INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 13, No. 2, p. 181-188, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Hydrogeochemical characterization of groundwater in the Trans boundary watershed of the Medjerda River (Extreme North-East Algeria)

Moncef Bourouga[1], Lamine Sayad[2], Nabil Bougherira[1], Hicham Chaffai[*1], Larbi Djabri[1], Azzedine Hani[1]

[1]*Laboratory of Water Resource and Sustainable Development (REDD), Department of Geology, Faculty of Earth Sciences, University Badji Mokhtar, Annaba, Algeria*

[2]*Department of Geology, Faculty of Earth Sciences, University Badji Mokhtar, Annaba, Algeria*

Article published on February 28, 2019

Key words: Aquifer, Chemical facies, Trans boundary basin, Mineralization, ACP, CAH.

Abstract

The purpose of this study is to understand the hydrogeochemical functioning of the waters of the transboundary aquifer system of the Medjerda. This will ensure the sustainability of the region's water resources in the face of increased demand from high socio-economic growth coupled with anthropogenic pollution and the hazards of climate change. The transboundary watershed of the Medjerda River, which is of great importance in relation to its geographical location, is considered vital for Tunisia, thus offering about half of the fresh water available in the country. This basin drained by the Medjerda wadi has a set of aquifers characterized mainly by the deep aquifers of the karstified limestones of the Maestrichtian, Campanian and Turonian periods, as well as alluvial formations of the Mio-Plio-Quaternary age. The processing of data obtained from physico-chemical analyses carried out on aquifer waters was carried out using multivariate hydrochemical and statistical methods. The results reveal the dominance of the bicarbonate facies resulting from the dissolution of the limestone formations that predominate in the Taoura syncline. It should also be noted that other chemical facies such as calcium sulphate, calcium chloride and sodium chloride are present due to the presence of evaporite formations on the edge.

***Corresponding Author:** Hicham Chaffai ✉ hichamchaffai@yahoo.fr

Introduction

The variation in groundwater quality in an area is a function of physical and chemical parameters that are strongly influenced by geological formations crossed and human activities (Subramani *et al*, 2010; Boubelli *et al*, 2018). Water resources have always been considered as a renewable and inexhaustible source. Today, several countries are facing the depletion of their water supplies due to several natural factors (Kahal *et al.*, 2018), increased demand (Chaffai *et al.*, 2005) and anthropogenic pollution (Boulgueraguer *et al.*, 2018). The Medjerda catchment area (transboundary basin with Tunisia) includes several complex and variable karst, dolomitic and carbonate aquifer systems (Chaffai, 1986; Chaffai *et al.*, 2006; Benhammadi and Chaffai, 2015). Structurally, the study area is marked by the existence of several anticlines and synclines characterizing the Taoura region and to which is added a very important triassic tectonic (Vila, 1980). The interaction of groundwater with aquifer minerals has been the subject of several studies in the Maghreb region and in North Africa as a whole. Some cases such as those of (Hssisou *et al.*, 2001; Fehdi *et al.*, 2009; Belghiti *et al.*, 2013; Boubelli *et al.*, 2018) have shown that the main origin of groundwater mineralization is due to water-roche contact impacted by very significant climate change in arid and semi-arid areas (Benhammadi and Chaffai, 2017).

According to SOGREAH (2009), the groundwater reserve in the study area is 11.5 Hm^3/year. Quantifying and analysing the quantity and quality of this water resource is essential for rational management to ensure its sustainability. The main objective of this study is to determine the physicochemical quality of groundwater in the region using multivariate hydrochemical and statistical methods, to determine the dominant chemical facies and to identify the major geochemical processes responsible for their mineralization.

Materials and methods

Geographical location of the study area

The Medjerda catchment area (code 1201) is located in the far north-east of Algeria. It is part of the large transboundary watershed of the Medjerda-Mellègue (Fig. 1). This basin extends from 7°34' to 8°25' East and 36°04' to 36°25' North, covers an area of 1505.6 Km^2 and is drained by the Medjerda wadi and its tributaries. The population of the study area is estimated at 340,000 inhabitants, representing a density at 226 inhabitants/km^2 and an estimated growth rate of 1.7%. Five main soil types are found in the watershed, including Cambisols calcium, Luvisols gleyics, Fluvisols limestones, Vertisols pelica and Luvisols chromica (Mtimet, 2001). The climate of this region is temperate, characterized by an average annual rainfall of around 740 mm and an average annual temperature of 17.5°C.

