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Contribution to the study of the hydrochemical characteristics of the Ramsar site: Afenourir Lake, Morocco

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Abstract

In order to better understand and manage the surface water quality of wetlands case of the Afenourir Ramsar site, located to the south of the Ifrane National Park in the Central Middle Atlas, an assessment of the water quality was carried out during the sampling campaign June 2015-March 2018. Spatiotemporal monitoring and analysis of the different physicochemical tracers in-situ (temperature, pH, electrical conductivity, dissolved oxygen) and in the laboratory (nitrites, nitrates, orthophosphates, sulphates), revealed on the one hand the temporary influence of climatic hazards (precipitation, floods, drought) and on the other hand the anthropic influence. For example, the surface water quality of Lake Afenourir can witness to a deterioration of the wetland, which would enhance an emergency management and management plan for the lake urgent.

Keywords: Wetland; Afenourir's lake (Morocco); Hydrochemical; Water quality; physicochemical parameters.

1. Introduction

Morocco has a set of wetlands, which, thanks to their geographical position and their biotic and abiotic characteristics, are of biological, ecological, economic and landscape interest [1,2]. For the purpose of conservation of wetlands, Afenourir wetland, ranked as a Ramsar site since 1981 is classified as a site of biological and ecological interest (SIBE), it shows a significant biological wealth, several species of birds and interesting benthic and floristic diversity [3,4]. Nevertheless, its water resources face problems of quantity and quality. They are limited by climatological reason and by anthropogenic activities (pumping, grazing, domestic and tourist discharges) that this wetland is undergoes. Unfortunately, few studies have been the subject of ecological monitoring. Some concern existing bird species at the lake level [5-6], but most are basics works. This study is original, since no hydrochemical, research was realised there before, and it contributes to a better knowledge of the physicochemical parameters of the lake.

2. Methodology

2.1. Description of the study area and sampling stations

Afenourir Lake (Aguelmam) is located in the central Middle Atlas of Morocco, with geographical coordinates (33 ° 17' N - 5 ° 16' W), an altitude of 1790-1800 m, covering an area of 400 ha. This Aguelmam is located to the south of the province of Ifrane at 30 km south of Azrou and relevant to Ain Leuh rural community. The lake is included in the perimeter of the National Park of Ifrane, and is classified RAMSAR [6-7-8]. It is a mountain site consisting of an eutrophic lake of nearly 400 ha, shallow, less than 2 m, a wet lawn around it and a stream located at the lake spillway [8-9]. To complete this study, four stations were chosen at the lake level, taking into account a number of criteria such as the direction of water flow, accessibility, and sources of pollution and dominance of aquatic vegetation. (**Table** 1 and Fig. 1).

Table 1. Characteristics of the study stations of the Afenourir Lake

Stations	**Geographical Coordinates**		**Substrate**	**Locality and others**
	Latitude	Longitude		
S1	33°17'0,26"N	5°15'14,33" W	Muddy, stony	Downstream near the dike, high anthropogenic activity (washing, grazing)
S2	33°16'54,61"N	5°15'20,82" W	--- ----	Upstream near the bird observatory, washing, grazing, tourist waste.
S3	33°16'38,3"N	5°14'57,75" W	-------	Upstream, On the side of the Ain Kahla forest, washing, grazing, pumping and pollution by household waste.
S4	33°16'49,71"N	5°14'51,22" W	-------	Downstream, on the side of the Ain Kahla forest, washing, grazing, pumping and pollution by household waste.

