noted that in this pH range, we are in an optimal zone of production for most animal and plant species [30]. According to the Moroccan standards of surface waters [29], all the studied station's present waters of excellent quality.

Electrical conductivity (EC)

During our study period, the mean values of the electrical conductivity (EC) indicate significant variations in the Oued Zegzel. They fluctuate on average between 545.83µS/cm at the station (S2) and reach 1067.82 µS/cm at the station (S5) (fig. 3). At the same time, this average conductivity follows a gradient increasing from upstream to downstream since it remains low in (S2) and increases overall from (S3). A decrease in this parameter is observed at (S2) following the contribution of groundwater from the source of Ain Bourbah characterized by lower conductivity values than those of Oued Zegzel waters. This strong ionization of the waters of our watercourse seems to be related to the geological (limestone) nature of the underlying lands which are crossed by the sources of this zone which still feed the stream from the (S3) station. Referring to the Moroccan standards of surface waters stipulated by SEEE [29], it can be concluded that the waters of Oued Zegzel can be classified in a good class.

Dissolved oxygen (O_2)

In our study, the seasonal evolution of dissolved oxygen shows higher concentrations in wet periods than in dry periods. Indeed, the recorded concentrations vary between 5.52 mg/l (S2) and 9.43 mg/l (S3) and between 4.26 mg/l (S6) and 8.24 mg/l (S4) respectively in wet and dry periods (fig. 3). This is mainly due to the decrease in water temperature; because cold water contains a greater amount of dissolved oxygen than warm water [31], and to high wind speeds that cause a continuous mixing of the water mass and consequently an enrichment of the dissolved phase with dissolved oxygen during the winter season. The high flow rate during the wet period can also increase the exchange of oxygen with the atmosphere and thus facilitate air circulation and subsequently influence the concentration of dissolved oxygen. Indeed, the high values are recorded at the stations ((S2), (S3) and (S4)) that experienced flooding during the February, March and April 2018 campaigns. However, during the summer season, the warming of the water and the low flow rate of the Oued due to the diversion of water to agricultural plots cause a decrease in the dissolution of dissolved oxygen aggravated by an increase in oxygen consumption by living organisms in the Oued. Thus, the low dissolved oxygen levels observed in the dry period at stations (S2) and (S6) are due to the organic load of discharges related to tourism and agricultural activities. Dissolved oxygen is reduced by the activity of bacteria by decomposing the organic matter present. Overall, the dissolved oxygen regime in the area studied is not

deficient, the phenomenon of assimilative capacity takes place, which makes it possible to enrich the dissolved oxygen level. These results show that waters of Oued Zegzel present well to excellent quality SEEE [29].

Total dissolved solids (TDS)

During our study period, the mean values of total dissolved solids indicate significant variations in Oued Zegzel. In general, it is found that the highest values are obtained at the station (S1) of an average of 764.42 mg/l and are correlated with the conductivity measured at this site (fig. 3). At the same time, this average (TDS) follows a gradient increasing from upstream to downstream since it remains low in (S2) increases globally from the station (S3). A decrease in this parameter is observed at (S2) following the groundwater inputs from the source of Ain Bourbah characterized by lower (TDS) values than those of the Oued Zegzel waters. This strong ionization of the waters of our watercourse is related to the geological nature (limestone) of the underlying lands, which are crossed by the sources of this zone that still feed the stream from the (S3) station.Referring to the Moroccan standards of surface waters stipulated by SEEE [29], the water of all the stations belong to the excellent class to the good quality.

Suspended materials (SM)

Overall, this parameter shows an increasing increase from upstream to downstream of our sampling area. For both the wet and dry seasons, the recorded suspended matter values range from 2.2 mg/l (S1) to 45.9 mg/l (S6) (fig. 3). These levels are the result of sudden hydrological events (floods), whose the charge of suspended materials can be attributed to intense erosion of the catchment area, following sudden thunderstorms that cause an increase in suspended solids (February, March and April 2018 campaigns) aggravated by the washing of vegetables and market gardening products in the watercourse. Despite the high level of suspended materials at the station (S6), it remains below 50 mg/l, which qualifies the waters of Oued Zegzel as an excellent quality according to the Moroccan standards of surface waters SEEE [29].

