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Hydrogeochemical characterization of a plain groundwater in a semi-arid area. Case of the F'Kirina aquifer (Northeastern Algeria)

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Abstract

The F'Kirina plain is located northeast of Algeria; its groundwater constitutes the main resource for potable water supply and irrigation in this area. The aquifer lithology is made up of alluvia and Maestrichtian limestone. The aim of this study is to determine the hydrochemical characteristics of groundwater of this aquifer. For this purpose monthly samples from boreholes and wells were collected. The physicochemical analyses by Piper diagram, PCA, as well as hierarchical ascendant classification analysis determined a high mineralization degree. The dominant chemical facies are calcium-sulfate, calcium-bicarbonate and calcium-chloride. This mineralization has its main origin in host rocks.

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Introduction

The F'Kirina plain is a part of the high Constantine plains situated in the northeast of Algeria which belongs to the North of Africa. This latter is typically a semi-arid region where water resources are rare and are under increasing human pressures and many are threatened by the increase of the salinity which is due to several causes (Williams, 2002). such as industrial discharges, use of fertilizers in agriculture, see–water intrusion into coastal areas, climatic parameters, exchanges between the aquifer and surface water and the dissolution of geological formations.

In this context, several studies in the world have been made concerning the determination of the origin of groundwater chemistry and the mechanisms of acquisition of mineralization, among which, those of (Hssisou *et al*, 2001, Chaffai *et al*, 2003, Fehdi *et al*, 2009, Belghiti *et al*, 2013, Boubelli *et al*, 2018).

Algeria loses significant quantities of water due to the salinity engendered by the water-rock interaction which has an undesirable effect on the quality of this resource (Ghrieb, 2011).

The present study is going to give an example of this type of contamination by the dissolution of the geological formations which influence on the chemical characteristics of groundwaters.

In fact, the latter circulating in the alluvial aquifer of F'Kirina come from the carbonate formations of the Upper Cretaceous bordering the plain, then they circulate in a very heterogeneous material (alluvium, clays, gravels, salt formations of the Mio -Plio-Quaternary, evaporitic deposits of the Triassic, .. etc), which will influence the acquisition of chemical elements (Gouaidia, 2008).

The aim of this paper is to characterize and classify the groundwater of the F'Kirina aquifer using several methods such as hydrochemical mapping and statistical analysis to find out the origin of the mineralization of these waters.

Material and methods

Study area

The F'Kirina plain is located northeast of Algeria with a surface area of 650 Km^2 and a population of 14914 inhabitants; it has a semiarid climate marked by an annual rainfall of the order of 392.68 mm and a mean annual temperature of 16.45°C.

The study area is limited to the east by a long range of carbonate formations constituting the major relief line, and to the west by « Gareat Et-Tarf », protected wetland (RAMSAR, 2005), to which discharge the majority of the plain streams, the most important of which are Nini wadi, Oulmene wadi and Isfer wadi (Fig.1). the geology of the plain is constituted of three sets: a marly substratum of lower Maestrichtian, a set belonging to upper Cretaceous, characterized by Maestrichtian limestone, and a third set formed by alluvial material of Mio-Plio-Quaternary covering the whole plain (Younssi, 2009). We note the existence of two superposed aquifers (Fig. 2), the first one is superficial made up of gravels and pebbles, and the second one is deep, made up of fissured limestone (Houha, 2007).

Piezometry

In order to establish a piezometric map of the study area, a campaign of piezometric surveys was carried out during low water period (November, 2016) on 15 wells and 6 boreholes (Fig. 3).

Hydrochemistry

The samples collected from 21 water points (15 wells and 6 boreholes) covering the whole study area are kept in a cool box at 4°C (Rodier, 2009) and transported to the laboratory for hydrochemical analysis. The dosage of chemical elements was performed as follows: Calcium (Ca^{++}), Magnesium (Mg^{++}) and Sulfates (SO_4^{2-}) by spectrophotometer of type (HI 83200, HANNA Instruments), Potassium (K^+) and Sodium (Na^+) by flame spectrophotometer of type (JENWAY.PFP7), Chlorides (Cl^-) using argentimetry and Bicarbonates (HCO_3^-) using spectrophotometer of (WTW 2000) type.