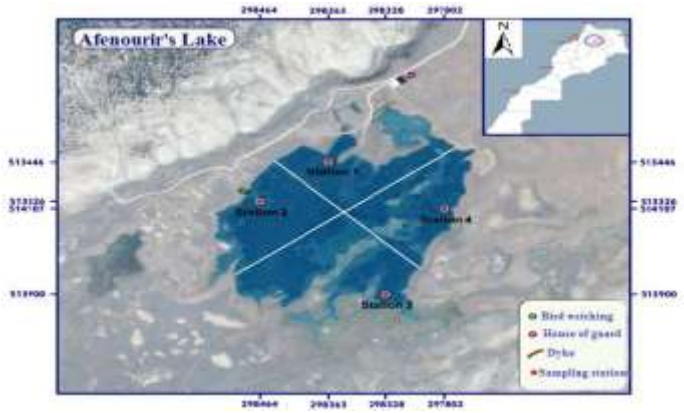

Figure 1. Localization of sampling stations at Afenourir Lake

2.2. Sampling

In-situ parameters were measured at each station, from June 2015 to March 2018. Regarding the parameters to be analysed in the laboratory, the water samples were taken monthly at each station from May 2017 until March 2018. The samples were taken using the 1000 ml polyethylene bottles, previously washed with distilled water and transported in a por**Table** cooler at 4 ° C, to the water quality laboratory at the National Center for Hydrobiology and Aquaculture in Azrou. During the dry period and the snow period, no sampling was carried out.

2.3. Physico-chemical analysis of water

The monitoring of the water quality of the Afenourir wetland was carried out by analysis and spatio-temporal evolution of eight physical and chemical parameters at the four stations. Four of these variables were measured in the field: temperature, pH, conductivity, and dissolved oxygen. Nitrite, nitrate, orthophosphate and sulphate were measured in the laboratory. Analytical techniques are showed in **Table** 2.

Table 2. Methods of analysis of the different physicochemical parameters

Parameters	Analytical methods	Units	Sources
Temperature	Mercury thermometer	°C	
pH	pH-meter NEOTEK-PONSEL SN-ODOEA-0118, electrode SN-PPHRA-0050.		
Conductivity	Conductimètre NEOTEK-PONSEL SN-ODOEA-0121, electrode SN-PC4EA-0016.	µS/cm	
Dissolved oxygen	Oximeter Thermo Scientific ORION 3 STAR SN-A 05370, electrode ORION 080017.	mg/l O_2	
Nitrite	The colorimetric method commonly used for nitrites uses diazotisants reagents. Nitrites react with these reagents to form in solution the diazonium salts. The spectrophotometric measurement is carried out at a wavelength close to 537nm of the coloration of the pink complex formed.	mg/l NO_2^-	**AFNOR, 1997 [10]**
Nitrate	In the presence of sodium salicylate, the nitrates give sodium para-nitrosalicylate, colored yellow and capable of a spectrometric determination.	mg/l NO_3^-	**J.RODIER 7^E.D [11]**
Orthophosphate	In acidic solution and in the presence of ammonium molybdate, orthophosphates give a phosphomolybdic complex which, reduced by ascorbic acid, develops a blue color susceptible to a spectrometric determination.	mg/l PO_4^{2-}	**AFNOR, 1997**
Sulphate	The sulphate ion is precipitated in hydrochloric acid containing barium chloride in such a way that uniformly sized barium sulphate crystals are formed. . The absorbance of the suspension of barium sulphate is measured by transmission to the spectrophotometer.	mg/l SO_4^{2-}	

3. Results and discussion

3.1. *Spatio-temporal assessment of the water quality of Lake Afenourir*

Each parameter analysed is represented by the profiles of its spatio-temporal evolution and those of the evolution of their mean values. These profiles make it possible to take a global and special approach to the quality of the surface waters of the wetland.

3.1.1. *Temperature*

The analysis of the annual average temperatures of water in the various stations of the wetland Afenourir shows that the year 2017 has recorded the highest temperatures compared to the other years of study (fig. 2).

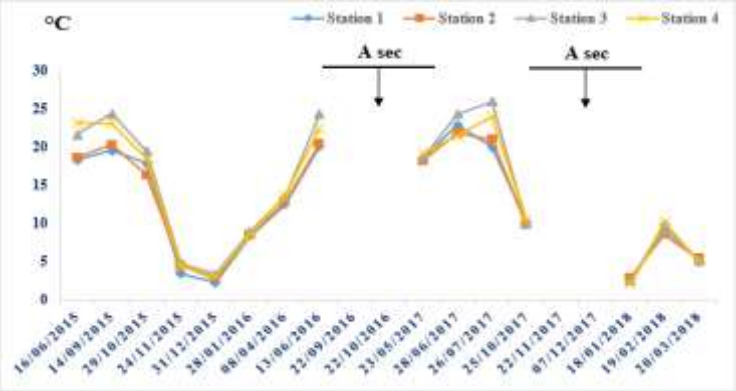

Figure 2. Monthly variation of the temperature of water by station in the wetland Afenourir

Figure 3. Space-time evolution of the annual median values of the water temperature in the wetland Afenourir from June 2015 to February 2018

Moreover, for the year 2015 recorded the values of the lowest temperatures also that for the two months of January and February studied of the year 2018 (Fig. 2). The annual average temperature for the year 2015 was of 13.52 °C; those of the years 2016 and 2017 are respectively 14.52°C, 18.52°C. The lowest temperature of 2.3 °C recorded during the month of December 2015 and the maximum temperature of 26 °C. Raised in the month of July 2017 (fig. 2).