Salinity (Sal)

The average water salinity of Oued Zegzel varies between 0.02 g/l and 0.26 g/l as the minimum and maximum extreme values recorded respectively in (S2) and (S1) (fig. 3). The spatial and seasonal evolution of the salinity of the analyzed waters recalls that of the conductivity. This difference in salinity is explained by the major elements whose concentrations are closely related to the geological nature of the underlying rocks but also to anthropogenic agricultural or domestic inputs that represent a significant source of chlorides and sulfates. Referring to the Moroccan standards of surface waters recommended by SEEE [29], it can be concluded that the waters of the Oued Zegzel can be classified in an excellent class.

Sulfates (SO_4^{2-})

The results obtained for the sulfates follow an increasing gradient from upstream to downstream of Oued Zegzel. In fact, the levels recorded in Oued Zegzel water range from a low of 34.75 mg/l to a high of 88.38mg/l (fig. 3). Nevertheless, in this watercourse, concentrations remain below 100 mg/l. In addition, these levels can be explained by the nature of the rocks crossed, the leaching of agricultural lands and also by the use of laundry by residents and visitors to the region. By reference to the Moroccan standards of surface waters SEEE [29], the recorded sulfate contents make it possible to classify the waters of our watercourse in a state of excellent quality.

Chlorures (Cl^-)

The spatial evolution of chlorides goes hand in hand with that of electrical conductivity in the Oued Zegzel. There is an increasing gradient from upstream to downstream (fig. 3). This is consistent with the findings of other authors who reported that chloride concentration increases continuously and proportionately as a result of the nature of the lands crossed [7, 23, 32]. Throughout the study period, chloride levels ranged from 33.78 mg/l (S4) to 106.34 mg/l (S1) and

remained well below the limit value recommended by SEEE [29], which makes it possible to classify these waters in the excellent class of surface waters.

Total Hardness (TH)

At the Oued Zegzel, the mean values of hardness do not stop increasing downstream. They fluctuate on average between 5.2 mg/l at station (S2) to 7.4 mg/l at station (S1) (fig. 3) and would be due to the effects of calcareous sedimentary rocks (rich in Ca^{2+}) and serpentine rocks (rich in Mg^{2+}) as well as infiltration into the soil and runoff [33]. In addition, the water rich in carbonic acid and dissolved oxygen usually has a great dissolving power in contact with soils or rocks containing appreciable quantities of minerals such as calcite, gypsum and dolomite, where it can acquire a hardness several thousand milligrams per liter [33-35]. Referring to the Moroccan standards of surface waters recommended by SEEE [29], it can be concluded that waters of Oued Zegzel can be classified in the excellent to a good class.

Calcium (Ca^{2+})

In the Oued Zegzel, the concentration of calcium ions ranges between 41.7 mg/l and 95.54 mg/l (S4) (fig. 3). The increase of this element in Oued Zegzel is the direct result of the lithological nature due to the dissociation of limestone rocks of the Jurassic, the main geological substrate of the watershed of this region.

Magnesium (Mg^{2+})

Magnesium concentrations generally vary between 14.4 mg/l (S2) and 50.33 mg/l (S3) (fig. 3), its origin is linked to the dominance of the Calco-dolomitic soils of the region.

Ammoniacal nitrogen (NH_4^+)

Analysis of the ammonium profile (fig. 3) shows that the levels vary between 0.002 mg/l (S1) and 0.14 mg/l (S6) in wet periods and between 0.006 mg/l (S1) and 0.38 mg/l (S6) in dry periods. The ammonium values found in the wet period are significantly lower than those of the dry period, particularly upstream of the study area, reflecting the effect of dilution and the good oxygenation of the water, leading to nitrogen oxidation in the winter period. The relatively high levels recorded at the station (S6) during the dry period reflect the incomplete degradation process of organic matter. The very low values of ammonium ions in the waters of the Oued Zegzel allow these waters to be placed in the excellent class according to the Moroccan surface water quality grid SEEE [29].

Nitrates (NO_3^-)

Unlike nitrites, the spatial evolution of nitrate content follows an increasing gradient from upstream to downstream of the Oued. The curve of nitrate contents in the waters of Oued Zegzel (fig. 3) shows a slight variation in these contents, which vary between 4.96 mg/l (S2) and 17.19 mg/l (S6) and between 6.32 mg/l (S2) and 20.95 mg/l (S6) respectively in wet and dry periods. Despite the excessive use of chemical fertilizers and pesticides linked to intensive agricultural activities developed on the banks of the Oued, these low concentrations can be explained by the phenomenon of dilution provided by the waters of the Bourbah source. It can be concluded that the nitrate concentrations recorded in the surface waters of this watercourse are below the level suggested by Moroccan and international standards (50 mg/l). This indicates that the waters studied are not subject to a risk of nitrate pollution and therefore can be classified as excellent SEEE [29].

