DOI: 10.2478/jwld-2018-0008

JOURNAL OF WATER AND LAND DEVELOPMENT
2018, No. 36 (I–III): 77–87
PL ISSN 1429–7426

Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld

Received 29.07.2017
Reviewed 01.11.2017
Accepted 15.11.2017

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Hydrochemistry and origin of principal major elements in the groundwater of the Béchar–Kénadsa basin in arid zone, South-West of Algeria

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For citation: Lachache S., Nabou M., Merzouguui T., Amroune A. 2018. Hydrochemistry and origin of principal major elements in the groundwater of the Béchar–Kénadsa basin in arid zone, South-West of Algeria. Journal of Water and Land Development. No. 36 p. 77–87. DOI: 10.2478/jwld-2018-0008.

Abstract

Béchar region is located in the southwest of Algeria, characterized by an arid climate with a Saharan tendency. It is subject to an increasing demand for water like all the great agglomerations due to the economic and demographic development. The groundwater of region is deteriorating because of the economic development, and the rapid growth of population. This article is devoted to the study of hydrochemistry and processes of mineralization of groundwater in this region. The results of physicochemicals analyses shows the same chemical facies of the chloride and sulphate-calcium and magnesium type, with high mineralization from North-East to South-West to the outlet of Béchar–Kénadsa basin. The determination of the mineralization origin and the main major elements were approached by multivariate statistical treatment and geochemical. This method has identified the main chemical phenomena involved in the acquisition of mineralization of water in this aquifer. These phenomena are mainly related to the dissolution of evaporite formations, the infiltration of runoff water and direct ion exchange and mixing. However, the high mineralization anomaly is observed at the centre of Béchar–Kénadsa basin progressively by going to the outlet of this basin.

Key words: *arid zone, Béchar–Kénadsa basin, hydrochemistry, major elements, mineralization, multivariate statistical analysis*

INTRODUCTION

The problem of water is essentially linked to the sustainable development insofar as water must be able to meet the need of the present and the future generations. In addition, there are many challenges leading to apply an efficient management of these water resources as well as problems related to their quality [MONDAL *et al.* 2005]. In countries affected by aridity, water resources are the primary economic and environmental importance and especially those of the Maghreb, which are already experiencing a water stress situation [BAHIR *et al.* 2008; TRABELSI *et al.* 2005]. These water resources are affected by many factors; population growth, climate change, the extension of irrigated areas and industrial development.

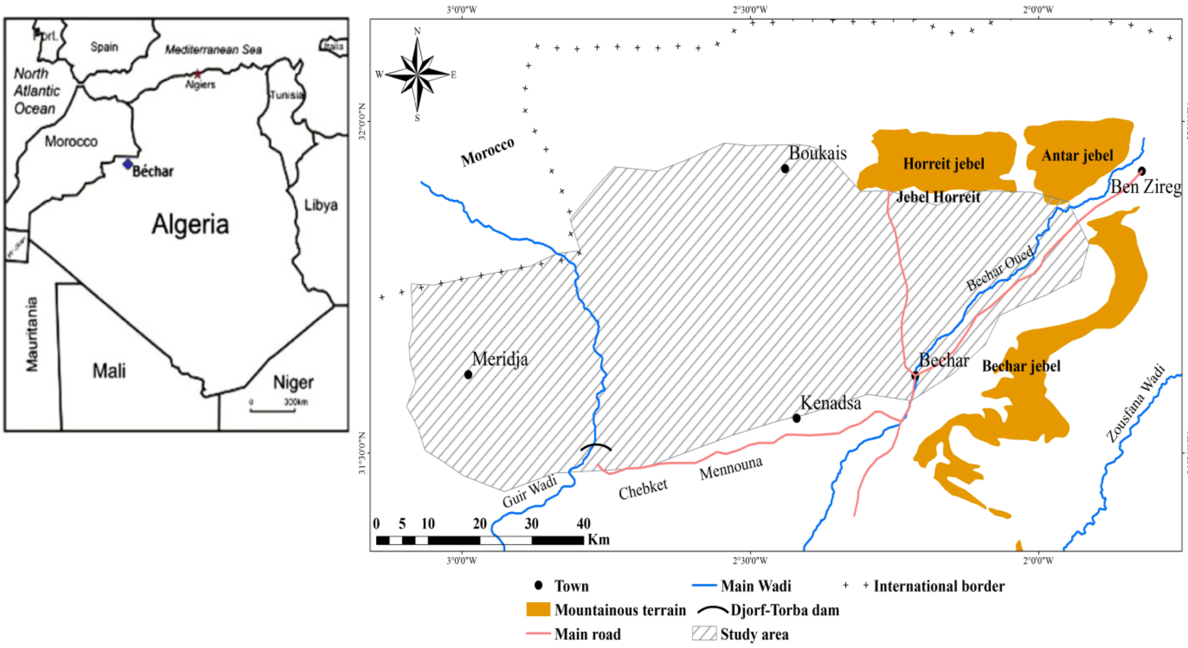

Fig. 1. Geographical location of the study area; source: own elaboration

They are actually threatened by various sources which spread contamination [EBLIN *et al.* 2014; FARID *et al.* 2012].

In the region of Bechar, the Turonian aquifer belongs to the great Cretaceous basin Er Rachidia–Béhar. It constitute the first groundwater resource in terms of importance and exploitation, ensuring of 20% of drinking water to a local population is estimated to have more than 192 900 inhabitants in 2007 [KABOUR *et al.* 2011]. Furthermore, this aquifer is an example of the source of water tributary to human factors and unfavorable climatic conditions. Several previous studies [IDROTECNECO 1976; MEKIDECHE *et al.* 1995] have been carried out in this area of research on the Turonian aquifer of Béchar–Kénadsa basin, shows that the reserve of this aquifer is certainly considerable with a flow that is reflected by two very important sources, sources of Boukais (S-K) and source of Djorf Torba (S-DJ.T). The identification of the sources of salinity and recharge becomes essential in this case to develop water resource management plans in the context of climate variability [SCALON *et al.* 2006]. At present, concentrations of salts and certain chemical elements exceed the international standards set by World Health Organization and the European Union directives for water intended for human consumption [RODIER *et al.* 2009]. In this context and at the scale of Béchar–Kénadsa basin, we have elaborated geochemical database (principal major elements and physico-chemical grandeur) collected during the year 2014. Principal objective of this article includes geochemical characterization, highlight the origin of major elements and processes of acquisition the mineralization of waters Turonian aquifer Béchar–Kénadsa basin.