The got results also show that the stations 1 and 4 located downstream recorded the lowest temperatures compared to the stations 2 and 3 located upstream wetland (fig. 1 and 2). Except for a few months of drought where the stations downstream which recorded the highest values. The space-time evolution of the median values of the water temperature oscillates between 5.63°C recorded on the level of station 3 of the year 2018, and 19.72°C raised in 2017 at the same station (fig. 3). The curves of monthly variations showed a difference in temperature, between the downstream and the upstream, not very significant that could be insufficient to radically modify nature of the chemical and biological process of the various stations of the wetland (fig. 3). In lack of precipitations, snow melting and low depth of the lake, besides other causes, stations 1.2 and 4 becomes dry except the station 3, which remains a little wet.

To act of the thermal stratification of the water mass of this lake, it does not present no**Table** variation because of its low depth. Indeed, the latter is of 1.5 m. In similar aquatic environments, the temperature variations are influenced much by the room temperature, itself function of the seasons, that by the effect of depth [12].

3.1.2. *Hydrogen Potential (pH)*

The hydrogen potential depends on the origin of water, of the geological nature of the substrate and the catchment area. The analysis of this parameter during four years of study show that the water of the wetland is in the vicinity of

neutrality to alkaline (fig. 4 and 5), with annual averages of 7.73; 7.78; 9.73 and 8.74 respectively in 2015, 2016.2017 and 2018.

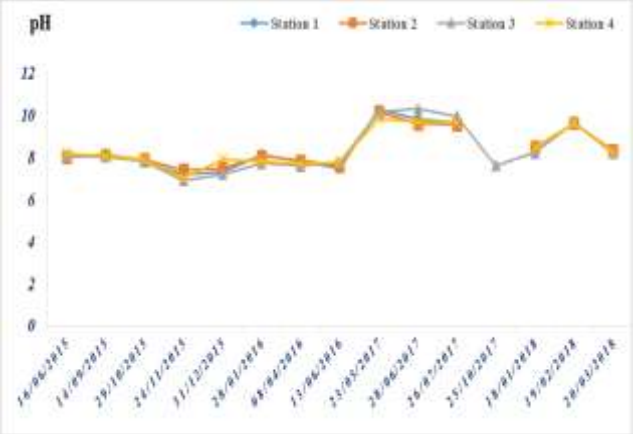

Figure 4. Monthly variation of the pH of water by station in the wetland Afenourir

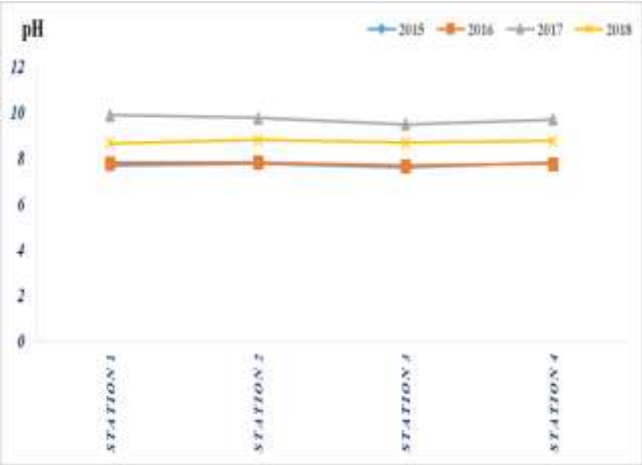

Figure 5: Space-time evolution of the annual median values of the pH of water in the wetland Afenourir from June 2015 to February 2018

The monthly evolution of the pH recorded the values highest on the level as of four stations during the year 2017, which oscillate between 7.62 and 10.3. Whereas low values were recorded during two years 2015, 2016 variable respectively enters, 7.60 and 7.82; 7.69 and 7.83. In accordance with the decree n° 2027-03 of the 11/5/2003 [13], setting the quality standards of piscicultural water, the limiting values of this parameter range between 5 and 9. The values having exceeded this interval are explained by the abundance of the vegetation. Which by the means of photosynthesis use carbonic gas of water and thus cause an increase in the pH. The opposite case was noted in November of the year 2015, where adverse conditions reduced chlorophyll assimilation, thus inducing the release of CO_2, which is responsible for the decrease in pH [4, 14].