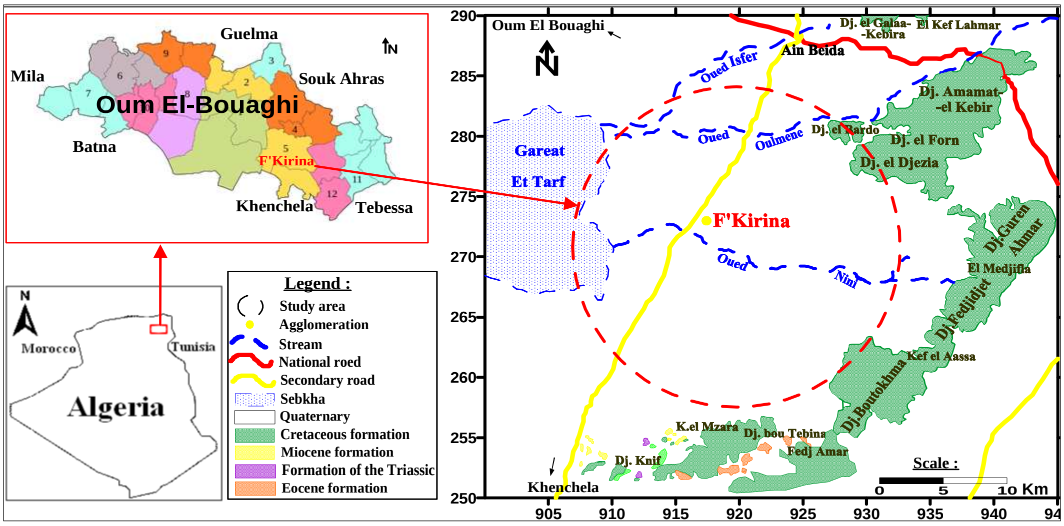

Fig.1. Geographical location and geology of the study area.

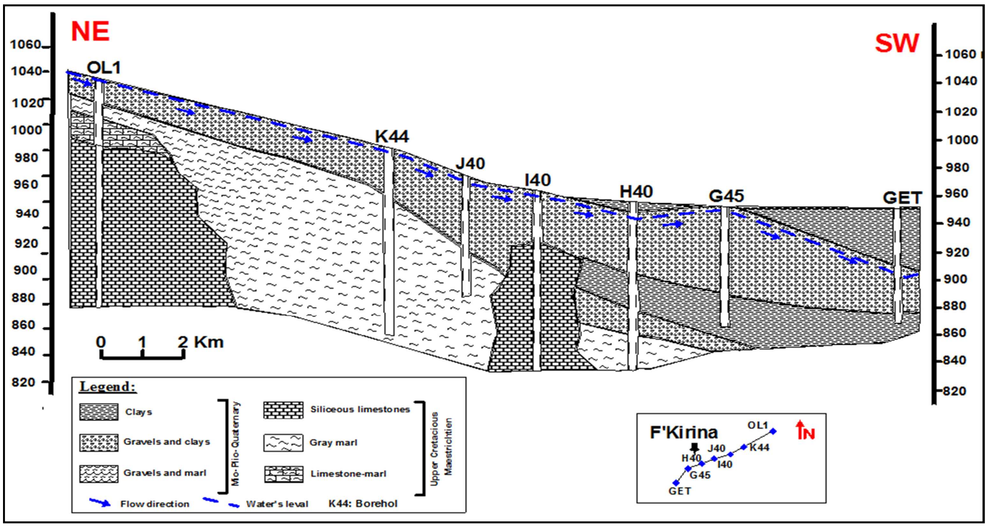

Fig. 2. Hydogeological section in the F'Kirina plain.