GENERAL FRAMEWORK

Béchar region is located at foot of the southern reverse of Saharian Atlas, a distance of 950 km to South-West of capital Algiers. It is a part of great Cretaceous basin d'Er Rachidia–Boudenib which extends over an area of 8 000 km^2. This area is limited to north by northern massifs Antar Jebel 1 960 m and Horriet Jebel 1 461 m, to south by Chebket Mennouna, in east by Béchar Jebel of 1 512 m, and in west by Algerian-Moroccan border (Fig. 1). The climate of this region is arid with Saharian trends where rainfall is irregular during the year, it is of the order of 72 $mm \cdot yr^{-1}$, for the period 1988–2008. The low temperatures 4°C were recorded in January and the high value 40°C in July, with an average of 27°C [KABOUR *et al.* 2015; KHARFIA, EL-AMINE 2014]. The average evaporation is 306 mm, while the evapotranspiration values exceed those of the precipitations implying a drought throughout the year.

GEOLOGICAL AND HYDROGEOLOGICAL CONTEXT

Béchar region is a portion of the old Saharian platform, monotonous, stable and cratonised. This area is an excellent open-air laboratory of a great geological diversity remarkable. Many authors were interested in the geological study of the Béchar region. They have demonstrated that geological formations of the Bechar region constitute a wide range of terrains ranging from ancient (Precambrian) to the present (Quaternary). This situation is represented of schematically under better conditions of outcrops (Fig. 2). It's about a succession of limestone bench, followed

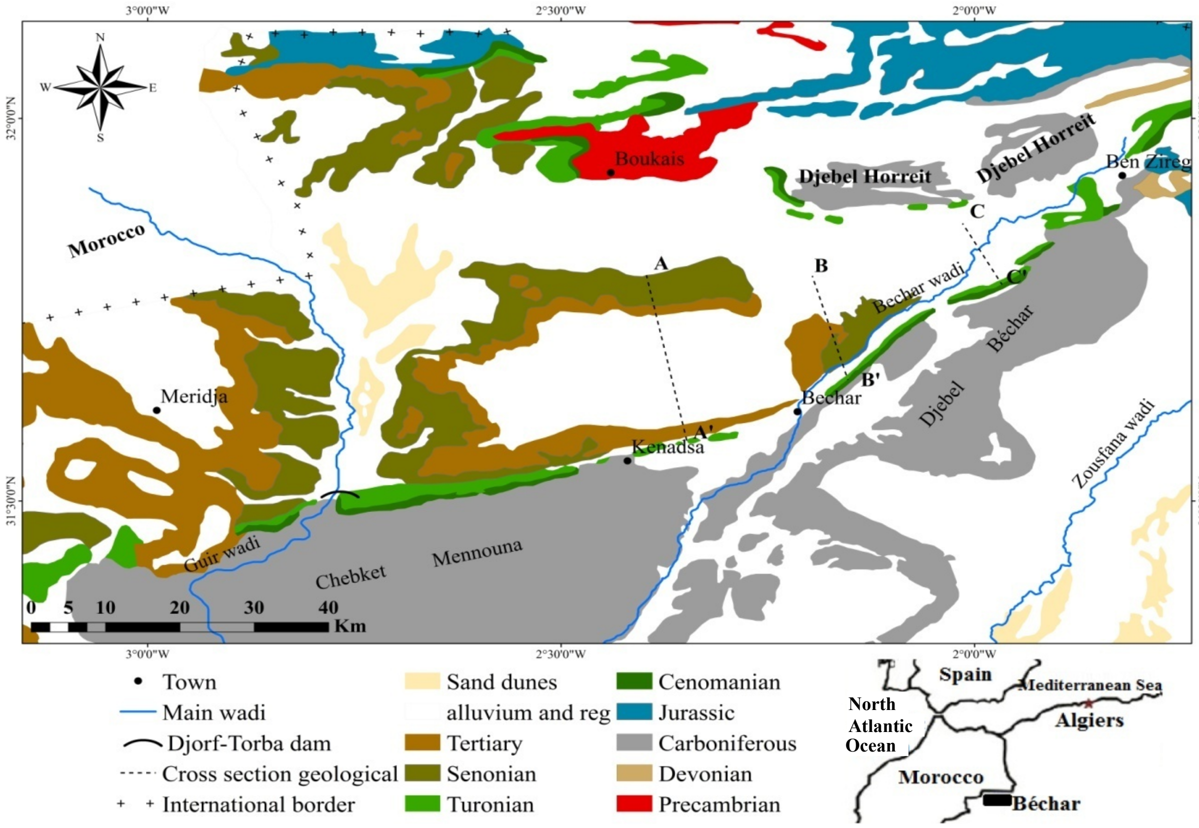

Fig. 2. Map of Béchar area representing the geology; source: own elaboration

by limestone in plate. The together is projecting in the topography forming cliffs well visible all along the road Béchar–Kénadsa–dam Djorf Torba. The land consists of several aquifers and different formations [BENARADJ *et al.* 2012]. To the north of the studying area, and more precisely at the level of the town of Boukais, this zone presents the oldest outcrop, whose volcanic terms predominate (basalt, andesite, dolerite, rhyolite) [BYRAMJEE, MEINDRE 1956; MEBARKI 2012], and at the heart of the Ben Zireg anticline (North-East) where are depicted by deposits of Cambro-Ordovician and Gothlandian. The Devonian are more ample in outcrop, they are identified at the bottom of the Koudiat El Haïdoura (Grouz), at the level of Talzaza, the Maïder El Mehadjib, to Soltane El Betoum and to Ben Zireg [MENCHIKOFF 1936; PERRODON 1957].