3.1.3. *Electric conductivity*

The electric conductivity of a natural water is the measurement of its capacity to lead an electric current. This one gives a good appreciation of the ionic composition (anions and cations) of this water. Besides there exists a relation between the content of dissolved salts of a water and its conductivity. One speaks then about

the total mineralisation of water [14]. According to analysis the results of the evolution electric conductivity in the wetland Afenourir, the space-time variation of this parameter is represented by the recording of a high average of 271.6 µs/cm in 2017 and also a weak average of 196.57 µs/cm in 2015. These values are in conformity with the standard n° 2027-03 when this last should be lower than 350 µs/cm in the case as of cool waters. Whereas the analysis showed an exception in October year 2017 on the level of the station 3 located upstream, which recorded a value of 592 µs/cm and it exceeds the limit of the standard, this is explained by one period during which mineralisation, under the effect of heat, is intense and the water level is reduced.

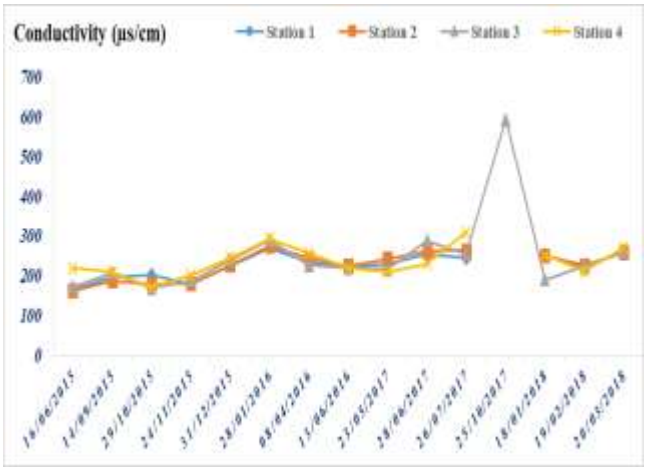

Figure 6. Monthly variation of the electric conductivity of water by station in the wetland Afenourir

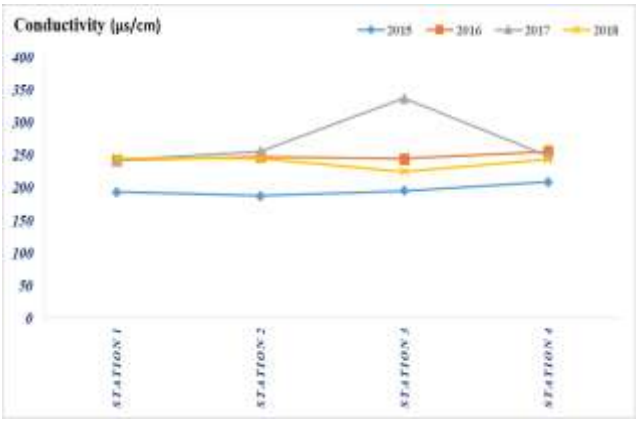

Figure 7. Space-time evolution of the annual median values of the electric conductivity of water in the wetland Afenourir from June 2015 to February 2018

3.1.4. *Dissolved oxygen*

Dissolved oxygen is a very important parameter owing to the fact that it conditions the state of several rock salt, the degradation of the organic matter and the life of the watery organizations. Its content can become critical, particularly in the major and little agitated mediums.

