JJEES

JJEES (2023) 14 (3): 203-209
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Evaluation of Groundwater Quality and its Suitability for Drinking and Agricultural Use in F’kirina Plain, Northern Algeria

Salima Djoudi[1*], Séverin Pistre[2], Belgacem Houha[3]

[1] Faculty of Natural and Life Sciences. Department of Ecology and Environment. Laboratory Water. Environment and Renewable Energy. The University of Abbes Laghrour. Khenchela. Algeria.
[2] Laboratoire HSM. Université Montpellier. CNRS. IRD – Montpellier. France severin.
[3]Laboratory Water. Environment and Renewable Energy. The University of Abbes Laghrour. Khenchela. BP 40000. Algeria.

Received 12th April 2022; Accepted 1st March 2023

Abstract

The purpose of this study is to determine the parameters that control the quality of groundwater in an aquifer located between carbonated rocks and a Salt Lake (Garâat ET Tarf) that is commonly used for agriculture. Forty-Five groundwater samples have been collected from F’kirina Plain which covers an area of approximately 350 km^2. To assess groundwater quality and suitability for irrigation and domestic use, various physicochemical parameters such as pH, electrical conductivity, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride were examined. The suitability of the water for agricultural use was tested using Sodium adsorption ratio (SAR), and sodium percent, The results illustrate that all samples are suitable for irrigation purposes except a few locations. which values beyond the permissible limits. The groundwater of the investigated area presents three types of water Ca-HCO_3 in carbonate outcrops evolving towards Ca-SO_4 and Ca-Cl type in the Plio-Quaternary filling in the direction of the Sebkha. The mapping of concentrations shows the effects of aquifer exploitation and practices on human and natural contamination of groundwater.

Keywords: *Groundwater quality, Hydrochemical facies, SAR, Sodium percent.*

1. Introduction

Groundwater is a major element of total water resources in arid and semi-arid areas. and it has major implications for economic growth (Subyani and Al Ahmadi, 2010). Due to fast population growth. industrialization. urbanization. and agricultural use of fertilizers and pesticides. groundwater quality has become a major water resource issue (Joarder et al., 2008). Natural factors such as lithology. groundwater velocity. recharge water quality. rock–water interaction. and contact with various types of aquifers all play a significant role in groundwater quality (Helena et al., 2000, Khan et al., 2015). Several contaminants produced by a variety of sources contaminate groundwater (Okogbue et Ukpai, 2013). In an endorheic basin, the presence of a salt lake hydraulically connected to groundwater could also change the water salinity by reversing the natural groundwater flow due to overexploitation of the latter (Ghodbane et al., 2016). Salinity and sodium hazard indicators can be used as a criterion to find the suitability of irrigation waters (Nishanthiny et al., 2010; Al-Hadithi et al., 2019). The most widely accepted method is that of the United States Department of Agriculture (USDA). and the sodium absorption ratio (SAR) is an effective evaluation index for most irrigation fluids (Al-Bassam and Al-Rumikhani, 2003; Al-Paruany, 2018). The study area is located in Algeria’s semi-arid zones. It is marked by scarcity and unequal distribution of water resources. with groundwater serving as the primary source for domestic. industrial. and agricultural needs. The focus of this research is to decipher the chemical differences in groundwater caused by natural and anthropogenic factors. as well as to determine its suitability for agricultural and home usage. It also seeks to assess the many hydrogeochemical mechanisms that influence groundwater quality. To examine the groundwater quality and classify the groundwater in the area into separate hydrochemical groups. typical graphical representations and statistical analysis were used.

2. Study area

The study area is located in the North of Algeria between 35° 39′ 50″ N and 7° 17′ 55″ E. This region includes the F’kirina Plain covers an area of approximately 540 km². It is limited to the North by the line of water formed by Djebel El Galaa Kebira (1246 m) and Djebel Amamat El Kebir (1203 m), on the South by the line of water formed by Djebel Boutekhma (1291 m) and Djebel Ahmar (1259 m), to the East by the watershed line formed by Djebel Fedjidjet (1291 m) and to the West by a large flat that corresponds to high “constant noises” Plains and by the Garaat Tarf (Fig. 1). The Sabkha of Garâat at Tarf. For the period 1960-2015, the mean annual rainfall in the study area ranges between 20 to 34 mm.