At the center of our zone, the outcrop of the Carboniferous lands are the most spreaded outcrop and the best studied [DELEAU 1951; PAREYN 1961]. They constitute the principal reliefs of the region (Djebel Antar, Djebel Horreït, Djebel Béchar and Chabket Mennouna) and are also the base of the town of Bechar. The successive orogenesis are represented by conglomerates and polygenic breccias of Permo-Triassic age followed to Chebket Fendi by lagoon deposits clay-limestone and gypsum from the Jurassic [MEKKAOUI 2000]. The Cretaceous lands are generally in the form of cuesta (cuesta de Ras Smar, Bezazil El Kelba and the cuesta of Djorf Torba dam). These are sandstone-clay soils to gypsum, evolving towards marls and massive limestones, the upper Cretaceous is represented by evaporite clays (halite and gypsum) [IDROTECNECO 1976; MEBARKI 2012]. These series of folded terraces are followed by a tabular series of the Tertiary–Quaternary, whose lower terms by sandy marls of continental medium and by lake limestones banks Eocene probably older [IDROTECNECO 1976]. Table 1 shows the different geological formations of the region studied.

At the scale of the Béchar–Kénadsa basin, the Turonian aquifer is formed by a white limestone slab, pink grey basically benches with wings sometimes dolomitic [IDROTECNECO 1976]. The substratum of this aquifer consists essentially of a marl series of Cenomanian from 15 to 50 m [BOUGUIDER, BOUARICHA 2000], with very low permeability. The roof of the aquifer consists of mottled sandy marl with banks of evaporites (gypsum, anhydrite and rock salt) of the Senonian under very low permeability (Fig. 3). The aquifer of the Turonian is considered the principal aquifer of Béchar region; free border, it becomes captive towards the center of the basin. The most important field of this aquifer located at the Ouakda pilot zone and has nine boreholes for a total flow of about 116 $dm^3 \cdot s^{-1}$.

Previous hydrogeological studies [KABOUR *et al.* 2011; MEKIDECHE *et al.* 1995; MEKKAOUI 2000] have shown that this aquifer receives good water supply. The entries to this aquifer can be done either directly by rain in the outcrop Turonian zone, or by a second indirect supply of the upper medium of water table

Table 1. Lithostratigraphic unit of the study region

Age	Lithology (thickness)
Precambrian	limestone, sandstones and conglomerates (450 m); volcanic rock and andesites (1500–2000 m)
Cambro-Ordovician	dolomitic limestones and quartzites (400–450 m)
Gothlandian	marl schist (360 m)
Devonian	limestone and schist (700 m) to Ben Zireg
Carboniferous	limestone, schist and clayey (>2000 m) at Ben Zireg
Albian	coarse sandstone followed by red dreary of gypsum (500 m)
Senonian	gypsum and anhydrite marls alternating with a bench of rock salt
Turonian	limestone bound in a large bench (25–40 m)
Cenomanian	marl reds not dated and from the marl with Ostrea susjacentes
Eocene	sandy and gypsiferous marls (75 m)
Pliocene	lakeside limestone cracked and conglomerate (50 m)
Quaternary	gravelly sandstone, medium and fine sand (15–20 m)

Source: own elaboration.

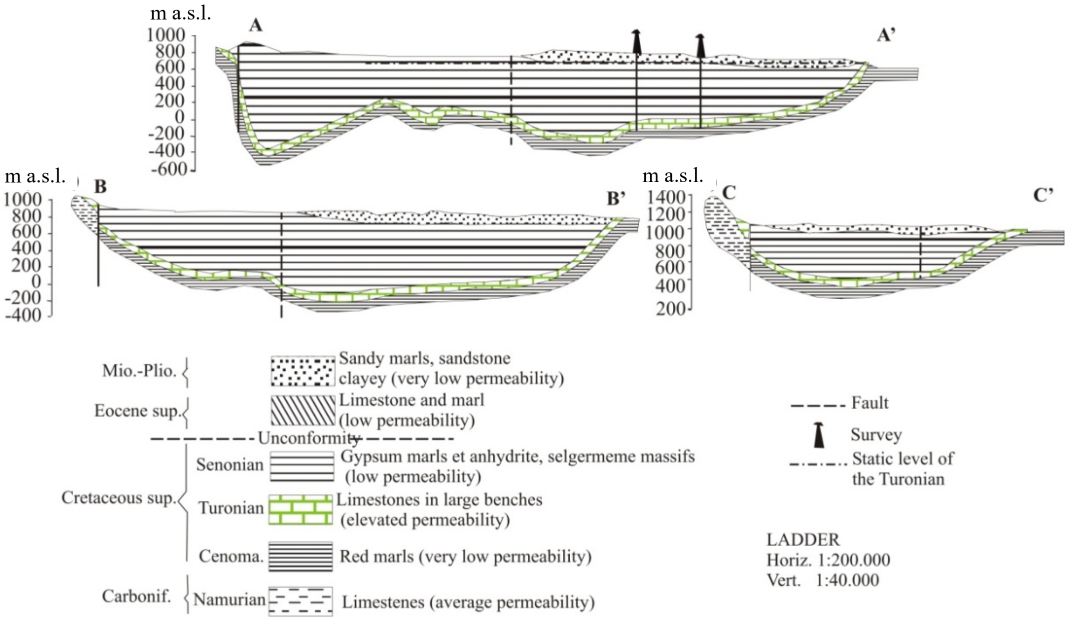

Fig. 3. Cross-sectional hydrogeological transversal interactive of the Turonian aquifer; source: own elaboration