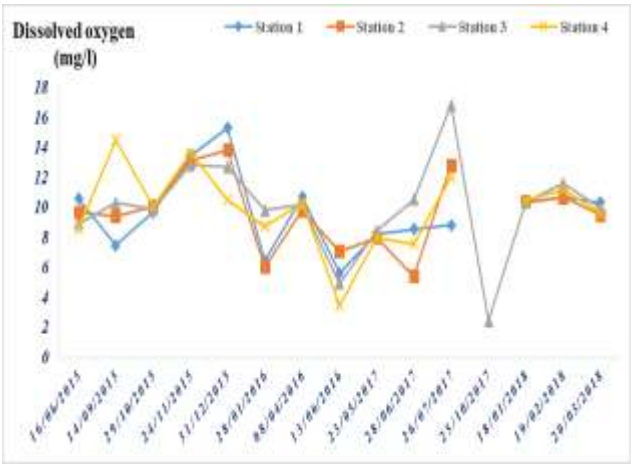

Figure 8. Monthly variation of the dissolved oxygen of water by station in the wetland Afenourir

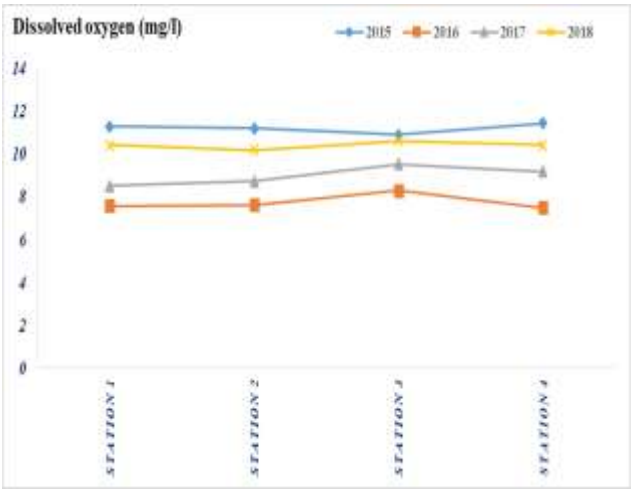

Figure 9. Space-time evolution of the annual median values of the dissolved oxygen of water in the wetland Afenourir from June 2015 to February 2018

The contents recorded annual averages vary in 2015, 2016.2017 and 2018 respectively between 10.91 and 11.45 mg/l; 7.49 and 8.3 mg/l; 8.51 and 9.53 mg/l; 10.18 and 10.61 mg/l. The space-time variation of this parameter showed that the highest value of 11.22 mg/l was recorded in 2015 on the other hand the weakest average of 7.75 mg/l was recorded in 2016 (fig. 9). The monthly evolution of the oxygen content is very variable from one station to another (fig. 8). One notes a maximum of 16.8 mg/l in station 3 during the month of July 2017 and a minimum of 2.4 mg/l in the same station during the month of October 2017 (fig. 8). The variation of oxygen in the four stations would be related to several factors such as the geographical position compared to the contributions. The values recorded in our study reflect uns**Table** conditions because of much accentuated evaporation. In the mediums with low level of renewal, the dissolved oxygen content tends to decrease when the temperature increases, but also on the one hand because of reduction in water level of the lake by climate change and on the other hand the consumption increased by the population. The transformation of nitrates into nitrites and sulphates into sulphides can be thus favoured [15].

3.2. *Nitrogenized substances*

The nitrogen is a critical component in the construction of the cell. In the watery field, the nitrogen exists in form molecular (N_2) or ionized (NO_3, NO_2^-, NH_4^+), like in dissolved or particulate organic form (proteins, amino acids,

urea, etc.). These various nitrogen shapes are in perpetual evolution. They pass from the one to the other by physicochemical processes and especially biochemical [14,16].

3.2.1. *Nitrite*

The nitrites or nitrite nitrogen are generally met in water with very low contents. The nitrite nitrogen is an intermediate compound in the aerobic process of transformation of ammoniacal nitrogen into nitric nitrogen [16]. The values recorded in NO_2^- are in conformity with the standard n° 2027-03 relating to the quality of Moroccan piscicultural water which requires contents lower than 0.5 mg/l. the monthly variation of nitrites in the water of the wetland Afenourir lie between 0.0048 mg/l recorded in November 2015 and 0.38 mg/l raised in October 2017. Except for a content, which exceeds the limit of the standard, was recorded in March 2018 of a value of 0.77 mg/l (fig. 10).