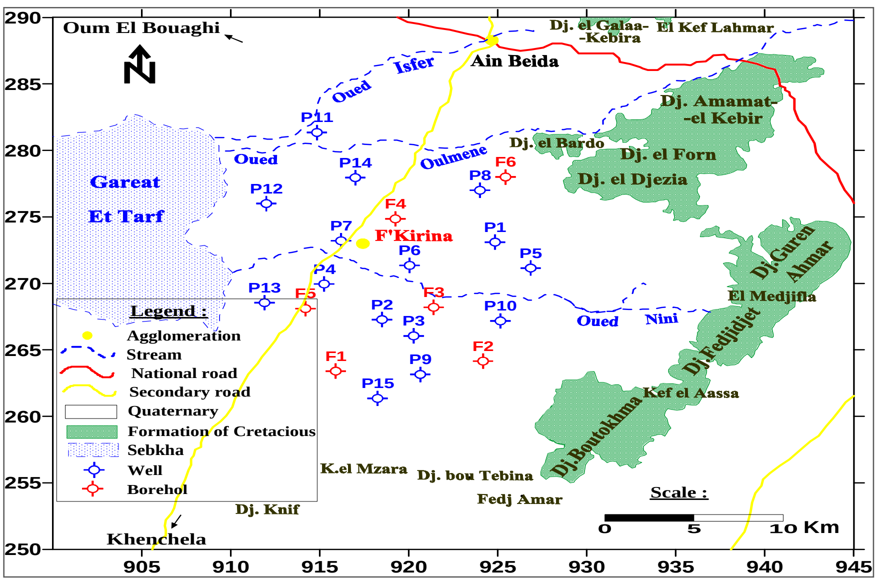

Fig. 3. Water points inventory map of the F'Kirina plain (November, 2016).

Results and discussion

Interpretation of the piezometric map

The examination of the piezometric map (Fig. 4) shows that the flow direction is oriented towards Gareat Et-Tarf, which constitutes a natural outlet (Dali, 2013). In eastern and western parts, the isohypses are distant, indicating a low hydraulic gradient. In contrast, they are closer together in the center of the plain, determining a high hydraulic gradient.

Chemical analyses

According to the map of calcium concentration, magnesium and sodium (Fig. 5), we see that for these three chemical elements, the low concentration not exceeding 150 mg/l, 50 mg/l and 100 mg/l for Ca^{2+}, Mg^{2+} and Na^{+} respectively are observed south of the plain. Whereas the highest ones characterize waters of wells (P11) and (P12) bordering Gareat Et-Tarf, thus indicating the influence of this latter on the mineralization degree of water, with a maximum at (P12) reaching 490 mg/l, 100mg/l and 288mg/l for Ca^{2+}, Mg^{2+} and Na^{+}, respectively, and east of the plain round wells (P1) and (P5), where there is the influence of Maestrichtian limestone, and at wells (P9) and (P15) located south near the diapir of Knif mountain, where there is the influence of Triassic.

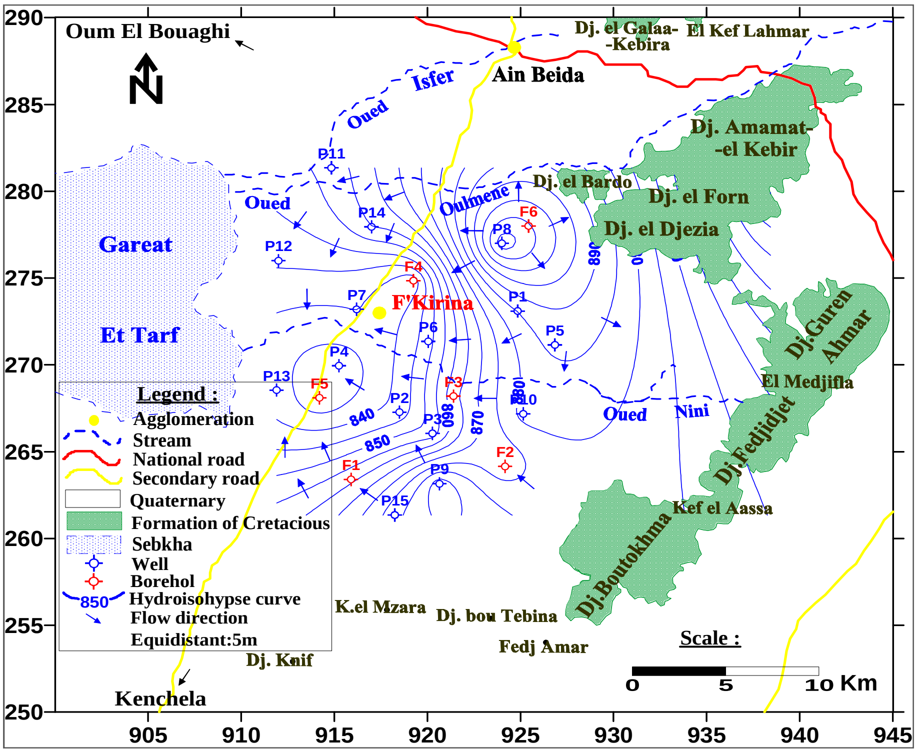

Fig. 4. Piezometric map of the low waters period (November, 2016).