Nitrites (NO_2^-)

Since nitrites constitute a form of transient nitrogen between nitrates and ammonium ions, this chemical parameter follows a decreasing gradient from upstream to downstream (inverse evolution to nitrate levels), and their concentrations in the waters of our environment remain relatively low and vary between a minimum of 0.001mg/l and a maximum of 0.049 mg/l, recorded respectively in (S6) and (S2) (fig. 3). These results are mainly due to the reduction of nitrates resulting from the agricultural activities at these stations. The nitrite values recorded in the

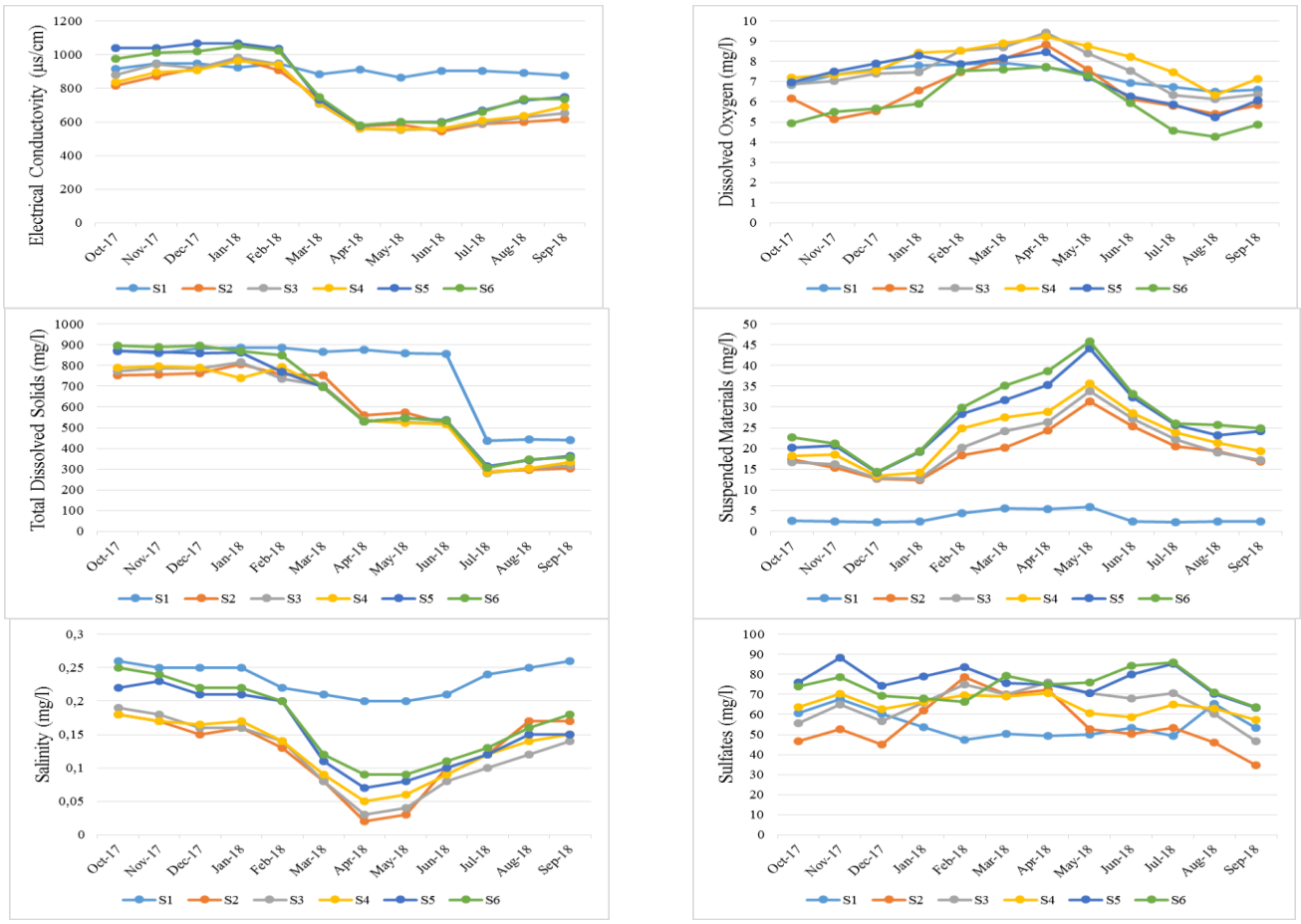
watercourse studied remain well below the value set by the Moroccan standards of surface waters SEEE [29], which makes it possible to classify these waters in an excellent class.