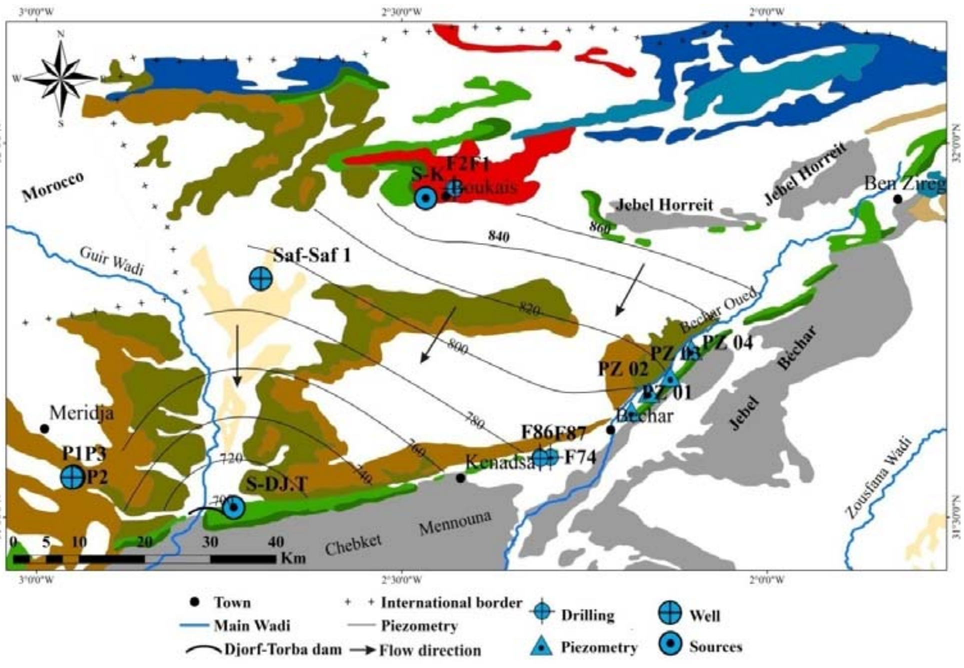

Fig. 4. Piezometric map for May 2014; source: own elaboration

superficial (inferoflux and Quaternary), and lateral aquifers of Atlas. This aquifer is considered the most important water table in Béchar region [IDRO-TECNECO 1976; KABOUR *et al.* 2011]. The pumping tests were realized by the agents of the National Agency for Hydraulic Resources of Adrar (Fr. Agence Nationale des Ressources Hydrauliques – ANRH) in 2014, on four drilling capturing this aquifer (PZ01, PZ02, PZ03 and PZ04) at the Ouakda area (Fig. 4). Values of transmissivity have an average between 10^{-3} and 10^{-4} $m^2 \cdot s^{-1}$, an average permeability of the order of 10^{-4} to 10^{-5} $m \cdot s^{-1}$ and a storage coefficient of the order of 10^{-4}.

PIEZOMETRY

The piezometric map of the Turonian aquifer (Fig. 4), established in May 2014, was made on the basis of statements made by the ANRH from a survey of the piezometric levels of this aquifer, which allowed to drew up a new piezometric map (Fig. 4). In view of the very limited number of water points, the piezometric reconstruction was limited by the lack of information at the center of basin where the piezometry was plotted on the basis of information from a single drilling (Saf-Saf1) (Fig. 4). This new map makes evident the configuration of the groundwater flow of Turonian aquifer. The flow direction is generally from northeast to South-West. This map reveals piezometric altitudes varying from 697 to 850 m. The highest values are to the east of the studying area, they gradually decrease towards the west to the natural outlet of the dam source (S-DJT) which is located at the dam Djorf Torba, giving a convergent type for this aquifer. The hydraulic gradient (calculated from the piezometry of May 2014) shows variations from east to west towards the dam of Djorf Torba, with values between 0.33% to 0.4% respectively. This result can be induced by the lithological nature of the Basin or by qualitative and quantitative variations in bills.

SAMPLING AND ANALYSIS

In the context of study of the Turonian aquifer system, we have selected all water points distributed in Béchar–Kénadsa basin and capturing only Turonian aquifer (Fig. 4). These water points were located by GPS (Global Positioning System). Physico-chemical parameters (pH, temperature, electrical conductivity and mineralization) were measured using a multiparameter probe (WTW). Water levels were measured using a piezometric probe. Chemical analyses of the major elements (cations and anions) were effectuate by ion chromatography at the laboratories of chemistry ANRH at Adrar.

The study of the acquisition of mineralization and origin of the major elements of Turonian aquifer in Béchar–Kénadsa basin is based on a total 20 samples that were taken in May 2014.

RESULTS AND DISCUSSION

The water temperatures of the Turonian aquifer are between 20°C and 26°C. The pH groundwater of this aquifer has an average of 7.19. Analysis chemical data of the groundwater of Turonian aquifer shows a wide variation in chemical composition. The values of the electrical conductivity recorded range from 0.98 and more 35 $mS \cdot cm^{-1}$ with an average of the order of 3.27 $mS \cdot cm^{-1}$ which explains why the waters of the studying area exceed standards World Health Organization. The map of the spatial distribution of the groundwater mineralization of Turonian aquifer for the month of May 2014 (Fig. 5) shows an increase in a logical manner in the flow direction of the piezometric map. Generally the aquifer has values between 615 and 9542 $mg \cdot dm^{-3}$. The mineralization of the waters north and northeast of the study area is inferior to 1000 $mg \cdot dm^{-3}$. The increase in mineralization to west and South-West of Béchar, where one finds in drilling (F74, F86 and F87) mineralization of (3924, 9129 and 3530 $mg \cdot dm^{-3}$) respectively, accompanied by an augmentation of Na^+, Cl^-, and after the dam of Djorf Torba (1364, 1033 and 1755 $mg \cdot dm^{-3}$) at wells (P1, P2 and P3) respectively. From chemical analyses, we can see the progressive enrichment of salts (chlorides and sulphates) to source (S-DJ.T) at the dam of Djorf Torba. Evaporite deposits in Béchar–Kénadsa basin are at the origin of such an evolution of chemistry. The results of the representation in major elements on the Piper diagram [PIPER 1944] shows that the waters of Turonian aquifer of same chemical facies of the chloride and sulphate-calcium and magnesium type (Fig. 6). The spatial distribution of these chemical facies linked essentially to the same lithological nature of aquifer and recharging conditions.

STATISTICAL ANALYSIS

Many studies have been devoted to the analysis of chemical data of water through multivariate statistical techniques, among others principal component analysis (PCA). This method would make it possible to specify relationships between the variables and the phenomena at the origin of these relations [BARAN *et al.* 2006; MOUISSI, ALAYAT 2016].

A statistical study (PCA) was performed on 10 variables of 20 individuals (Tab. 2) capturing the Turonian aquifer in the period of May 2014. Analysis of the factorial plane (F1/F2) shows that more than 75% of the total variance is expressed. The analysis in this plan is acceptable (Fig. 7). Many significant correlations exist between the different ions (Tab. 2).