This influence is also noted for Potassium in the map (Fig. 6), which shows contents exceeding 2mg/l only at well (P9) and (P15), where they reach 20mg/l. The map of chlorides and sulfates concentration (Fig. 7) makes it possible to distinguish the areas where the values are high, the first one is located east of the plain (P1) and (P5), which can be explained by leaching of Maestrichtian limestone; the second one is found west at the vicinity of Gareat Et-Tarf, which can influence its high chloride and sulfate contents, which is the case at well (P12), which is the most mineralized ,with concentrations exceeding 800 mg/l, and the third area is located south of the plain, notably at (P9), the sulfates concentration of which reaches the maximum (919 mg/l), where we have the leaching of Triassic formations (diapir of Djebel Knif).

For bicarbonates, we can attribute the very high contents, exceeding 400 mg/l and characterizing the center (F4) and the southeast (P10) of the plain (Fig. 8), to leaching of the carbonate formations of the plain edge (Ghrieb, 2011).

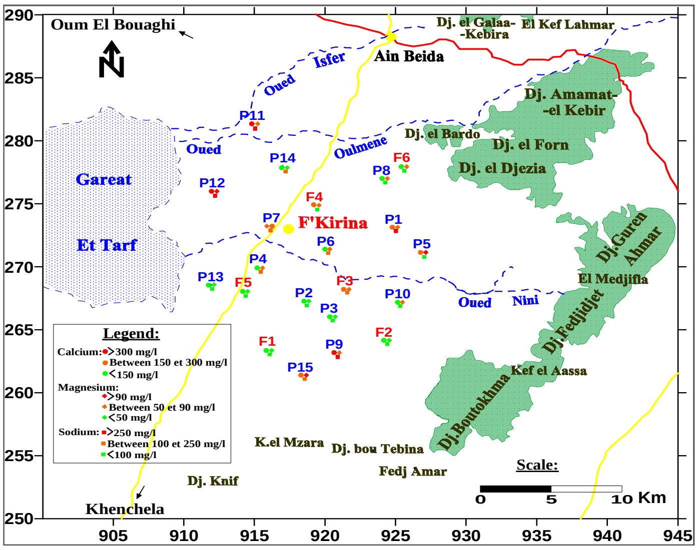

Fig. 5. Concentration's map of calcium, magnesium and sodium (November, 2016).

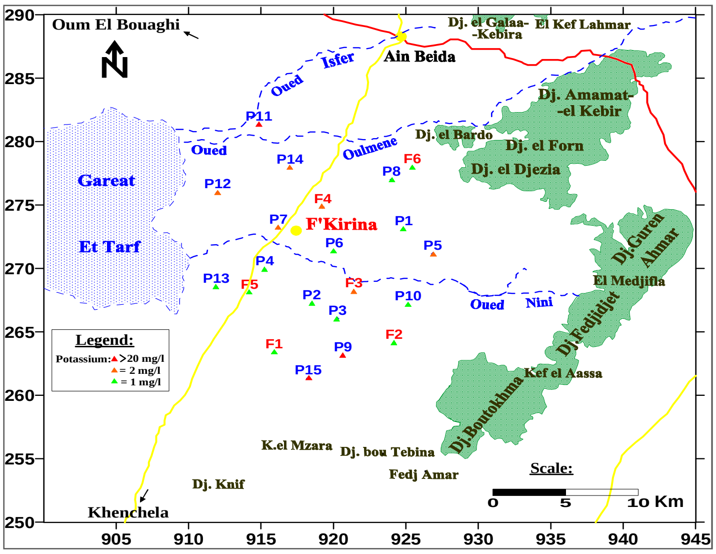

Fig. 6. Concentration's map of potassium (November, 2016).