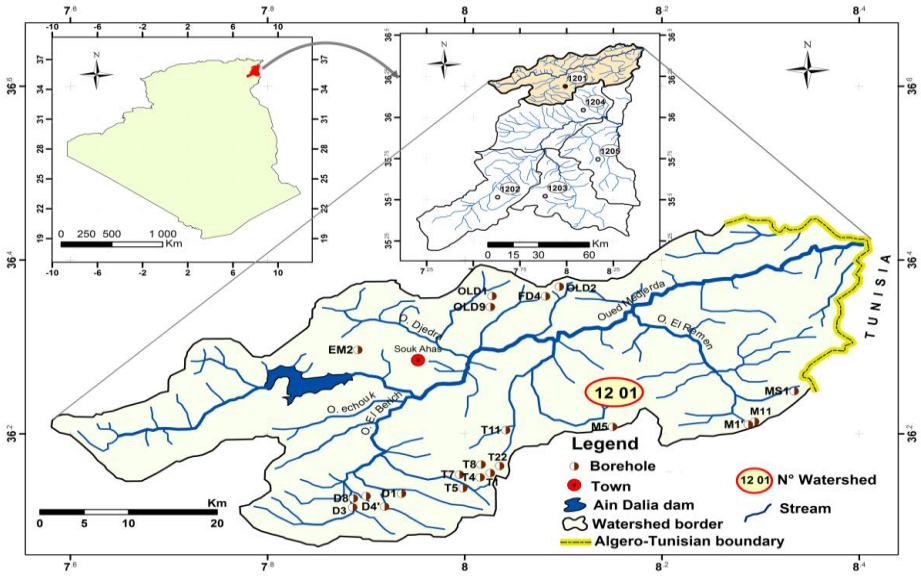

Fig. 1. Geographical location of the Medjerda watershed.

The study area was part of the folded alpine zone, located on the edge of the highlands. The lands encountered belong to the marine, terrigenous and triassic evaporite carbonate formations. Continental facies are represented by loose or weakly cemented Pliocene, Plio-Quaternary and Quaternary formations (Fig. 2).

Tectonics is distinguished by two major fundamental units: the Tellian chains and the Saharan Atlas which are in contact. The hydrogeology of the region is marked by a dominance of the deep water table of the Taoura syncline (Fig. 3). This carbonate groundwater contains large water reserves (Rouaibia, 2018).

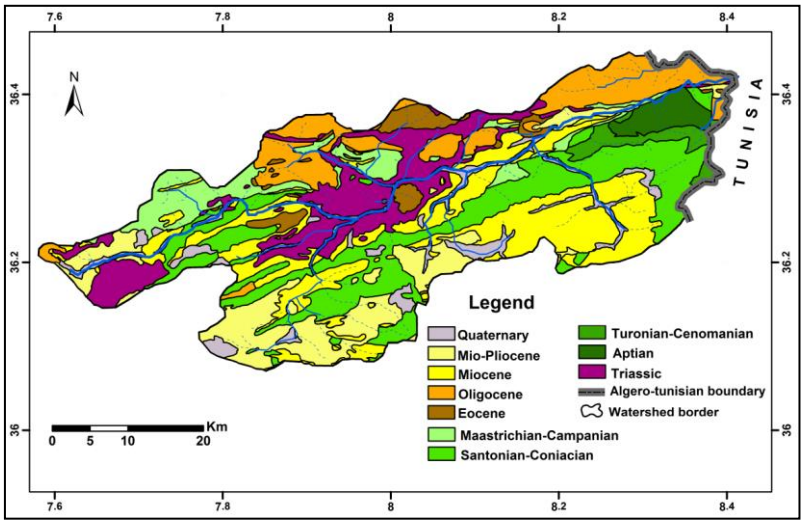

Fig. 2. Geological map of the study area.