* Corresponding author e-mail: djoudi.ecologie@gmail.com

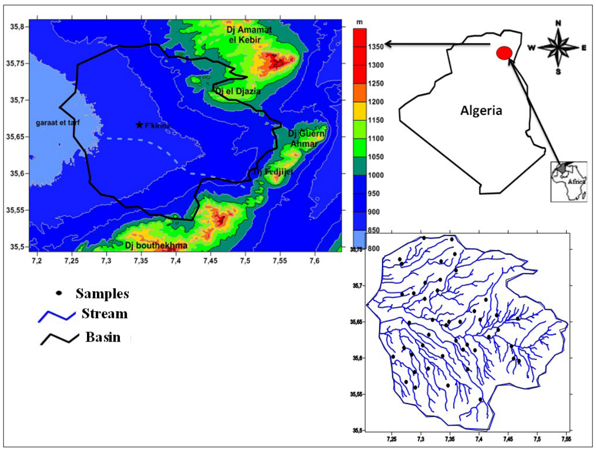


Figure 1. Localization of study area.

3. Geology of the studied area

The lithostratigraphy of the study area extends from Triassic to the Quaternary series and could be briefly presented in the following way (Figure 2):

In the study area, the Triassic Outcrop was observed in the Northeast and South West of Ain Delâa and F'kirina. Cretaceous Formations are represented by marl-limestone with platelet limestone at the base. It also appears on the surface in the northern margin of Ain Beïda where it is highly fractured. The Eocene Formations show a marly and a carbonate sequence separated by slightly sandstone facies. Outcrops of the Miocene present small dimensions and are only distributed in the southern part of the plain. It's a series composed of a set of marls limestones at the top, and a set of thick limestone layers at the center of the series (Salima and Belgacem, 2017).

The Pliocene is made up of sandy continental detrital deposits, conglomerates, marls, and reddish clays. Quaternary deposits have covered most of the plains. These deposits are very varied however the sedimentation is essentially clay and marly

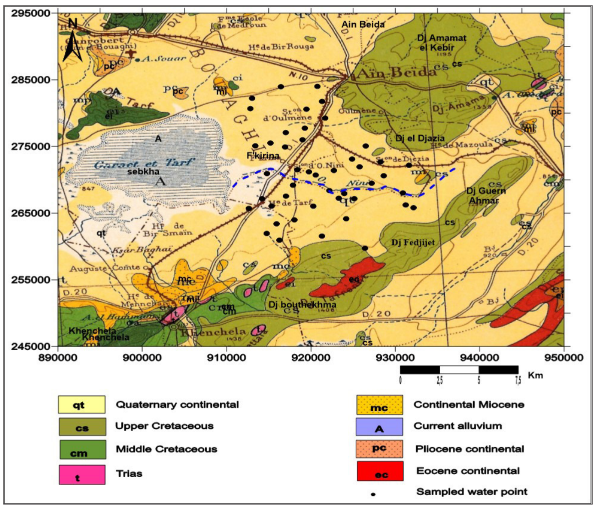


Figure 2. Geological map of the study area. (ANRH, 2012).

4. Method of Sampling and Analysis

Forty-five (45) groundwater samples were collected and analyzed in LACILAP Laboratory (Ain M'lila.) Algeria during Mai 2015. These sampling points were chosen on accessibility, integrity, and spatial distribution criteria. The procedure was carried out after a brief pumping time in polyethylene bottles. The physical parameters temperature, electrical conductivity, and pH were recorded on-site using a Multi–parameters. Analyses of the elements HCO_3- (bicarbonate), Na^+ (sodium), Cl- (chloride), SO_4^{2}- (sulfate), Ca^{2+} (calcium), Mg^{2+} (magnesium), Na^+ (sodium), K^+ (potassium), and NO_3- (nitrate) were performed by flame spectrophotometry, volumetry, and UV-visible spectrometry.

The global positioning system (GPS) was used to record the geographic location of each sampling point. All the geographic coordinates of the sampling location were imported in SURFER software v 12 for geospatial analysis and in the DIAGRAM v 6.4 program for the chemical facies.