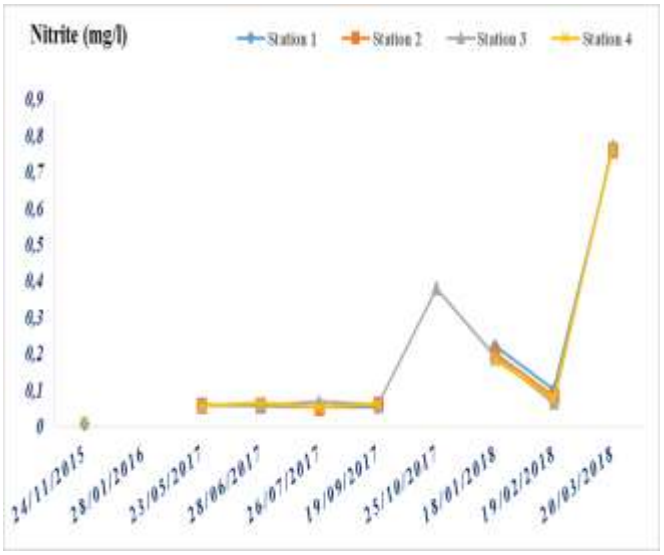

Figure 10. Monthly variation of nitrites in water by station in the wetland Afenourir

3.2.2. Nitrate

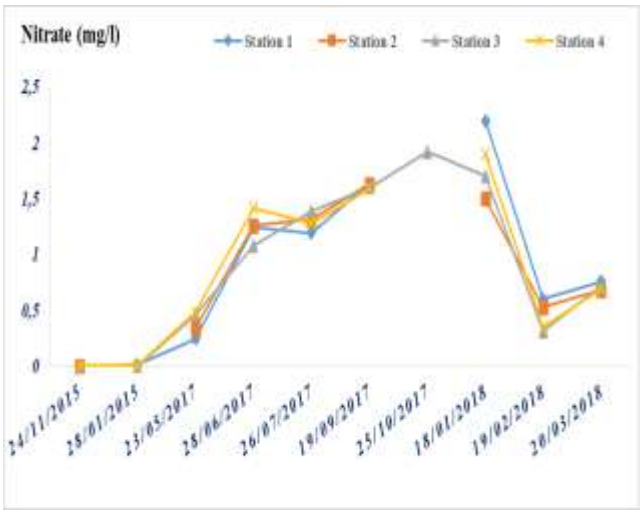

Figure 11. Monthly variation of nitrates in water by station in the wetland Afenourir

3.3. *Orthophosphates*

Phosphorus is the most valuable metalloid for aquatic life, the least abundant in general, and is in the simplest form, orthophosphate. Orthophosphates are phosphates that can be measured without hydrolysis or without oxidative digestion. Its role is essentially at the level of primary production. Phosphorus in natural waters comes mainly from the use of detergents as well as the drainage of fertilized farmland. In general, phosphorus is not toxic to humans, animals or fish and it is mainly to slow the growth of algae in aquatic environments that phosphorus concentration should be limited [14, 16, 18].

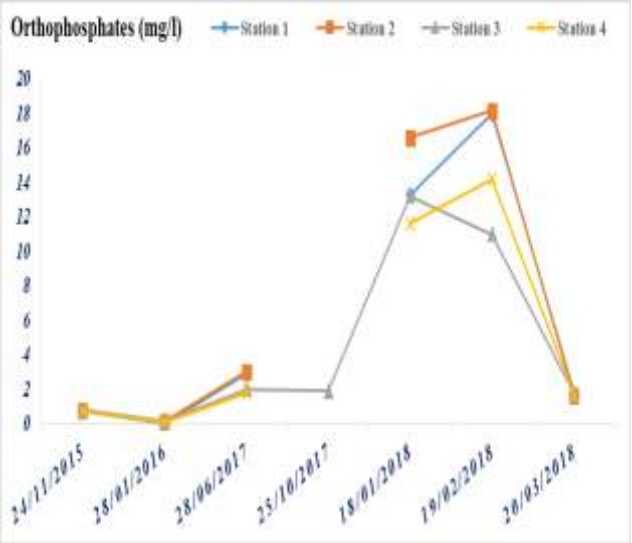

Figure 12. Monthly variation of orthophosphate in water by station in the wetland Afenourir

The monthly variation in orthophosphate levels shows significant differences over the years of study. The highest value of 18.15 mg /l was recorded in February 2018, while the low value of 0.0011 mg / l is at the trace level was noted in January 2016. The results obtained showed, a huge increase in orthophosphate concentration in the lake water at the four stations during the two months January and February 2018 averaging 13.65 mg / l and 15.3 mg / l, respectively.