Orthophosphates (PO_4^{3-})

The analysis of the results (fig. 3) shows that the orthophosphates concentration in the surface waters of Oued Zegzel varies between 0.04 mg/l (S2) and 0.40 mg/l (S1) in the wet season and between 0.01 mg/l ((S4), (S5) and (S6)) and 0.46 mg/l (S3) in the dry season. At the stations ((S2) to (S6)), orthophosphates levels are low and are less than 1 mg/l for both seasons. However, at the station level (S1), orthophosphates follow a temporal variation marked relatively by a stability trend. This availability of orthophosphates may be due to leaching from local populations and agricultural activities in the region. These concentrations remain below the Moroccan standard set at 1mg/l, which makes it possible to classify the waters of Oued Zegzel in the excellent class SEEE [29].

Oxidability (Oxid)

Surface waters have oxidabilities that most often oscillate between 3 and 8 mg/L. The analysis of the results (fig. 3) shows that the spatial evolution of oxidability follows an increasing gradient from upstream to downstream. The water values in our environment remain relatively low and range from a minimum of 0.95 mg/l to a maximum of 4.16 mg/l recorded in (S6) and (S3) respectively. These low values are mainly explained by the assimilative capacity phenomenon ensured by the activity of aerobic bacteria on the one hand and by the dilution phenomenon ensured by the waters of the Bourbah source on the other hand. he results recorded in oxidability at this watercourse make it possible to classify waters of Oued Zegzel in the excellent to good class according to the Moroccan standards of surface waters SEEE [29].