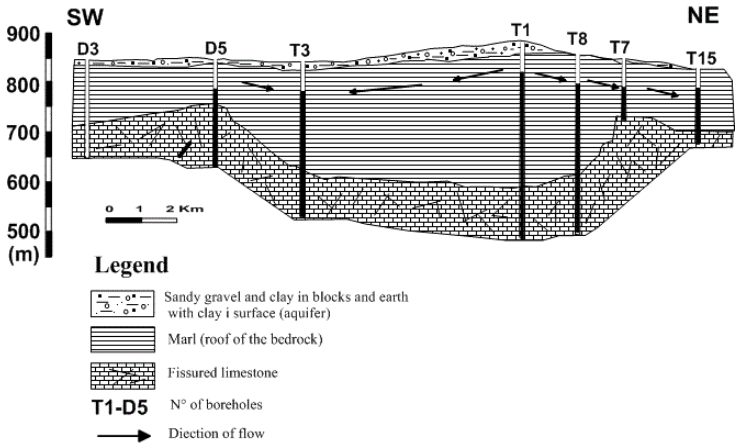

Fig. 3. Hydrogeological section of the Taoura synclinal groundwater.

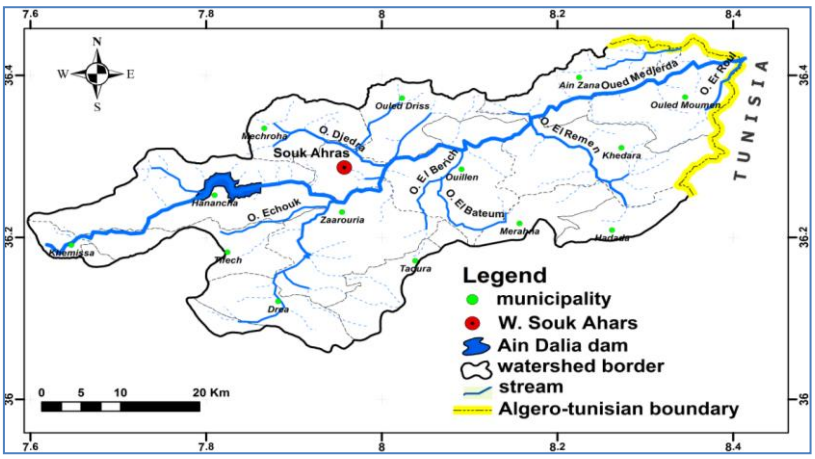

Fig. 4. Hydrographic network of the study area.

There are other secondary aquifers: Eocene karst and Mio-Plio-Quaternary alluvial. These groundwater tables are relatively low potential (SOGREAH, 2009). The hydrographic network of the region is represented by the Medjerda wadi and its important tributaries: Oued El Hammam, Oued El Berrich and Oued El Bateum (Fig. 4). The Ain Dalia dam, with a capacity of 76 hm^3, is the only major hydraulic structure in this study area.

Hydrochemical analysis

For the purposes of this study, 21 borehole water samples were collected, distributed among the main water bodies in the study area. The parameters chosen are those that allow the best assessment of water quality, namely: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-}. Water samples were collected and analyzed according to standard analytical techniques (Rodier, 2009) at the quality control laboratory: Eurl "Fethalah" in Tébessa.

Multivariate statistical analysis

Principal Component Analysis (PCA) is a data analysis tool that explains the structure of correlations or covariances using linear combinations of the original data. Its use allows data to be reduced and interpreted in a small space (Maliki, 2000). PCA is a method widely used in a wide range of environmental fields to highlight associations between individuals and/or variables. The PCR was performed on a data matrix consisting of 21 individuals and 07 variables (Calcium, Magnesium, Sodium, Potassium, Bicarbonates, Chlorides and sulfates).

Ascending Hierarchical Groundwater Classification (HAC)

The statistical method of the Hierarchical Ascending Classification (HAC) aims to determine the origin of water mineralization. HFA is a technique that measures dissimilarity or similarity between samples to define a criterion for class aggregation (Templ *et al*, 2008).

Results and discussion

Hydrochemical analysis

Examination of the spatial distribution maps of ion concentrations in the study area shows that in the anion distribution map (Fig. 5), bicarbonates predominate over other anions with values ranging from 136 to 580mg/l and an average of 293mg/l, these concentrations are mainly due to carbonate formations represented by karst aquifers which particularly characterize some regions of the Medjerda-Mellègue watershed. Chlorides and sulphates with a lower degree, average values of 85 and 128mg/l respectively, influenced by triassic saline formations.