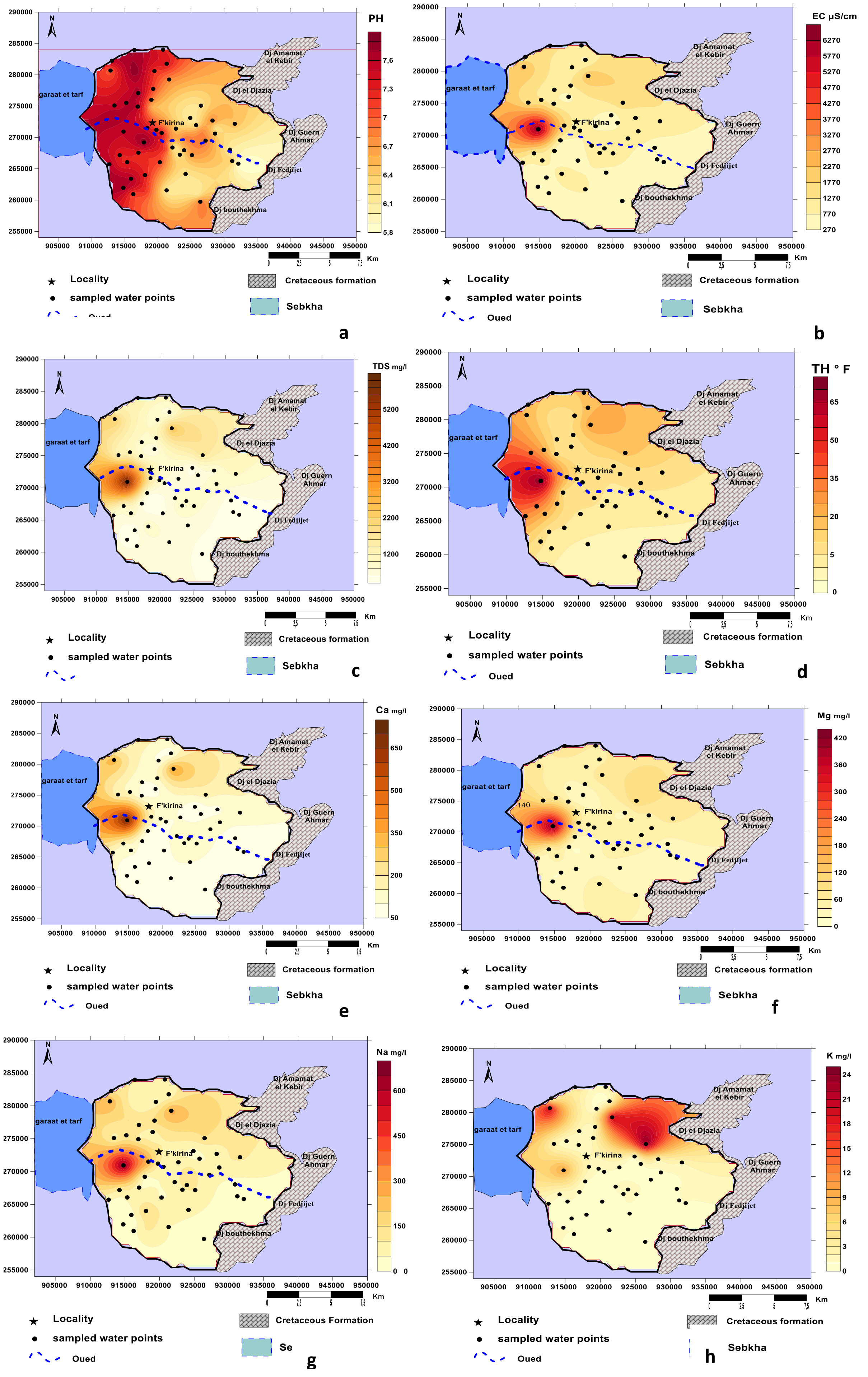
5. Results and Discussion

The quality standards for drinking water have been specified by the World Health Organization (WHO) in 2017. The range of the physicochemical parameters (pH, EC, TDS, TH) and the major ions (Ca^{2+}, HCO^-_3, SO_4^{2-}, Mg^{2+}, Na^+, Cl^-, K^+, NO_3^{-}) and their comparison with WHO 2017 standards are presented in Table1.