3.4. Sulphates

Sulphates (SO_4^{2-}) can be found in almost all natural waters. The origin of most sulphate compounds is the oxidation of sulphite ores, the presence of shales, or industrial waste [14].

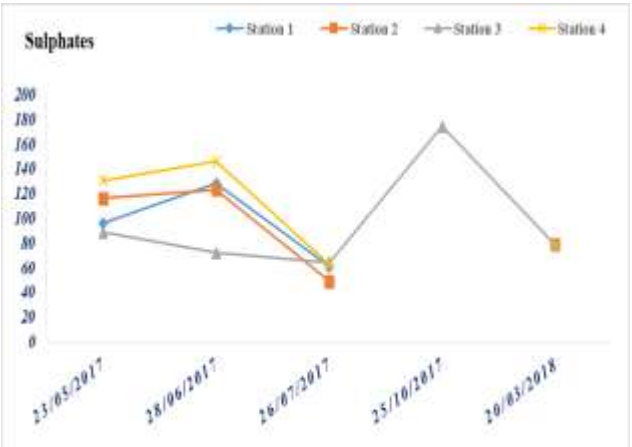

Figure 13. Monthly variation of sulphates in the water by station in the wetland Afenourir

Sulphate is one of the major components of compounds dissolved in rainwater. High concentrations of sulphate in water can have a significant effect combined with calcium and magnesium, the two major compounds of water hardness [16]. In general, the monitoring of sulphates at the level of the Afenourir wetland shows a high presence at station 3 during the month of October 2017; its value is 174.21 mg / l. while a low value of 48.6 mg /l was recorded in Station 2 in July 2017. The monthly variation also showed an increase in the concentration of sulphates in water during the month of June by a difference of 9.54 compared to the month 05/2017, thereafter the concentration decreases in July, from where the wetland remains less loaded with sulphates, by a very noticeable difference of -58,16. The recorded values do not exceed the limiting value of the standard 2027-03, which requires a concentration lower than 200 mg/l. Low sulphate levels could be explained by intense biological activity (high plant cover, considerable planktonic and microbial activity). According to *Yamane*, 1969 [19], the reduction of sulphate levels at certain points and at times is probably due to the microorganisms that act in anaerobiosis in submerged soils after 3 to 4 weeks from the beginning submersion, and in particular by oxidation and formation processes of water-soluble elements such as $CaSO_4$ and $MgSO_4$.

4. Conclusion

Water is a strategic global, regional and national issue whose management must imperatively fit into a multi-sectoral policy perspective of sustainable development in Morocco. The composition of natural waters is determined by some important processes. In particular, rock alteration, interactions between organisms and water by photosynthesis, respiration, and exchanges between the atmosphere and water. Oxygen (O_2) and carbon dioxide (CO_2), which play a key role in the composition of water, are regulated, in addition to exchanges with the atmosphere, photosynthesis and respiration of living organisms and by the alteration of rocks. The alteration reactions provide, in particular, the main cations and anions in the water (Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, Cl^{-} and SO_4^{2-}). Interactions between water, rocks and CO_2 in the atmosphere buffer the water with acid-base conditions. Analysis and treatment of all the hydrochemical data allowed us to understand the spatio-temporal evolution of the physicochemical characteristics of water in the Afenourir wetland. Indeed, the examination and interpretation of the physico-chemical analysis results show that:

The contents observed for most of the physicochemical parameters studied at the level of a certain station do not exceed the standard relating to the quality of piscicultural water. Waters are characterized by physicochemical parameters that increase from one period to another and from one station to another.

The pH values reflect the basic characteristic of the waters analysed and the origin of this alkalinity resulting from the dominance of the aquatic vegetation and Macrophyte; this can also be derived from the leaching of the geological grounds of the watershed. These data made it possible to define a spatial typology marked by a climatic influence on the one hand and anthropic on the other hand.

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