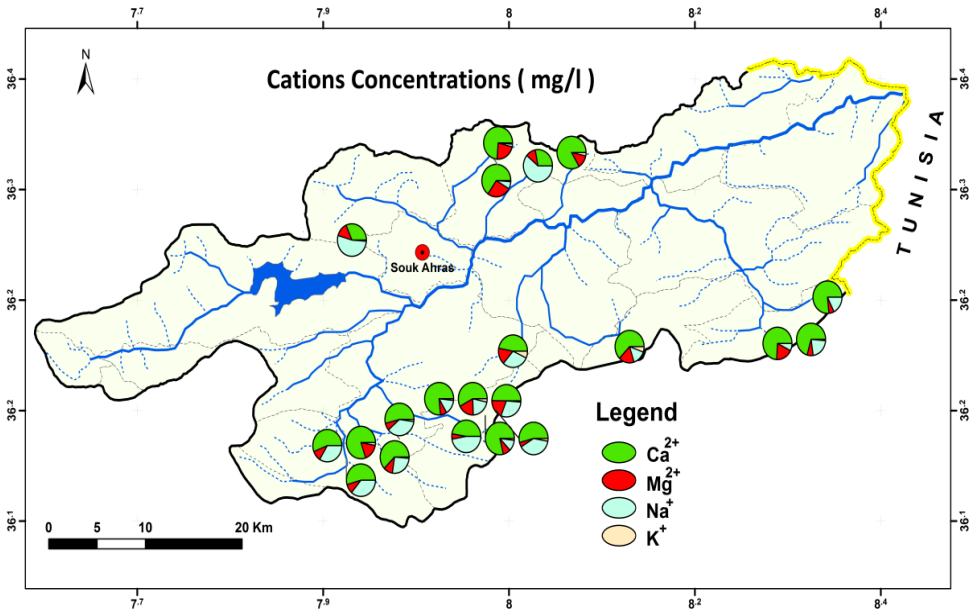

Fig. 5. Spatial distribution of cations.

For cations (Fig. 6), calcium is generally the dominant element and its contents vary from 45 to 235mg/l, this is mainly due to the nature of the soils crossed by carbonate or gypsum facies which represent formations characteristic of the study area. Sodium is also present with concentrations that can vary from 0.9 to 210mg/l, indicating a low or fairly high presence of highly influential evaporite formations in the various aquifers of the region. The representation of chemical analyses by the triangular Piper method (Fig. 7) and by the ionic formula revealed the chemical facies of four major water categories in the study area. Mainly the calcium bicarbonate facies predominates with a rate of 66.67% characterizing the nature of the carbonate formations of the Taoura syncline. The calcium sulphate facies represented by 9.5% of the samples is probably due to leaching of the triassic formations that outcrop in the region.

The chlorinated calcium facies representing 14.3% of the water points can be explained by the presence of salt formations of the Mio-Plio-Quaternary. Finally, 9.5% represents the rate of sodium chlorinated facies, which can only originate in evaporative formations.

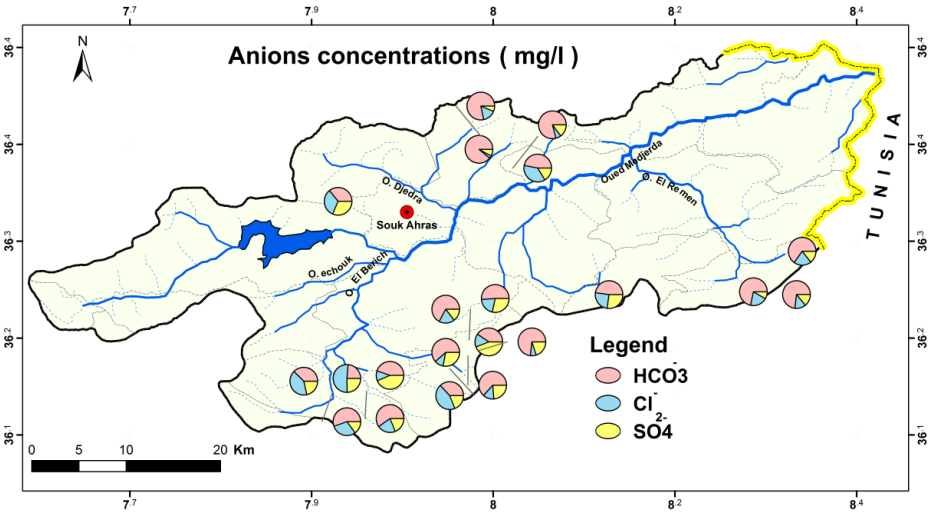

Fig. 6. Spatial distribution of anions.