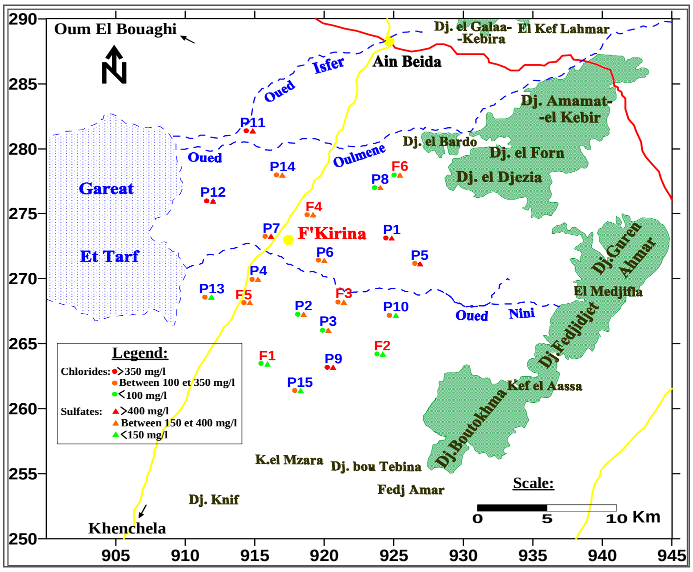

Fig. 7. Concentration's map of chlorides and sulfates (November, 2016).

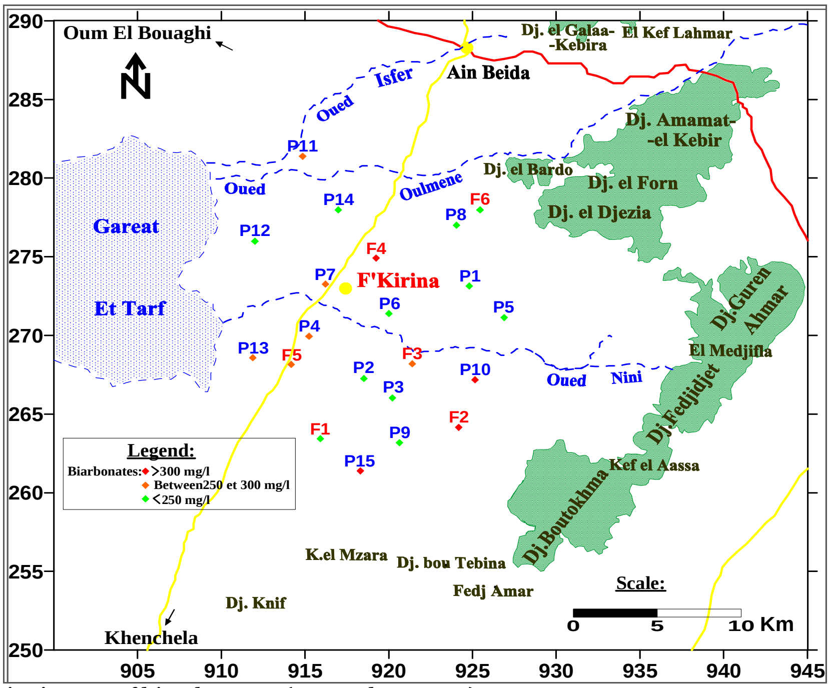

Fig.8. Concentration's map of bicarbonates (November, 2016).

The Piper diagram (Fig. 9) highlights three main types of chemical facies, namely calcium-sulfate, which accounts for 33.33 % of samples and appears according to the distribution map of facies (Fig. 10).

At points (P2), (P3), (P5), (P7), (P9), (P11) and (F5), calcium-bicarbonate facies (28.57 % of samples), which characterizes waters of boreholes (F1), (F2), (F4) and those of wells (P10), (P13) and (P15). The carbonate and Triassic formations can be the origin of these facies (Baali *et al.*, 2007). The calcium-chloride facies accounting for 23.80 % of samples is present inside the plain and characterizes waters of wells (P1), (P4), (P6) and those of borehole (F 3) located at the vicinity of Nini wadi and well (P12) close to Gareat Et-Tarf, which can be explained by the influence of this latter and the presence of salt formations of Mio-Plio-Quaternary age (Gouaidia *et al*, 2012).