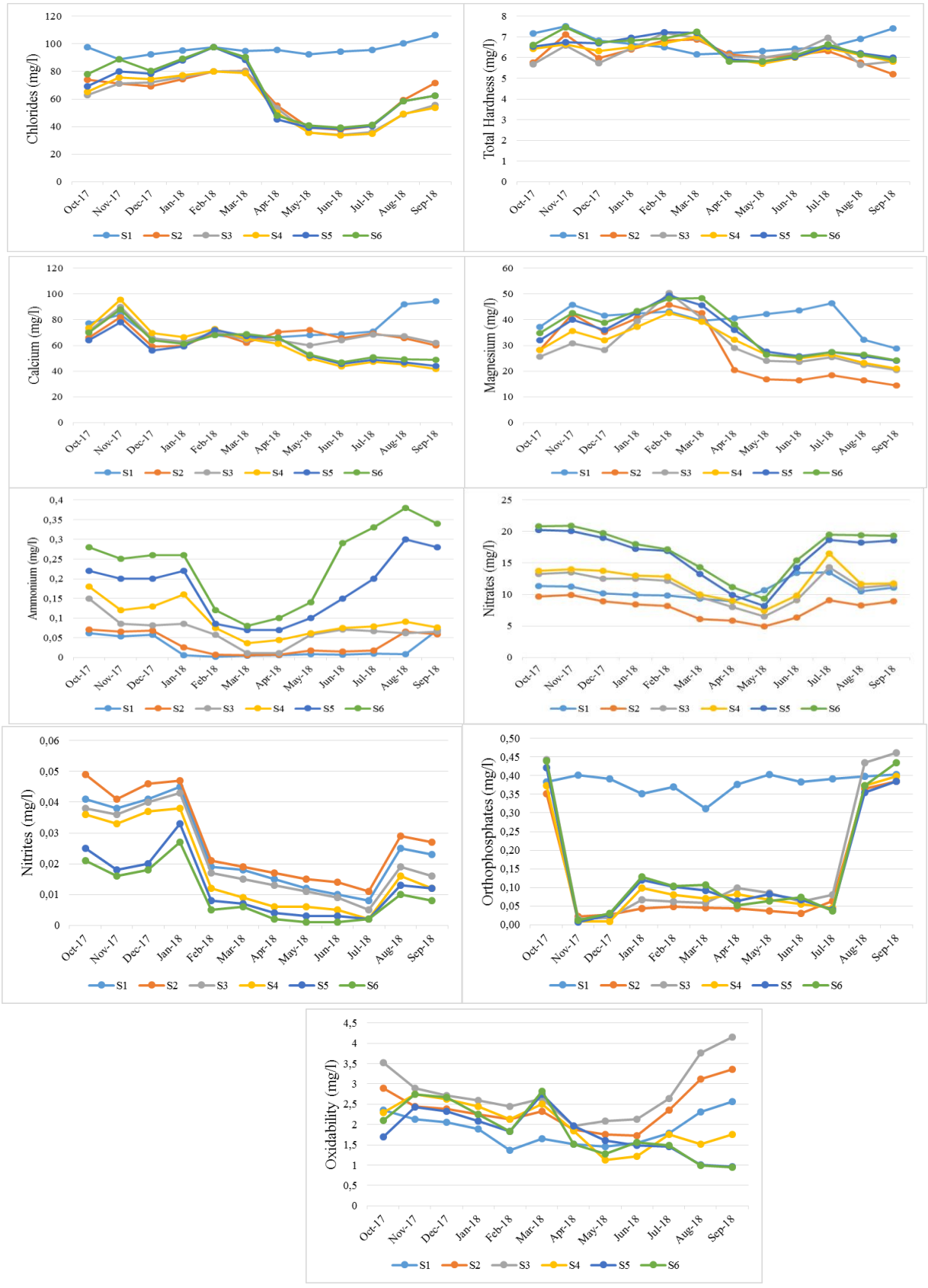


Figure . 3. Spatio-temporal variations of physicochemical parameters studied

Principal Component Analysis (PCA)

Examination of the numerical results of this (PCA) shows that the eigenvalues (fig. 4) indicate that the F1 axis explains (32.48%) the total variance of the data. Axis F2 indicates 17.91% of the total variability of the data. Thus, 50.39% of the variability of the data **Table** is extracted by the factorial design F1 X F2. Therefore, the analysis of the (PCA) results will be limited to these first two areas. Examination of the data relating to the matrix of correlations between variables (**Table** 2) allowed us to reveal the existence of a significantly high correlation between conductivity, total dissolved solids, salinity, Sulfates, chlorides, total hardness, Calcium, Magnesium on the one hand, and a significantly high correlation between Oxidability, Nitrates and Orthophosphates on the other hand.

Table 2. Correlation coefficient between the different variables, (* = P< 0.05); (** = P< 0.01)

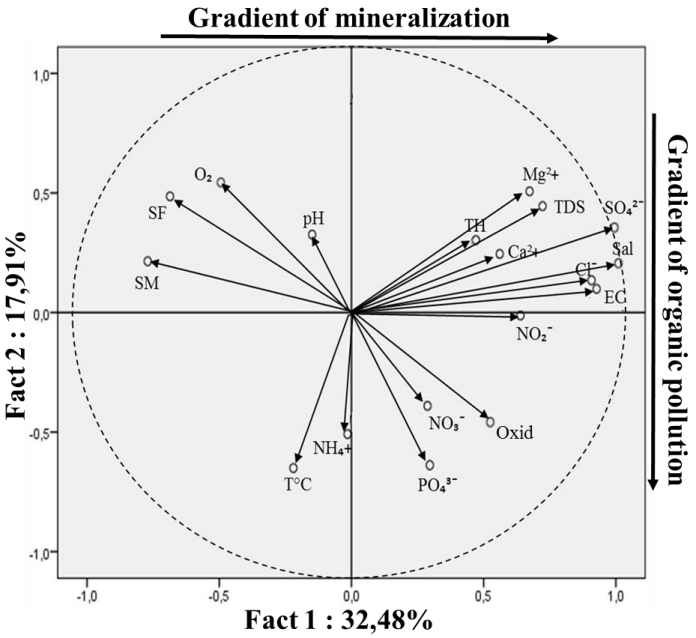
	SF	T°C	O_2	pH	EC	TDS	SM	Sal	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	TH	NO_3^-	NO_2^-	NH_4^+	PO_4^{3-}	Oxyd
SF	1,00																	
T°C	-0,01	1,00																
O_2	0,52**	-0,37**	1,00															
pH	0,15	-0,10	0,42**	1,00														
EC	-0,66**	-0,46**	-0,03	-0,11	1,00													
TDS	-0,26*	-0,49**	0,32**	-0,11	0,77**	1,00												
SM	0,58**	-0,20	0,11	-0,06	-0,59**	-0,37**	1,00											
Sal	-0,76**	0,09	-0,34**	-0,24*	0,79**	0,47**	-0,74**	1,00										
Cl^-	-0,48**	-0,19	0,11	-0,18	0,81**	0,66**	-0,67**	0,75**	1,00									
SO_4^{2-}	-0,09	-0,34**	-0,07	-0,02	0,86**	0,72**	-0,11	0,96**	0,83**	1,00								
Ca^{2+}	-0,13	0,03	0,11	0,03	0,44**	0,43**	-0,42**	0,39**	0,54**	0,97**	1,00							
Mg^{2+}	-0,19	-0,53**	0,32**	-0,15	0,70**	0,72**	-0,30*	0,43**	0,75**	0,85**	0,36**	1,00						
TH	-0,20	-0,29*	0,16	-0,12	0,43**	0,32**	-0,23	0,30*	0,54**	0,77**	0,23	0,62**	1,00					
NO_3^-	-0,44**	-0,16	-0,44**	-0,22	0,43**	0,09	0,01	0,47**	0,17	0,31**	-0,10	0,19	0,22	1,00				
NO_2^-	-0,45**	-0,18	-0,08	0,11	0,55**	0,50**	-0,63**	0,49**	0,44**	-0,41**	0,40**	0,16	-0,02	-0,13	1,00			
NH_4^+	-0,28*	-0,09	-0,56**	-0,34**	0,15	-0,09	0,26*	0,20	-0,15	0,38**	-0,32**	-0,13	-0,03	0,83**	-0,13	1,00		
PO_4^{3-}	-0,36**	0,60**	-0,31**	-0,11	0,11	-0,11	-0,49**	0,52**	0,31**	-0,43**	0,00	-0,12	-0,06	0,07	0,19	0,04	1,00	
Oxyd	-0,85**	-0,11	-0,95**	-0,89**	-0,17	-0,12	-0,83**	-0,13	-0,21*	-0,25*	-0,35**	-0,41**	-0,38**	0,92**	0,36**	-0,14	0,85**	1,00