Table 1. Statistical parameters of the chemical elements in groundwater. Min: minimum; Max: maximum; SD: standard deviation.

	Units	Min	Max	Mean	SD	WHO standard 2017
pH		6.700	8.000	7.323	0.302	6.5 -8.5
EC	µS/cm	437.000	6710.000	1106.356	965.560	500-1500
TDS	mg/L	451	6100	1047.38	884.460	500-1000
TH	°f	5	71 .6	11	8.96	100-500
Ca^{++}	mg/L	37.000	705.000	119.533	108.931	75-200
Mg^{++}	mg/L	2.000	412.000	41.600	59.298	50-150
Na^+	mg/L	1.000	665.000	85.644	108.036	200
K^+	mg/L	1.000	20.000	2.756	4.872	12
HCO_3^{--}	mg/L	101.000	1046.000	229.578	138.760	300-500
SO_4^{--}	mg/L	3.000	2645.000	278.711	412.770	250-400
Cl^-	mg/L	10.000	1085.000	157.111	172.586	250-400
NO_3^-	mg/L	0.000	124.000	35.222	30.956	45

The number and the good distribution at the basin scale allow interpolating the concentrations or chemical parameters values


PH
EC µS/cm
TDS mg/l
TH ° F
Ca mg/l
Mg mg/l
Na mg/l
K mg/l
garaat et tarf
F'kirina
Dj Amamat el Kebir
Dj el Djazia
Dj Guern Ahmar
Dj Fedjijet
Dj bouthekhma
Locality
sampled water points
Oued
Cretaceous formation
Sebkha
Km
a
b
c
d
e
f
g
h