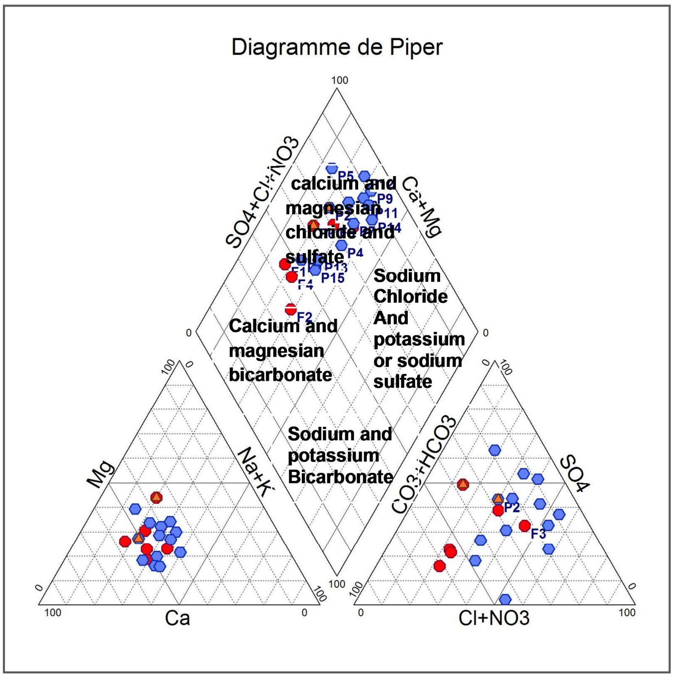

Fig. 9. Piper diagramme (period of low waters, November, 2016).

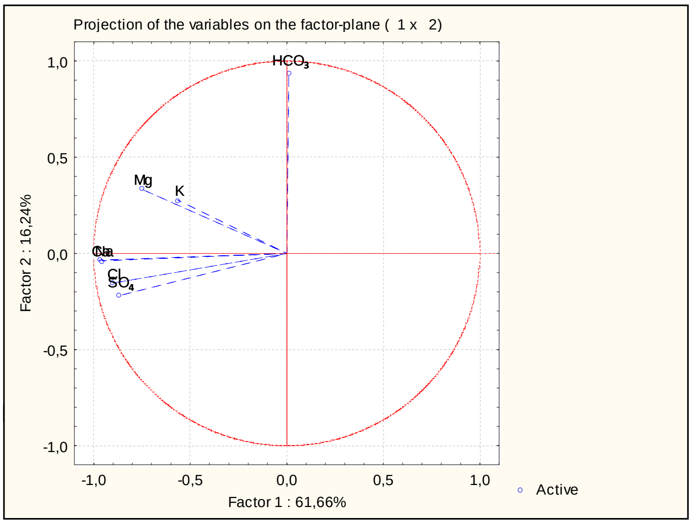

Fig.10. Projection of variables on the factor-plane (1x2).

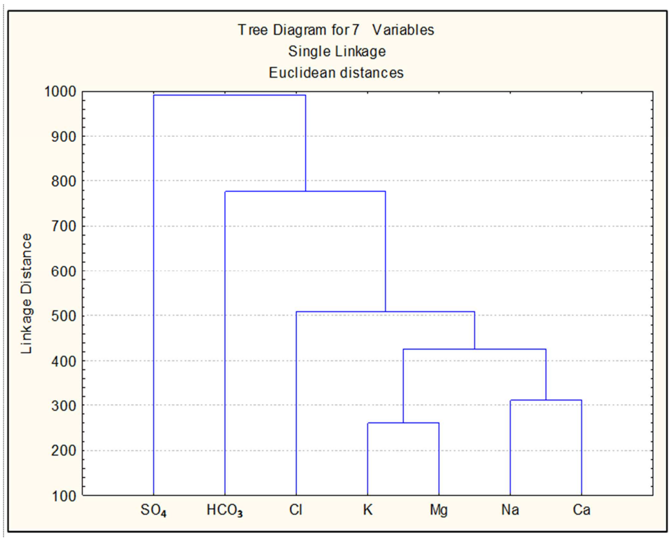

Fig.11A. Dendrogramme of hierarchic classification of chemical elements.