The projection of the variables on the factorial plane F1-F2 (fig. 4) shows that: Conductivity, total dissolved solids, salinity, Sulfates, chlorides, total hardness, Calcium, Magnesium are positively correlated with F1, unlike dissolved oxygen, pH, streamflow and suspended matter which are negatively associated with this axis. The latter provides information on most of the parameters that determine the degree of mineral pollution of waters, and thus contrasts mineralized waters with slightly or less charged waters. He then defines a mineralization gradient from left to right of the axis. The parameters: Oxidability, Nitrates, Nitrites and Orthophosphates are negatively correlated with F2. This division, therefore, includes most of the parameters that determine the degree of organic pollution. This axis then defines an organic pollution gradient from the positive pole to the other negative pole of the axis. The analysis of the projection of individuals on the F1-F2 factorial plane allowed us to define a typology dominated by the individualization of three groups of stations (fig. 5):

Group 1: consisting exclusively of stations (S1) and (S4) (located further upstream from the Oued) positively correlated with the F1 component. The waters of this group are more mineralized.

Group 2: it is an intermediate group made up of the waters of station (S3) (highly oxygenated and high-flow).

Group 3: the latter group characterizes downstream individuals ((S2), (S5) and (S6)) and corresponds to the waters of the Oued that are the most loaded with organic matter and most threatened by discharges related to tourism and agricultural activities.



Streamflow (SF); Temperature (T °C); Hydrogen potential (pH); Dissolved oxygen (O_2); Suspended materials (SM); Salinity (Sal); Electrical conductivity (EC); Total Dissolved Solids (TDS); Chlorides (Cl^-); Sulfates (SO_4^{2-}); Calcium (Ca^{2+}); Magnesium (Mg^{2+}); Total hardness (TH); Nitrates (NO_3^-); Nitrites (NO_2^-); Ammonium (NH^{4+}); Orthophosphates (PO_4^{3-}); Oxidability (Oxid).

Figure 4. Représentation des variables sur le plan factoriel F1 et F2.