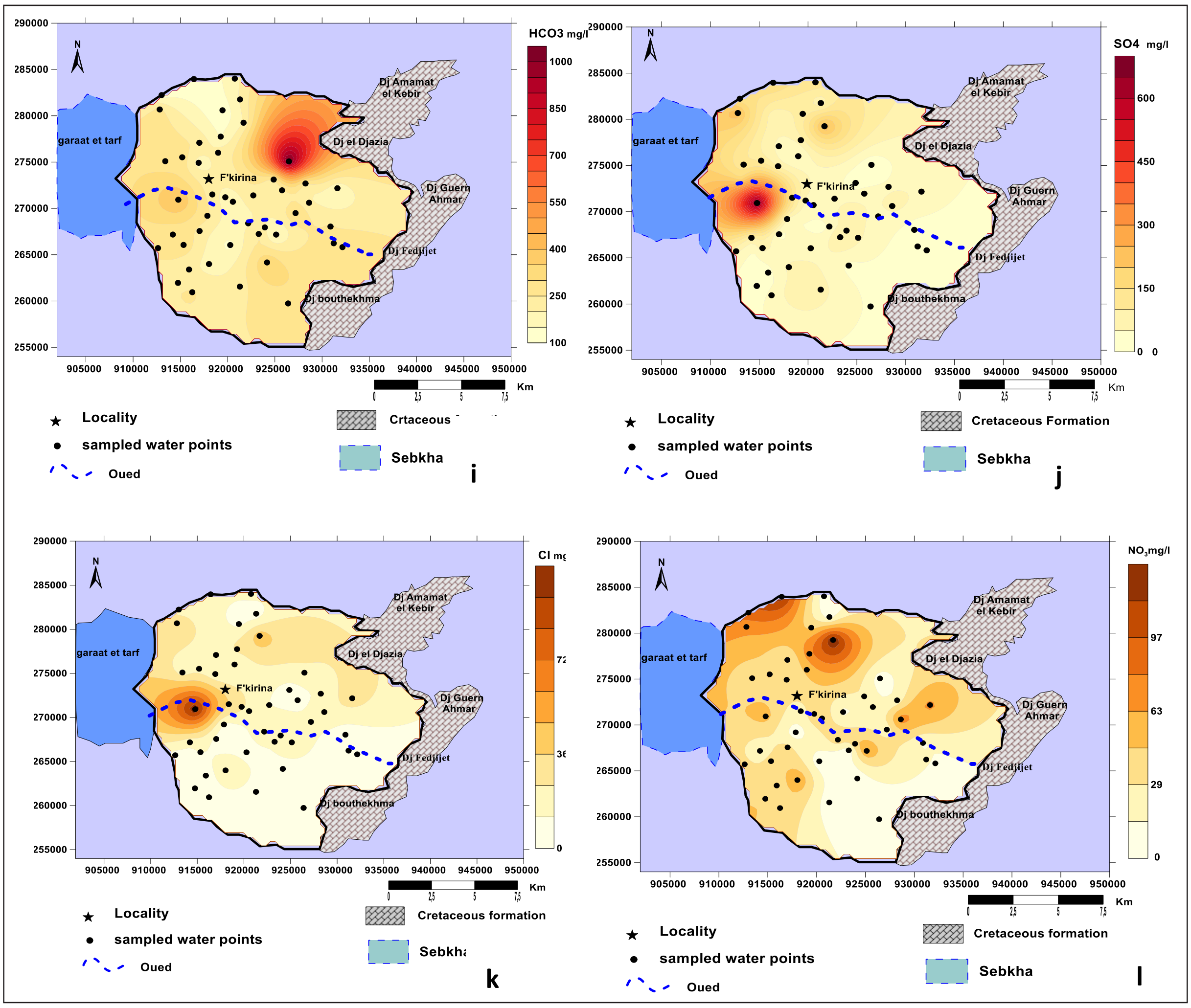


Figure 3. Map of F'kirina plain groundwaters for iso values of pH (a), EC (b), TDS (c), TH (d), Ca (e), Mg (f), Na (g), K (h), HCO_3 (i), SO_4 (j), Cl (k), NO_3(l).

5.1. pH

The measured pH values in all of the groundwater samples are uniform and close to neutral. It ranges from 6.7 to 8, with a mean of 7.30. The lowest values are found near carbonate deposits, while the highest values are found in the middle of the plain westward direction (Fig. 3a). This rise is very clear in the west part of the aquifer. It would be due to the water facies evolving (central zone). Natural phenomena such as the intrusion of sebkha waters (Garâat at Tarf) into the aquifers provide the highest pH values.

5.2. Electrical Conductivity (EC)

Electrical conductivity can be used as an approximate indicator of the total amount of dissolved material in water (Sarath Prasanth et al., 2012). Temperature, concentration, and the types of ions present all have a role (Hem, 1985). The study area's conductivity values range from 437 to 6710 µS/cm, with an average of 1106 µS/cm (Fig. 3b). A higher conductivity value indicates salt concentration in the groundwater. It rises towards Salt Lake (Garâat at Tarf), indicating that the salinity of the water rises in the flow direction. One point is distinguished by a higher value probably due to local anthropic or natural contamination.

5.3. Total Dissolved Solids (TDS)

TDS levels range from 451 to 6100 mg/L across the entire research area (Table 1). The use of agricultural fertilizer is responsible for higher total dissolved solids value. Nonetheless, only a few locations exceed the 1000-1500 mg/L drinking water standard. The TDS map logically shows the same tendencies as the EC map with the same high salinity point.

5.4. Total Hardness (TH)

The water hardness varies between (5 and 71°f), characterizing soft to moderately soft water from south to north and from east to west. In the west, the water becomes very hard (Fig. 3d). The previous point is also distinguished but the rise concerns other points close to the sebkha whose intrusions seems to have a major effect on water hardness rise. In the northern part, water is harder due to cretaceous carbonate aquifer as in the karstic spring Aïn Beïda.

5.5. Calcium and Magnesium (Ca^{+2} and Mg^{2+})

Calcium concentrations range from 37 and 705 mg/L (Table 4; Fig. 3e). The increased Ca^{+2} concentration (705 mg/L) was found substantially above the acceptable range for drinking water. Magnesium concentrations range between 2 and 412 mg/L (Table 1; Fig. 3f). The maximum Mg^{+2} concentration in drinking water that can be tolerated is 150 mg/L (WHO, 2017). Except in the western section of the image, the magnesium map shows that the Mg^{+2} level is rather low throughout practically all of the plain. In the northern part, Ca and Mg are separately more elevated but their addition explains the water hardness.

5.6. Sodium and Potassium (Na and K)

Sodium is always present in water from the leaching of geological formations rich in NaCl and the dissolution of clay and marl formations(WHO, 1984). The concentration of Na^+ in the study area varied from 1 to 665 mg/L. (Table 4; Fig. 3g). The maximum permissible limit of sodium is 200 mg/L.