Strong negative correlation is observed between pH and electrical conductivity, as well as between the electrical conductivity and HCO_3^-, that is to say any increase of one, implies a decrease in the other and and the opposite (Tab. 2), and a strong correlation between pH and HCO_3^-, these elements are responsible for the acquisition of mineralization of the ground-

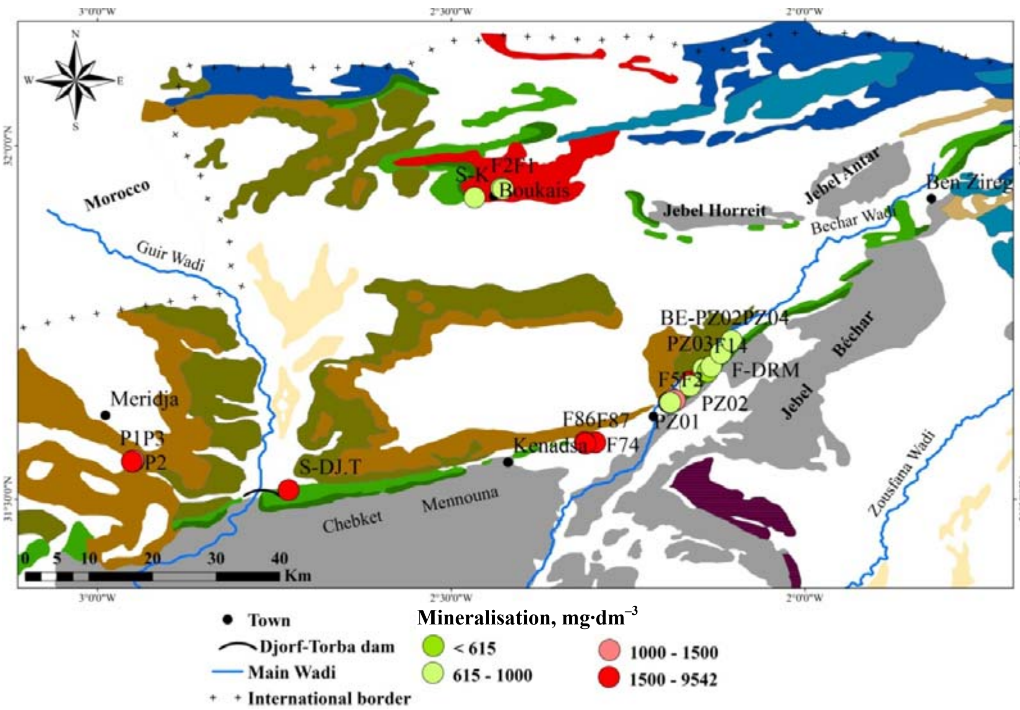

Fig. 5. Groundwater mineralization map; source: own elaboration

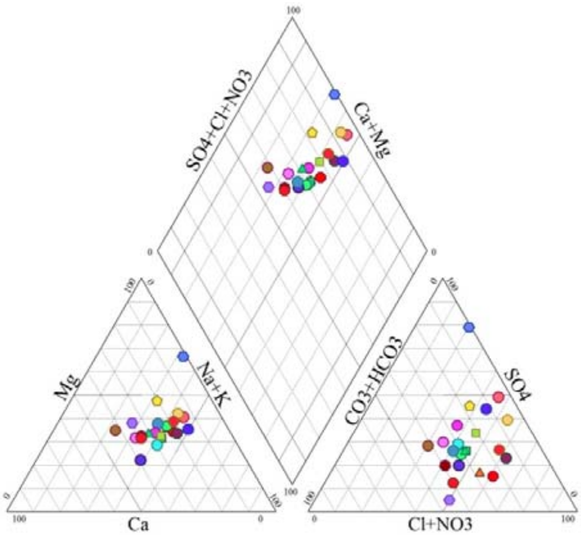

Fig. 6. Piper diagram with indication of the groundwater samples; source: own study

water of the Turonian aquifer. Concomitantly, the pH is placed in opposition to the electrical conductivity and the ion of HCO_3^- on the F1 axis with a total variance of 29.09%, this can be explained by the fact that the waters have a high electrical conductivity due to the effect of the formations of the Upper Cretaceous formation. A strong correlation ($0.51 < R < 0.93$) was observed between the ions Mg^{2+}, Na^+, Cl^-, SO_4^{2-} and Ca^{2+} (Tab. 2), these elements are represented in the same axis of F1 with a total variance of more than 46% (Fig. 7). This axis is responsible for the acquisition of the evaporite origin (halite, gypsum and dolomitic) of the groundwater of this aquifer. Associated with the geological origin by the dissolution of the evaporite formations and the dolomitic limestone.

The factor F3 of (PCA) determined by the chemical elements of K^+ and NO_3^- shows that the superficial infiltration of water comes originally from the degradation of organic material (fertilizers).

Table 2. Pearson correlation matrix between the chemical elements of the Turonian aquifer (May 2014)

Parameter	pH	*EC*	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HCO_3^-	NO_3^-
pH	1									
EC	**–0.953**	1								
Ca^{2+}	0.285	–0.225	1							
Mg^{2+}	–0.365	0.447	**0.628**	1						
Na^+	–0.048	0.113	**0.912**	**0.863**	1					
K^+	0.014	0.008	–0.064	–0.005	–0.144	1				
Cl^-	0.006	0.066	**0.935**	**0.840**	**0.990**	–0.061	1			
SO_4^{2-}	–0.468	**0.539**	**0.510**	**0.985**	**0.783**	0.047	**0.750**	1		
HCO_3^-	**0.810**	**–0.811**	0.128	–0.337	–0.191	0.311	–0.116	–0.396	1	
NO_3^-	0.206	–0.051	0.201	0.285	0.238	–0.356	0.225	0.218	0.026	1

Explanations: *EC* = electrical conductivity of water. Values in bold represent strong and medium correlations.
Source: own study.