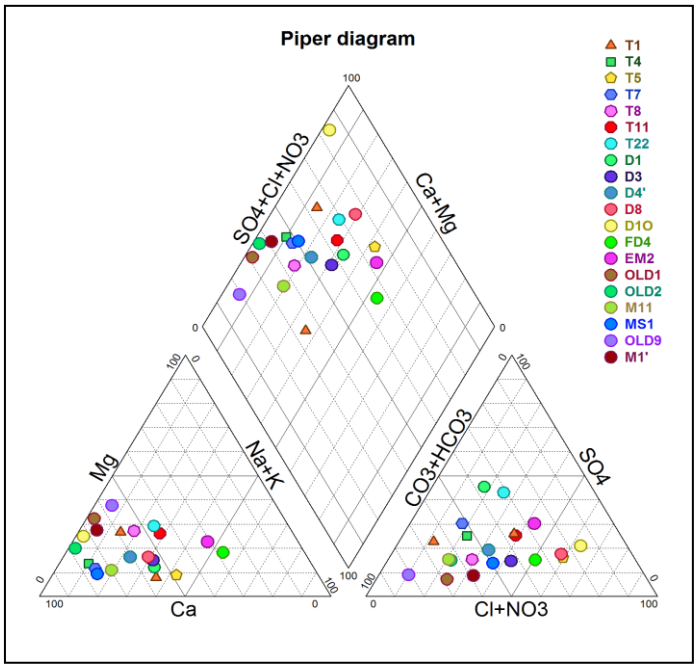

Fig. 7. Transfer of chemical analysis results to the Piper diagram.

Principal Component Analysis (PCA)

The PCA will allow samples with characteristics of similar origin or evolution to be grouped according to identical factors. The CPA's interpretation then consists in determining the responsible factors (main components) of the observed structure (Debièche, 2002). The data matrix is composed of 07 variables (major (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-}) and 21 individuals represented by drilling (Table 1).

The correlation coefficient between the variable and the axis considered presents the contribution of the variable to the composition of the main factorial axis, as much as this coefficient is important, as much as the variable contributes to the design of this axis. The examination of Table 2 shows very significant correlation relationships, particularly between elements of mineralization that could provide additional information on groundwater status. Calcium is positively correlated with bicarbonates (r=0.544), chlorides (r=0.541) representing the mineralization of waters whose origin is linked to the lithological characteristics of the Taoura aquifer. Sodium is positively correlated with chlorides (r=0.690) and sulfates (r=0.544) are due to leaching from triassic diapiric formations in the region.

Analysis of the ACP circle (F1x F2)

The correlation circle formed by axes F1 and F2 (Fig. 8) displays 57.35% of the total information and shows the following observations along axis F1 (40.38%): The distribution of the variables measured in the F1 and F2 axes shows that along the F1 axis, the majority of the variables related to mineralization are grouped together in a set.

Table 1. Mean and standard deviation of physico-chemical variables.

Paramètres (mg/l)	Mean	Minimum	Maximum	Std.Dev.
Ca^{2+}	136.1	45.3	234.5	52.8
Mg^{2+}	26.9	11.4	46.0	12.2
Na^{+}	68.6	0.9	210.0	64.6
K^{+}	3.7	0.0	13.6	3.0
Cl^{-}	133.8	10.0	325.0	105.0
HCO_3^{-}	313.8	136.8	579.5	120.5
SO_4^{2-}	122.9	26.0	284.6	71.6

Table 2. Matrix of correlations.

	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{2-}
Ca^{2+}	1						
Mg^{2+}	0,245	1					
Na^{+}	0,299	0,373	1				
K^{+}	-0,116	-0,059	0,097	1			
Cl^{-}	0,541	0,601	0,690	-0,182	1		
HCO_3^{-}	0,544	-0,002	0,357	0,115	0,001	1	
SO_4^{2-}	0,268	0,301	0,544	0,282	0,359	0,043	1

These are chlorides, sulphates, calcium, sodium and magnesium, which represent information on the total mineralization of the aquifer waters. Along the F2 axis, bicarbonates and potassium are grouped together. Axis F2 summarizes information on the influence of the dissolution of evaporative and carbonates formations in the feeding areas.