The greater concentration of Na^+ seen around Garâat at Tarf could be the result of evaporation from the water table. In the rest of the study area, the lowest levels are found.

The concentration of K^+ is varying from 1 to 20 mg/l (Fig. 3h). The maximum permissible limit of potassium in the drinking water is 12 mg/l and it was found four water samples are above the permissible limit of WHO (Table 1). Three points in the northern part have elevated concentrations of K. Two of these seem correlated with moderate concentrations of K. The origin can be fertilizers or aquifer lithology.

5.7. Bicarbonate (HCO_3)

Bicarbonate is often the dominant ion in groundwaters but in the case of F'kirina plain, the values of HCO_3^- range from 101 to 1046 mg/L (Table 1). The repartition is quite homogeneous with low values but one point shows a very high concentration (Fig. 3i). The increased concentration of HCO_3^- in the groundwater source indicates that mineral dissolution is the dominant process (Stumm and Morgan, 2012).

5.8. Sulfate (SO_4^{-2})

Sulfate concentration in the study area ranges between 3 and 2645 mg/L. The average value of sulfate concentration is recorded as 278 mg/L. The spatial distribution of sulfate ion concentration in groundwater is illustrated in Fig. (3j). The results showed that the maximum concentration of sulfate is observed in the western part, on one isolated point close to the salt lake. This may be linked to a dissolution of formations rich in sulfate minerals, or contamination of the water table by the waters of Oued Nini or Garaat at Tarf, while the low concentration is observed in the eastern part of the study area.

5.9. Chloride (Cl)

The concentration of chloride in the study area ranges from 10 to 1085 mg/L (Fig. 3k). The acceptable chloride limit for drinking water is set at 250 mg/L (Table 1). The chloride concentrations are higher in the western and northwestern parts of the study area. The presence of too much chlorine in the water is commonly used as a pollution indicator and is referred to as tracer groundwater contamination (Loizidou and Kapetanios, 1993). A relative correlation appears with the Na map (Fig. 3g) which could indicate an origin from halite dissolution. The Pliocene continental detrital deposits are a heterogenous formation that contains evaporite deposits including halite.

5.9. Nitrate (NO3)

In the studied region, the sources of nitrate in groundwater are anthropogenic; It could be domestic wastewater, artificial fertilizers, or animal farms (Haycock and Burt, 1990)

The maximum permissible limit of NO_3^- is 45 mg/l (WHO, 2017), but several points are close to or exceed this value. There is no real tendency in the repartition but the map (Fig. 3l) revealed that significant nitrate concentrations were found in the north and northwest of the plain. The value is particularly elevated at point P10 (124 mg/l), this higher concentration is due to domestic wastewater from the agglomeration of F'kirina. On the other points, contamination is associated with agricultural practices.

6. Hydrochemical Facies

The term "hydrochemical facies" is used to describe the bodies of groundwater in an aquifer that are different from their chemical composition because of interaction with the surrounding rock and soil as water flows through an aquifer and assumes a characteristic chemical composition because of interaction with the surrounding rock and soil (Ravikumar and Somashekar, 2013).

The idea of hydrochemical facies is based on the assumption that, given current conditions, the chemical composition of groundwater at any point approaches chemical equilibrium with the matrix rocks. Hydrochemical facies interpretations can help determine mass flow patterns, origins, and chemical histories (Sarikhani et al., 2015). The concentration of major cations and anions in the Piper trilinear diagram can be used to understand the evolution of hydrochemical parameters in groundwater (Piper, 1944).

The representation of the results of chemical analyses on the Piper diagram defines three families of water globally distributed according to evolution from East to West. Out of limestone outcrops the water is $Ca\text{-}HCO_3$ type. The carbonate and Triassic formations can be the origin of these facies (Baali, 2007) whereas in the Plio-Quaternary fill; it becomes $Ca\text{-}SO_4$ type to finish towards a Ca-Cl water type near the Sebkha which can be explained by the influence of this latter and the presence of salt formations of Mio-Plio-Quaternary age (Gouaidia, 2008). (Fig. 4).