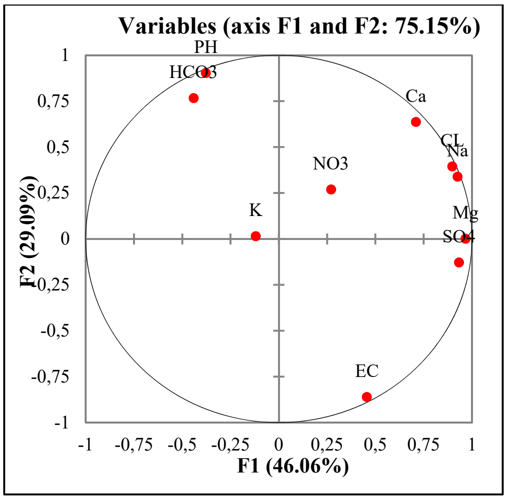

Fig. 7. Projection of the variables on factor plane 1–2 (May 2014); source: own study

ORIGIN OF MINERALIZATION

The study of the correlations established between the concentrations of major elements (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-}, HCO_3^-) and total mineralization of water has allowed the at the origin of the mineralization of the sampled waters (Fig. 8). Generally speaking, calcium, sodium and chloride concentrations are well correlated with mineralization. This translates by a strong participation of these elements in the acquisition of the saline charge of the waters Turonian aquifer. On the other hand, the participation of magnesium and sulphate concentrations with its coefficients of determination R^2 of 0.65 and 0.51 respectively, are showing average participation with mineralization in salinization of groundwater (Fig. 8). However, the concentrations of potassium and bicarbonate do not show a clear correlation with the mineralization, indicating a low participation of these ions in the salinization of groundwater. This is corroborated by the saturation indices (*SI*) calculated by program WATEQF [PLUMMER *et al.* 1976] which shows a state of undersaturated for the majority of samples screw-have-screw halite and a light state of undersaturated to saturation screw-have-screw the gypsum and the anhydrite. The presentation of saturation indices on (BoxPots) shows that the majority of water points in the Turonian aquifer are saturated vis-à-vis carbonated minerals, aragonite, calcite and dolomite (Fig. 9).

When the saturation indices (*SI*) [DREVER 1997; SUBYANI 2005].
If $SI < 0$, the water is undersaturated.
If $SI > 0$, the water is oversaturated.
If $SI = 0$, water is in equilibrium.

The correlation of Ca^{2+} as a function of SO_4^{2-} shows the totality of the analytical points are positioned above of the line of slope equal to 1, this excess of SO_4^{2-} and accompanied by a deficit in Ca^{2+} (Fig. 10a). The SO_4^{2-} enrichment due to the origin of Turonian aquifer and dissolution of the formation of Senonian. Furthermore, this deficit in Ca^{2+} accompanied by enrichment of Na^+ indicates the participation of these two ions in the basic exchange between the Turonian aquifer and the clay minerals. The clays release the ions of Ca^{2+} or Mg^{2+} and fix Na^+ or K^+ ions following a process that can be reversible [FEHDI *et al.* 2009a, b]. The Figure 10b illustrates the arrow correlation between Mg^{2+} as a function of SO_4^{2-}, this approach tends to indicate that the salinity of the water would result from a dissolution of salt formations. This is confirmed by a strong correlation between these two ions of ($R^2 = 0.962$). The acquisition of Na^+ as a function of Cl^- in natural waters is often related to the dissolution of the halite. This is corroborated by the graphical presentation of these two ions Na^+/Cl^- [FEHDI *et al.* 2009a, b; KAMEL *et al.* 2010] (Fig. 10c). The majority of the points are grouped around the line of slope equal 1, influenced by the dissolution of halite and /or anhydrite. This confirms a strong positive correlation between chlorides and sodium, displaying a coefficient of determination ($R^2 = 0.97$) (Fig. 10c).

The diagram of $(Ca^{2+} + Mg^{2+})/(HCO_3^- + SO_4^{2-})$ as a function of (Na^+/Cl^-) (Fig. 10d) to examine the $Ca^{2+} + Mg^{2+}$ origin compared to the ions $HCO_3^- + SO_4^{2-}$, and can highlight the basic exchange of water-rock, as well as to identify the principal origin of these ions. In Figure 10d we observe more than 70 % of the water points have an excess in $Ca^{2+} + Mg^{2+}$ relative to the ions $HCO_3^- + SO_4^{2-}$ due surely to the leaching of the evaporites which provide more Ca^{2+} and Mg^{2+} ions, and reverse base exchange which cannot consume the effect of chemical precipitation or the effect of calcium and magnesium binding by clays. In addition, almost of 30% of water points undergo a basic exchange. An examination of the origin of calcium compared to the ions of bicarbonates and sulphates, can highlight the basic exchanges in water-rock, and identify the two the principal source of Ca^{2+} to know the carbonates and evaporites [ABID *et al.* 2009; GHEBOULI, BENCHEIKH 2008]. A decrease in calcium content compared to the ions of $HCO_3^- + SO_4^{2-}$ is accompanied by a deficit of Na^+ and Cl^-, which implies a high concentration of HCO_3^- and SO_4^{2-}. This situation due to the dissolution of the evaporite formations [CHERY (ed.) 2006; DEBIECHE 2002].

The projection of the different points on the diagram $(Ca^{2+})/(HCO_3^- + SO_4^{2-})$ as a function of (Na^+/Cl^-) (Fig. 11e) show that 60 % of the water points undergo a base exchange reverse by which the ions Na^+ are adsorbed on the surface of clay minerals ions by releasing $Ca^{2+}/(HCO_3^- + SO_4^{2-}) < 1.25\%$ of the water points undergo a direct exchange of bases by which the ions Ca^{2+} $(Na^+/Cl^-) > 1$, and 15 % of the points represent the natural state $Na^+/Cl^- = 1$. All water points have a deficit in Ca^{2+} compared to the ions $HCO_3^- + SO_4^{2-}$, surely due to evaporite formations which can be consumed under the effect of the fixation of the calcium by clays and to precipitation of calcite.