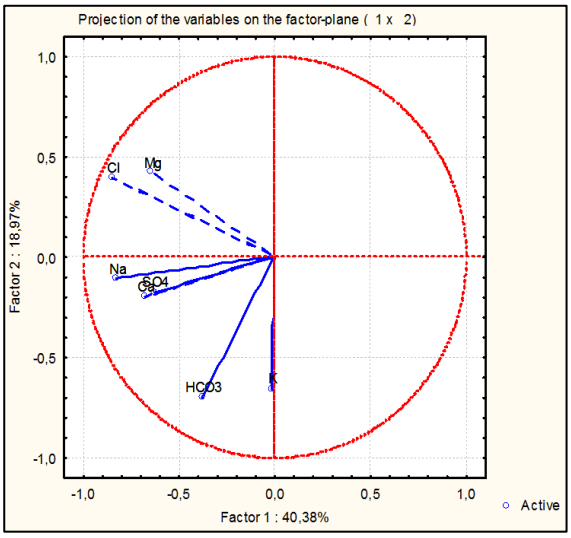

Fig. 8. Correlation circle (F1*F2).

Ascending Hierarchical Groundwater Classification (HAC)

The dendrogram (Fig. 9) confirms the results of the PCA and reveals two groups, one of which is represented by two subgroups. The first group includes the point P13 marked with excessively high conductivity and a facies dominated by calcium sulphate. The second group generally represents calcium bicarbonate waters with relatively low to medium conductivity.

The grouping of the measured parameters is based on two trends: a main group represented by the bicarbonate formations of the Taoura syncline and a secondary group constituted by the remaining variables.

The binding is done by dependence between calcium and sulphates which are closely related to magnesium and potassium. These two couples are linked to sodium and the whole is related to Chlorides which constitute the feeding zones for the edges. This last group is to be linked to bicarbonates.

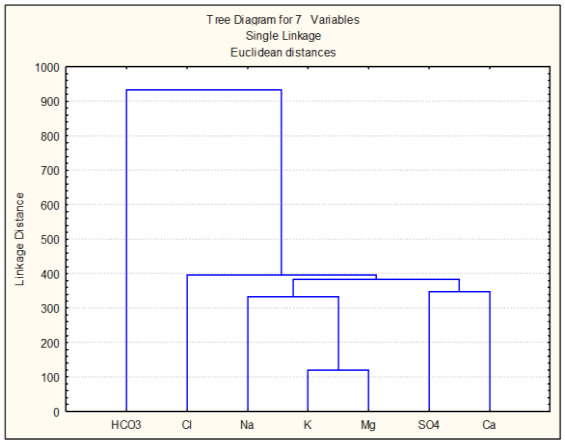

Fig. 9. Hierarchical Ascending Classification of observations (HAC).

Conclusion

This study made it possible to assess the physico-chemical quality of the waters of the transboundary aquifer of the Medjerda. Hydrochemical analysis revealed that the dominant chemical facies is calcium bicarbonate with a rate of 66.67%. Calcium sulphate facies (9.5%), calcium chloride facies (14.3%) and sodium chloride facies (9.5%) can be explained by the presence of salt formations of the Mio-Plio-Quaternary.

Statistical analysis by major components (PCA) shows significant positive correlations between mineralization variables. The Ascending Hierarchical Classification shows a major bicarbonate pole characterized by strong mineralization located in the Taoura nappe. The second and third groups are characterized by moderate to low mineralization and are located along the edges of the study area.

References

Benhammadi H, Chaffai H. 2015. The Impact of Karsts Structures on the Urban Environment in Semi Arid Area Cheria Plateau case (Northeast of Algeria). Electronic Journal of Geotechnical Engineering (EJGE) ISSN 1089-3032, Vol. **20**, Bund. **8,** 2107-2114.

Benhammadi H, Chaffai H. 2017. Climate and human impact on the Karstic environment in the semi-arid zone of the Chéria plateau (Northeast of Algeria). J. Bio. & Env. Sci. Vol. 11, No. **4,** p. 146-151.

Boubelli S, Chaffai H, Sakaa B, Djidel M, Kherici N. 2018. Hydrogeochemical characterization and assessment of the quality of surface waters of Oued Saf-Saf (North-East Algeria). J. Bio. Env. Sci. **12(2),** 168-178.

Boulgueraguer Z, Chaffai H, Toumi N, Saidi S, Djorfi S, Djabri L. 2018. Origin of mineralization and impact of anthropogenic pollution on water quality in Boussellam wadi and its environment, Wilaya of Sétif (North-East Algeria). J. Bio. Env. Sci. **12(6),** 176-185.