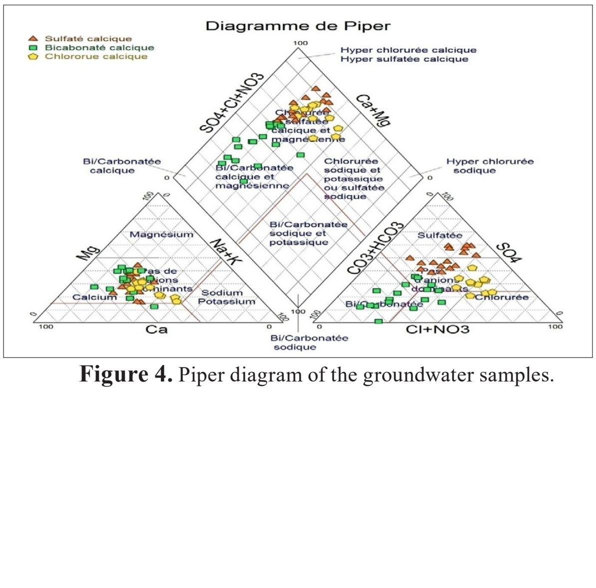


Figure 4. Piper diagram of the groundwater samples.

7. Irrigation Suitability

The suitability of groundwater for irrigation is evaluated using electrical conductivity (EC), percent of sodium (Na^{2+} %), and sodium adsorption ratio (SAR). Wilcox diagram (Na^{+}% vs EC plot) and USSL diagram (SAR vs EC plot) (El-Naqa et Al Adas, 2019).

7.1. Sodium Percent (Na%)

Percent sodium (Na%) is also commonly used to assess the suitability of water for irrigation (Wilcox, 1955). High sodium concentrations in groundwater have negative consequences because sodium reacts with soil to limit permeability and promote little or no plant development (Janardhana Raju et al., 2009, Vasanthavigar et al., 2010). The sodium percent (Na %) values were obtained by using the following equation: Na%= (Na/(Ca+Mg+Na+K))*100% where all ionic concentrations are expressed in meq/L. The water quality classification for irrigation purposes performed using the Wilcox diagram showed that 43% of the groundwater samples fall in the field of very good to good quality. 51 % fall in the field of good to permissible. 4 % fall in the field of doubtful for irrigation and 2 % fall in the unsuitable category (Fig. 5).

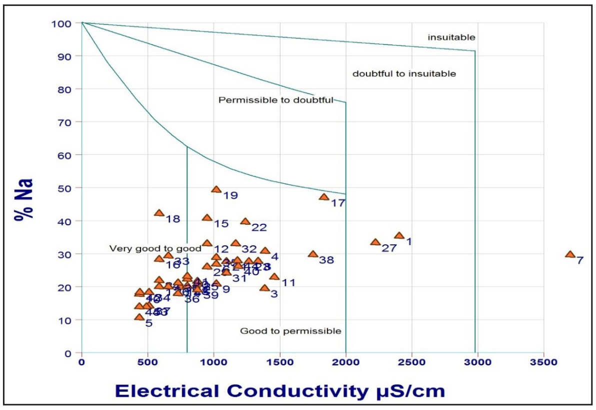


Figure 5. Wilcox diagram irrigation samples for groundwater quality.

7.2. Sodium Adsorption Ratio (SAR)

Because sodium concentration can decrease soil permeability and soil structure, the sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation (Todd and Mays, 2004). The sodium adsorption ration (SAR) is calculated using the following formula:

$$SAR = (Na/[(Ca+Mg)/2])^{1/2}$$

Where sodium, calcium, and magnesium concentrations are in meq/L.

The abundance of sodium in irrigation water can also cause dispersion and destruction of the soil structure if the sodium content is at least three times that of calcium. Under such conditions, it can become extremely difficult to meet the crop's water requirements. The risk of salinity is determined from the absorbable sodium value: "Sodium Absorption Ratio" (S.A.R). For the same conductivity, the risk is greater as the S.A.R. is higher (Al-Hadithi et al., 2019).

Examination of the diagram of the SAR (Fig. 6), from the USSL method shows that the danger of alkalization is low but the danger of salinity is high. In detail, (most of the samples are in S1-C3 class), Figure (6) indicates that the water is not suitable to irrigate crops under normal conditions and can be used if the cultivated species have a good tolerance to salinity and the soil is particularly well drained. The evolution of the salinity must however be controlled.