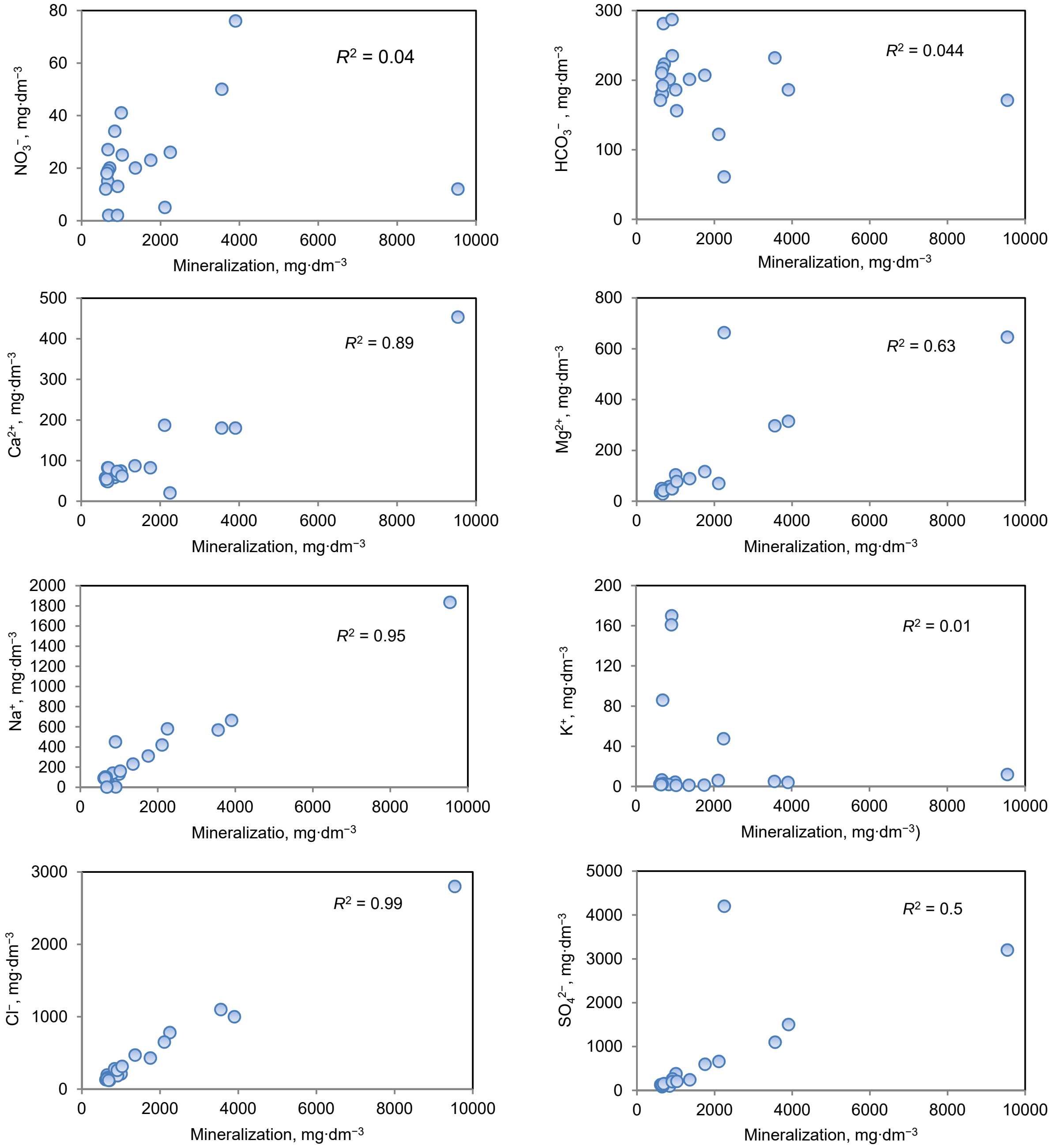

Fig. 8. Variation of concentrations of major chemical elements with mineralization of waters; source: own study

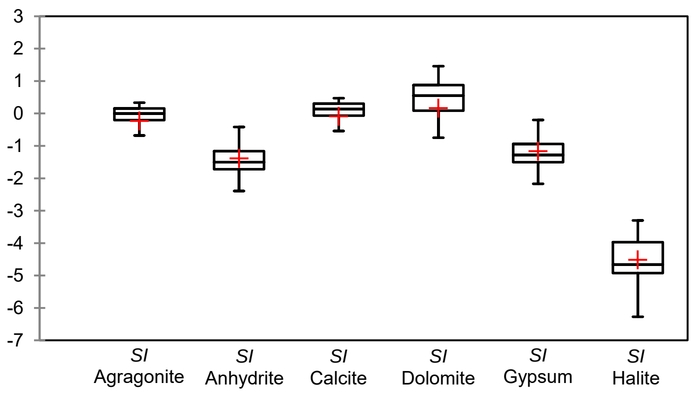

Fig. 9. Box plots illustrating the variation of the saturation indices (*SI*) of certain minerals of the aquifer formations; source: own study

The natural origin of the ion Ca^{2+} which exists in waters of Turonian aquifer and comes from mostly of the carbonate origin (calcite, aragonite and dolomite) and/or evaporite (gypsum and anhydrite). Figure 10f presents the relationship of Ca^{2+} as a function of HCO_3^- + SO_4^{2-}, is used to determine the ion exchange processes, indicates that some of the calcium and magnesium could come from of the carbonate dissolution of aquifer matrix.