Bureau national des études pour le développement rural (BNEDER). 2007. Etude relative à la caractérisation et la délimitation du massif montagneux de la Medjerda 83 p.

Chaffai H, Djabri L, Lamrous S. 2005. Réserves hydriques de la Wilaya de Annaba. Inventaire, évaluation et besoins futurs en ressources en eaux. Larhyss Journal, N° **04,** 31-36. http://larhyss.net /ojs/index.php/larhyss/article/view/52/47

Chaffai H, Laouar R, Hani A, et Baali F. 2006. Les formations karstiques du plateau de Chéria (Algérie). Identification et évaluation des ressources en eau. Larhyss Journal, N°05 121-131. http://larhyss. net/ojs/index.php/larhyss/article/view/71/65

Chaffai H, Toubal A, Lacroix M, Boubelli S, et Djabri L. 2013. Hydrogéologie d'un système aquifère en zone semi-aride. Cas de la région de Khenchela (Algérie). Courrier du Savoir, N°**15**, 41-45. http:// revues.univ-biskra.dz/index.php/cds/article/view/39

Chaffai H. 1986. Evaluation des ressources en eaux de la plaine de Chéria (Algérie). Synthèse et analyse des données. Thèse Doctorat 3ème cycle, USTL, Montpellier II, France 245 p.

Kahal A, Saaidia B, Chaab S, Sayad L, Chaffai H. 2018. Hydrogeochemical characterization of a plain groundwater in a semi-arid area. Case of the F'Kirina aquifer (Northeastern Algeria). J. Bio. Env. Sci **12**(**5**), 432-440.

Kotti FC, Gil M, Habaieb H, Dieulin C, Calvez R, Ben Ali H. 2016. Etude des pluies et des débits sur le bassin versant de la Medjerda, Tunisie. Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Terre, nº **38**, 19-28.

Mtimet A. 2001. Soils of Tunisia. In: Zdruli P, Steduto P, Lacirignola C, Montanarella L. Eds. Soil resources of Southern and Eastern Mediterranean countries. CIHEAM-IAMB, Options Méditerranéennes, Série B, Etudes et Recherches, **34,** 243-268.

Rajendra Prasad DS, Sadashivaiah C, Rangnna G. 2009. Hydrochemical Characteristics and Evaluation of Groundwater Quality of Tumkur Amanikere Lake Watershed, Karnataka, India. E-Journal of Chemistry 6(**S1**), S211-S218. http://www.e-journals.net

Rodier J, Legube B, Merlet N. 2009. L'analyse de l'eau. 9ème édition, Dunod, Paris 1579 p.

Rouaibia F, Djabri L. 2017. *Caractéristiques* chimiques des eaux de la nappe du synclinal de Taoura, Souk Ahras (Nord-Est de L'Algérie). Rev. Sci. Technol., Synthèse 35, 124-139. https://www.ajol. info/index.php/srst/article/view/166815/156260

Sayad L, Djabri L, Bouhsina S, Bertrand C, Hani A, Chaffai H. 2017. Hydrochemical study of Drean–Annaba aquifer system (NE Algeria). Journal of Water and Land Development (JWLD), No. **34(VII–IX),** 259-263.
DOI: 10.1515/jwld-2017-0061

SOGREAH. 2009. Etude d'inventaire et de développement de la Petite et moyenne hydraulique, wilaya de souk Ahras. Société Grenobloise d'Etudes et d'Applications Hydrauliques, Nº 2340074.

Subramani T, Rajmohan N, Elango L. 2010. Groundwater geochemistry and identification of hydrogeochemical processes in a hard rock region, Southern India, Environ. Monit. Assess **162,** 123-137.

Templ M, Filzmoser P, Reimann C. 2008. Cluster analysis applied to regional geochemical data: Problems and possibilities. Appl. Geochem **23**, 2198-2213.

Vila JM. 1980. La chaîne alpine de l'Algérie orientale et des confins algéro-tunisiens. Thèse de Doctorat, Paris VI 663p.

Wenning RJ, Erickson GA. 1994. Interpretation and analysis of complex environmental data using chemometric methods. TrAC Trends in Analytical Chemistry **13**(**10**), 446-457.
DOI: 10.1016/0165-9936(94) 85026-7.