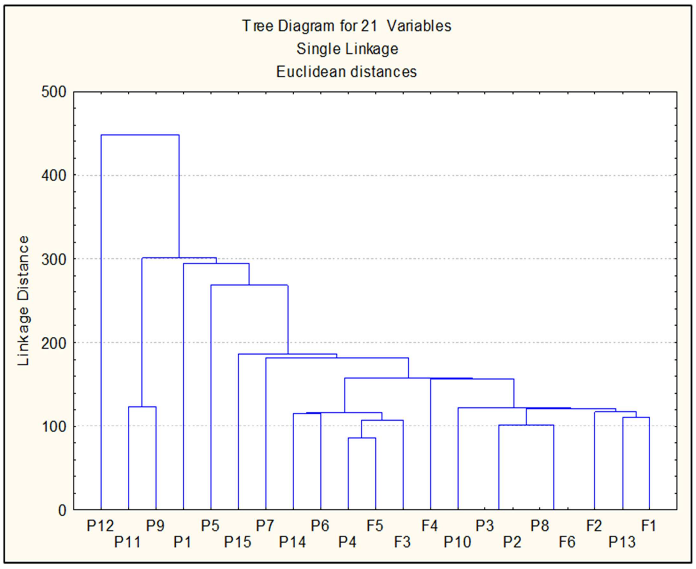

Fig.11B. Dendrogramme of hierarchic classification of the water's points of F'Kirina's aquifer.

Principal Component Analysis (PCA)

The Analysis in Principal Components (ACP) is a tool for analysis of data which makes it possible to explain the structure of the correlations by using linear combinations of the original data. The (ACP) aims to present, in a graphical form the maximum of contained information in data table based on the principle of double projection on the factorial axes (Ramdani et Laifa, 2017).

Correlation analysis

The correlation matrix (Table 1) highlights many very significant correlations, especially between Ca^{2+} and Cl^- (r= 0. 92), Ca^{2+} and Na^+ (r= 0. 92), Ca^{2+} and SO_4^{2-} (r= 0. 86), Na^+ and Cl^- (r= 0. 90), Na^+ and SO_4^{--} (r= 0. 80), which can be due to the common origin of these elements (Sekiou *et al.*, 2014) that is the leaching of carbonate or Triassic or salt formations of Mio-Plio-Quaternary. For Mg^{2+}, K^+ and HCO_3^-, there is no significant link between them and the other chemical elements.

Table 1. Correlation matrix between chemical parameters

	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	SO_4^{2-}	Cl^-
Ca^{2+}	1,00						
Mg^{2+}	0,66	1,00					
Na^+	0,92	0,61	1,00				
K^+	0,46	0,44	0,55	1,00			
HCO_3^-	0,01	0,20	-0,02	0,05	1,00		
SO_4^{2-}	0,86	0,55	0,80	0,38	-0,16	1,00	
Cl^-	0,92	0,61	0,90	0,26	-0,08	0,72	1,00

The projection of variables on the design F1-F2 (Fig. 10) shows two poles, the factor 1 accounts for 61.66 % of variance; it is determined by the elements Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl, SO_4^{2-} linked to high mineralization, and the factor 2, which accounts for 16.24 % of variance; it is determined by the element HCO_3^- deriving especially from leaching of carbonate formations (Bodin, 2008).

Ascendant Hierarchic Classification (AHC)

The dendrogram of hierarchical classification of groundwater of the F'Kirina aquifer (Fig. 11A, B) highlights the existence of three groups. The first group represents the class of very high mineralization; it is formed by the point (P12) close to Gareat Et-Tarf, the second one represents the class of high mineralization, notably due to leaching of carbonate and Triassic formations; it is constituted of the points (P11), (P9), (P1), (P5) and (P15), and the third group is characterized by a low mineralization; it represents the rest of water points.

Conclusion

The application of graphical (mapping and Piper diagram) and multivariate statistical tools (PCA and AHC) on groundwater of the F'Kirina aquifer allowed us to determine the chemistry mechanisms of this water and those of mineralization acquisition, and also enabled us to classify them into several facies types, the distribution of which depends especially on lithology of the crossed terrains and on the phenomena of leaching and evaporation (Gouaidia, 2008).

The Maestrichtian limestone of the plain edge gave rise to calcium-bicarbonate facies; the salt materials of Mio-Plio-Quaternary filling and clayey and marly levels gave rise to calcium-chloride and sodium-chloride facies, and the Triassic deposits gave rise to calcium- sulfate and magnesium-sulfate facies.

References

Baali F, Rouabhia A, Kherici N, Djabri L, Bouchaou L, Hani A. 2007. Qualité des eaux souterraines et risque de pollution en milieu semi-aride. Cas de la cuvette de Chéria, NE Algérien. Estudios Geologicos **63,** 127-133.

Baali F. 2007. Contribution à l'étude hydrogéologique, hydrochimique et Vulnérabilité d'un système aquifère karstique en zone semi-aride. Cas du plateau de Chéria, N.E.Algérien. Thèse de Doctorat, Université d'Annaba, Algérie 152 p.