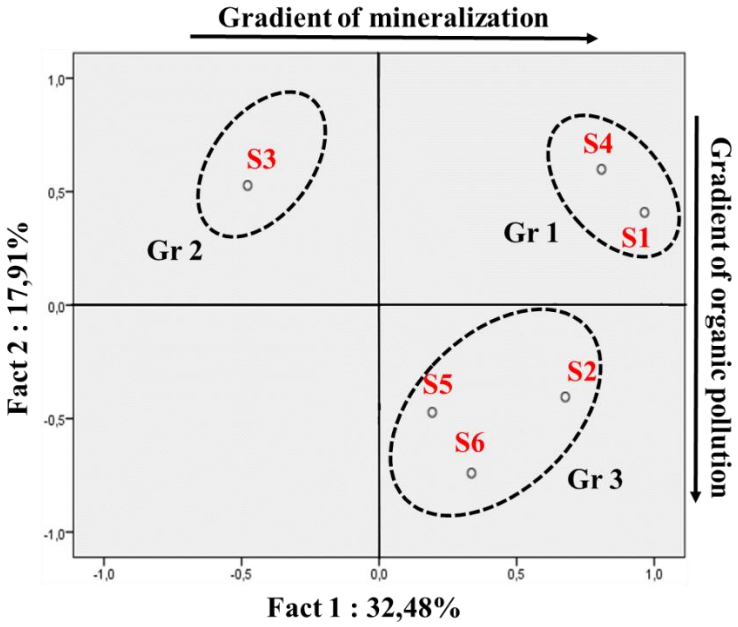


Figure 5. Representation of the sampling stations on the factorial level F1 and F2.

At the end of this analysis in the PCA, it can be said that the stations are well-typed and therefore well structured by their physicochemical data: a two-dimensional space was sufficient to summarize most of the information concerning the variability present in the initial 18 dimensional space.

4.CONCLUSION

This work presents a contribution to the study of water quality in Oued Zegzel (a river crossing the eastern Beni Snassen Mountains). This investigation allowed us to assess the degree of pollution generated by agricultural and tourist activities. Generally, all the levels observed for most physicochemical parameters do not exceed the Moroccan standard presented for surface water quality. However, the results of the physicochemical analyses show that, in terms of quality, the waters of this watercourse are characterized by significant mineralization, as shown by the high values of electrical conductivity, total dissolved solids, chlorides, sulfates, Calcium and Magnesium at all the stations of the Zegzel watercourse. Indeed, the high average concentrations of these parameters reflect the lithological nature (limestone rocks) drained by the waters of the Oued Zegzel.

REFERENCES

[1]. Mc. Kinney, L. Michael, *Bioscience.*, 52 (10) (2002) 883-890.

[2]. R. Mulliss, D. M. Revitt, R. B. E. Shutes, *Water Sci. Technol.*, 36 (8-9) (1997) 195-199.

[3]. Jr. Burton, G. Allen, Robert Pitt, CRC Press., 2001.

[4]. Dussart, Bernard, *Limnologie: l'étude des eaux continentales*, Gauthier-Villars, 1966.

[5]. J. Armengol, J. L. L Riera, J. A. Morguí, Verh Internat Verein Theor Angew Limnol, 24 (2) (1991) 1363-1366.

[6]. Sabater, Sergi, Josep Ramon Roca, *Br. Phycolo. J.*, 27 (2) (1992) 203-213.

[7]. S. Oubrahim, Qualité physico-chimique et biologique des cours d'eau du réseau hydrologique de la Meseta occidentale marocaine : Casablanca, cas de l'oued Mellah. Thèse de doctorat, université de Casablanca. (2002).

[8]. R. Bouaicha, A. Benabdelfadel, *Sécheresse.*, 21 (4) (2010) 325-326.

[9]. J. Alibou, Impacts des changements climatiques sur les ressources en eau et les zones humides du Maroc. **Table** Ronde Régionale en Méditerranée Athènes, Grèce, 2002, p 1-39.

[10]. A. Chahlaoui, P. Cugny, S. Lek, A. Zaid, M. Ramdani, Bull. Soc. Hist. Nat., 133 (1997) 71-76.

[11]. J. J. Barathon, Travaux de la R. C. P. CNRS, 249 (4) (1978) 1-23.

[12]. J. J. Barathon, Bassins et littoraux du Rif oriental (Maroc) : Evolution morphoclimatique et tectonique depuis le néogène supérieur. Centre Interuniv d'Etudes Médit., Univ. de Poitiers, (1989), 531 pp.

[13]. A. Kahouadji, Recherches floristiques sur le massif montagneux des Béni Snassen (Maroc Oriental). Thèse Doct. 3ème cycle, Univ. Sci. Tech. Languedoc, Montpellier, (1986), 235 pp.

[14]. A. Laaouina, Le Maroc nord-oriental : reliefs, modelés et dynamique du calcaire. Publ. Rectorat Univ. Mohammed Ier, Oujda, 1, (1990), 605 pp.