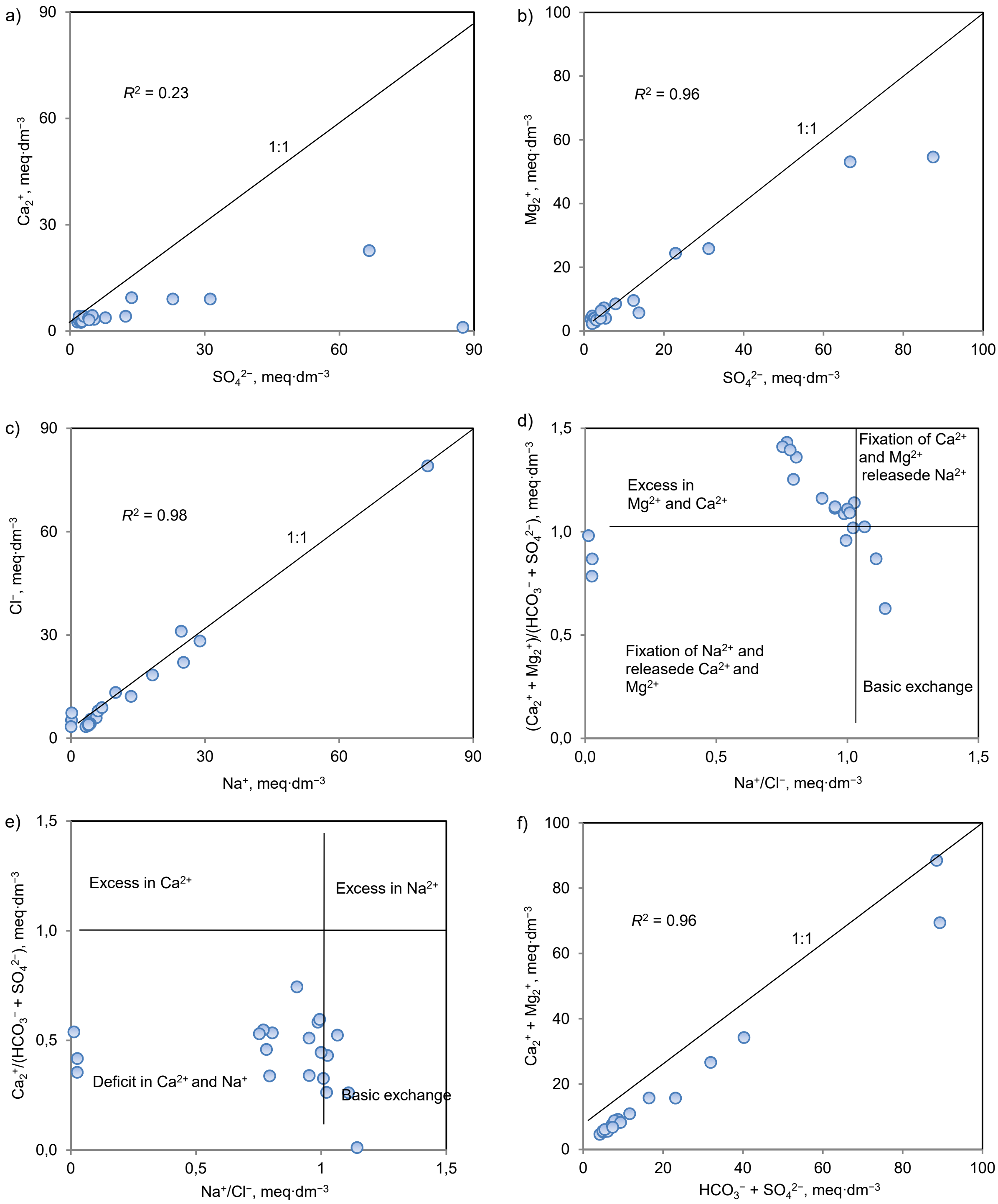

Fig. 10. Correlations between analysed chemical elements: a) Ca^{2+} *vs* SO_4^{2-}, b) Mg^{2+} *vs* SO_4^{2-}, c) Na^+ *vs* Cl^-, d) $(Ca^{2+} + Mg^{2+} / HCO_3^- + SO_4^{2-})$ *vs* (Na^+/Cl^-), e) $(Ca^{2+}/HCO_3^- + SO_4^{2-})$ *vs* (Na^+/Cl^-), f) $(Ca^{2+}+Mg^{2+})$ *vs* $(HCO_3^- + SO_4^{2-})$; source: own study

CONCLUSIONS

This study on the groundwater of Béchar–Kénadsa basin allow us to highlight the different chemical phenomena that can take place within this important aquifer. Chemical analysis of samples the Turonian aquifer show that the waters are generally of the chloride and sulphate-calcium and magnesium type, with high mineralization from north-east to south-westerly until the outlet of this aquifer.

The hydrochemical and statistical study allowed to identified the different processes of mineralization and the origin of principal major elements of the waters. Indeed, by going the northeast and to the southwest, the mineralization of the waters increases in parallel to the direction of the groundwater flow as indicated piezometry shows. The chemistry also evaluated in same direction; indeed, the content either absolute, either relative (reaction value) of ions SO_4^{2-} increase.

However, the principal major elements who controlling the salinization of the waters of the Turonian aquifer in Béchar–Kénadsa basin comes mostly from the dissolution of the superior Cretaceous formations. These elements show high concentrations at the center of the Béchar–Kénadsa basin to the outlet of the Turonian aquifer, they are in relation with high levels of sodium, chloride, sulphate and the presence basic exchange reactions between aquifer waters and the clay formations.

The processes of dissolution gypsum, of halite or/and anhydrite help the salinization of groundwater. This is elsewhere in perfect agreement with the state of undersaturated of the waters screw-have-screw of these minerals. Cationic exchange phenomena and dissolution/precipitation processes of carbonated minerals (calcite, dolomite and aragonite) are generally the origin of the variation of cations concentrations (Ca^{2+}, Mg^{2+}, and Na^{+}) in groundwaters.

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Właściwości hydrochemiczne i pochodzenie głównych pierwiastków w wodach gruntowych basenu Béchar–Kénadsa w strefie suchego klimatu południowozachodniej Algierii

STRESZCZENIE

Region Béchar w południowozachodniej Algierii charakteryzuje klimat suchy z wpływami saharyjskimi. Jak wszystkie duże aglomeracje, region ten wykazuje rosnące zapotrzebowanie na wodę w związku z rozwojem ekonomicznym i demograficznym. Rozwój gospodarczy i szybki przyrost populacji jest powodem pogarszania się jakości wód gruntowych. Niniejszy artykuł jest poświęcony badaniom właściwości hydrochemicznych i procesów mineralizacji wód gruntowych w regionie. Wyniki analiz wykazują występowanie podobnych facji chemicznych typu chlorkowego i siarczanowo-wapniowych lub magnezowych o wysokim stopniu mineralizacji od północnego wschodu do południowego zachodu basenu Béchar–Kénadsa. Źródła mineralizacji i główne pierwiastki zostały oznaczone metodami geochemicznymi z zastosowaniem wieloczynnikowej analizy statystycznej. Metody te dały podstawy do identyfikacji głównych zjawisk chemicznych wpływających na mineralizację wody, takie jak rozpuszczanie formacji ewaporytowych, infiltracja spływów powierzchniowych, bezpośrednia wymiana jonowa i mieszanie. Anomalię wysokiej mineralizacji malejącą w kierunku odpływu zaobserwowano w środkowej części basenu Béchar–Kénadsa.

Słowa kluczowe: *basen Béchar–Kénadsa, główne pierwiastki, hydrochemia, mineralizacja, strefa klimatu suchego, wieloczynnikowa analiza statystyczna*