Bahir M, Menani M, Oliveira da Silva M, Blavoux B. 2003. Impact de la sécheresse sur la ressource en eau en zone semi-aride. Cas de l'aquifère Barrémien-Aptien de la zone côtière d'Essaouira, Maroc. Ecnologia de la intrusion de agua de mar en acuiferos costeros, paises mediterraneos **84,** 740p.

Belghiti ML, Chahlaoui A, Bengoumi D, El Moustaine R. 2013. Study of physico chemical quality bacteriological growth of the underground plio quaternaire in the Meknès area. Morocco. Larhyss Journal **14,** 21-36.

Bodin J. 2008. Licence Professionnelle Protection de l'Environnement Usage et Qualité des Eaux. Module Géologie Lithologie et Chimie des Eaux Souterraines.

Boubelli S, Chaffai H, Sakaa B, Djidel M, Khérici N. 2018. Hydrogeochemical characterization and assessement of the quality of surface waters of Oued Saf-Saf (North-East Algeria). Journal of Biodiversity and Environmental Sciences **12,** 168-178.

Chaffai H, Baali F, Djabri L, Rouabhia A. 2003. Facteurs influençant le chimisme des eaux dans une zone semi-aride. Cas des aquifères d'El Ma Labiod, Tébessa, Hammamet et Chéria, ICOWaP., Biskra, Algérie 339-344.

Dali N. 2013. La gestion durable des ressources en eaux du bassin versant de Gareat el Tarf (Hauts Plateaux Constantinois, Algérie). Journal of hydrocarbons Mines and Environmental Research **3,** 61-65.

Fehdi C, Boudoukha A, Rouabhia A, Salameh E. 2009. Caractérisation hydrogéochimique des eaux souterraines du complexe aquifère Morsott-Laouinet. Région Nord de Tébessa, Sud-Est algérien. Afrique science **05,** 217-231.

Ghrieb L. 2011. Impact de la minéralisation des formations triasiques sur la qualité de l'eau et du sol en zone semi-aride. Cas de la plaine Bekkaria, Tébessa (Extrême Nord-Est Algérien). Thèse de Doctorat, Université d' Annaba, Algérie 175p.

Gouaidia L, Guefaifia O, Boudoukha A, Hemila ML, Martin C. 2012. Évaluation de la salinité des eaux souterraines utilisées en irrigation et risques de dégradation des sols. Exemple de la plaine de Meskiana, Nord-Est Algérien. Physio-Géo **6,** 141-160.

Gouaidia L. 2008. Influence de la lithologie et des conditions climatiques sur la variation des paramètres physico-chimiques des eaux d'une nappe en zone semi-aride. Cas de la nappe de Meskiana. Nord-Est Algérien. Thèse de Doctorat, Université d'Annaba, Algérie, 199p.

Houha B. 2007. Etude du fonctionnement hydrogéologique et salin d'un bassin semi-aride. Rémila, Khenchela, Algérie. Thèse de Doctorat, Université d'Annaba, Algérie 174p.

Hsissou Y, Bouchaou L, Krimissa M, Mudry J. 2001. Caractérisation de l'origine de la salinité des eaux de la nappe côtière d'Aguadir., Maroc, First Institut p. 1-11.

Melloul A. 1992. The "principal components" statistical method as a complementary approach to geochemical methods in water quality factor identification. J. of Hydrol **140,** 49-73.

Ramdani H, Laifa AH. 2017. Physicochemical quality of Wadi Bounamoussa surface waters. Northeast of Algeria. Journal of Water and Land Development **35,** 185-19.

Rodier J. 2009. L'analyse de l'eau. 9ème Edition. Dunod, Paris p. 1404-1405.

Sekiou F, Kellil A. 2014. Empirical characterization and classification and graphic Multivariate Statistics of bottled spring water of Algeria. Laryss newspaper **20,** 225-246.

Williams WD. 2002. Stalinization: A major threat to water resources in the arid and semi-arid regions of the world. Paper presented at the International Conference on the Concervation and Management of lakes, Copenhagen, May 1999 p. 1.

Younssi H. 2009. Epuisement de la nappe aquifère de la région de F'kirina. W. d'Oum El Bouaghi, Algérie, et ses répercutions sur la gestion des ressources en eau. Thèse de Magister. Université d'Annaba, Algérie 124p.