[15]. N. Chergui, E. Pattee, Acta Oecol., 13 (3) (1992) 291-298.

[16]. B. Legssyer, Evolution de l'activité des micro-organismes et des invertébrés durant la décomposition des feuilles du saule dans le réseau de la basse Moulouya. Thèse 3ème cycle, Fac. Sci., Oujda, (1993), 129 pp.

[17]. A. Maamri, Flux, rétention et incorporation des apports allochtones végétaux dans les réseaux trophiques des eaux douces de la basse Moulouya. Thèse 3ème cycle, Fac. Sci., Oujda, (1994), 133.

[18]. S. Fadlaoui, M. Mahjoub, O. Elasri, M. Melhaoui, *Inter. J. Zool.*, (2019).

[19]. S. Fadlaoui, O. El Asri, L. Mohammed, A. Sihame, A. Omari, M. Melhaoui, *Prog Chem Appli Chit Deriv*, *24*, 23-35, (2019).

[20]. J. Rodier, L'analyse de l'eau, eaux naturelles, eaux résiduaires, eau de mer. (9ième édition), Dunod, Paris, (2009).
[21]. M. Fekhaoui, Recherches hydrobiologiques sur la moyen Sebou soumis aux rejets de la ville de Fès : suivi d'une macro-pollution et évaluation des indices sur les composantes physiques, chimiques et biologiques de l'écosystème , Thèse d'état, (1990), 173 p.
[22]. L. Bennasser, Diagnose de l'état de l'environnement dans la plaine du Gharb: suivi de la macro-pollution et ses incidences sur la qualité hydrochimique et biologique du bas Sebou. Thèse de doctorat d'état Es Science, Univ. Ibn Tofail; Kenitra, Maroc, (1997), 157p.
[23]. B. Fawzi, Peuplement diatomique du réseau hydrographique de l'Oued Mellah : Composition, structure, autoécologie et indices de qualité. Thèse de doctorat. Faculté des Sciences Ben M'Sik, (2002).
[24]. S. El Blidi, M. Fekhaoui, A. El Abidi, L. Idrissi, T. Benazzou, Vec. Env., (2006) 46–53.
[25]. M. El Morhit, M. Fekhaoui, A. Serghini, S. El Blidi, A. El Abidi, R. Bennaakam, ..., M. Jbilou, *Bull. Inst. Sci*, Rabat, section Sciences de la Terre., 30 (2008) 39-47.
[26]. M. Makhoukh, M. Sbaa, A. Berrahou, M. Van Clooster, *LARHYSS J.*, 9 (2011) 2602-7828.
[27]. H. Lamrani, A. Chahlaoui, J. El Addouli, A. Ennabili, Science Lib Éditions Mersenne., 3 (2011).
[28]. M. L. Belghiti, A. Chahlaoui, D. Bengoumi, R. El Moustaine, *LARHYSS J.*, 14, (2013).
[29]. SEEE, Secrétariat d'Etat auprès du Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement, chargé de l'Eau et de l'Environnement : normes marocaines définissant la grille de qualité des eaux de surface, (2007).
[30]. M. Nisbet, J. Verneaux, Ann. Limno., 2, (1970), 161-190.
[31]. S. Hebert, S. Legre, Suivi de la qualité de l'eau des rivières et petits cours d'eau. Direction du suivi de l'état de l'environnement, Ministère de l'Environnement Gouvernement du Québec, (2000), 5 p.
[32]. R. Bermond, R. Vuichaard, Les paramètres de la qualité des eaux. Documentation Française, Paris, (1973), 179p.
[33]. C.N. Sawyer, P. L. McCarty, Chemistry for sanitary engineers. 2nd edition. Mcgraw-Hill. New York, (1967), 518pp.
[34]. S. De Fulvio, & L. Olori, Definitions and classification of naturally soft and naturally hard waters. Chemical and physical characteristics of the water in some member states of the European community. Dans : Hardness of drinking water and public health. Proceedings of the European Scientific Colloquium, Luxembourg. Pergamon for the Commission of the European Communities, New York, (1975), 95 pp.
[35]. R. Amavis, W. J. Hunter, J. G. P. M. Smeets, Hardness of drinking water and public health. Proceedings of the European Scientific Colloquium, Luxembourg, 1975. Commission Of The European Communities, Pergamon Press, (1976), 553pp.