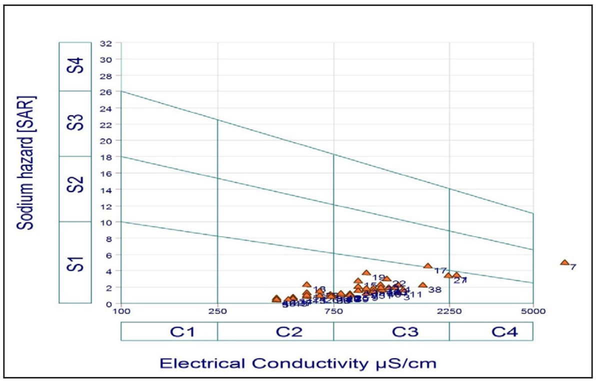


Figure 6. Classification of irrigation water quality. concerning salinity hazards and sodium hazards.

8. Conclusions

The present study is conducted to evaluate the hydrochemical properties of groundwater in the semi-arid region of F'kirina Plain. Most of the groundwater samples are acceptable (permissible limits) for the irrigational and drinking purpose recommended by the WHO standard.

The hydrochemical classification of water from the Piper diagram showed that the water falls into three types of facies. Which are the Ca-HCO_3. Ca-SO_4 and Ca-Cl water types. The spatial distribution maps of groundwater quality parameters showed that the water is moderate to highly mineralized as conductivity is generally high and oscillates between 320 µS/cm and 6500 µS/cm. The low values of mineralization are located near the limestone massifs, and the strong values are observed in the North East part and especially near the Garaet.

Nitrate distribution remains moderate and does not exceed the set established by the World Health Organization (WHO) standards. However, there are certain areas where the concentration of nitrate is higher than 50 mg/L. These variations and distributions depend mainly on the type of irrigation: The low values were observed in places where drip irrigation is used, while high concentrations were measured in areas using gravity irrigation. The application of water quality in this study has been found useful in assessing the overall quality of water. It is also helpful for the public to understand that water quality is a useful tool in many ways in the field of water quality management.

References

Al-Bassam, A. M., and Al-Rumikhani, Y. A. (2003). Integrated hydrochemical method of water quality assessment for irrigation in arid areas: application to the Jilh aquifer, Saudi Arabia. Journal of African Earth Sciences, 36(4), 345–356.

Al-Hadidhi, M., Hasan, K., Algburi, A., and Al-Paruany, K. (2019). Groundwater quality assessment using water quality index and GIS in Baghdad, Iraq. Jordan Journal of Earth and Environmental sciences, 10 (1), 15-20

Al-Paruany, K.B. (2018). Creating a drinking water quality index (WQI) map using the geographic information system (GIS) technique for Karbala city, Iraq. Jordan Journal of Earth and Environmental sciences, 9 (3), 153-166

ANRH (2012). Agence National des Resources Hydrique Canstantine.

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.

El-Naqa, A., and Al Adas, A.A. (2019). Development of Irrigation Water Quality Index for Wadi Araba Basin, Southern Jordan. Jordan Journal of Earth and Environmental sciences, 10 (2), 118-126

Ghodbane, M., Boudoukha, A., and Benaabidate, L. (2016). Hydrochemical and statistical characterization of groundwater in the Chemora area, Northeastern Algeria. Desalination and Water Treatment, 57(32), 14858–14868.

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

Haycock, N., and Burt, T. (1990). Handling excess nitrates. Nature, 348(6299), 291.

Helena, B., Pardo, R., Vega, M., Barrado, E., Fernandez, J. M., and Fernandez, L. (2000). Temporal evolution of groundwater composition in an alluvial aquifer (Pisuerga River, Spain) by principal component analysis. Water Research, 34(3), 807–816.

Hem, J. D. (1985). Study and interpretation of the chemical characteristics of natural water (Vol. 2254). Department of the Interior, US Geological Survey.

Joarder, M. A. M., Raihan, F., Alam, J. B., and Hasanuzzaman, S. (2008). Regression analysis of groundwater quality data of Sunamganj District, Bangladesh.

Khan, A., Umar, R., and Khan, H. H. (2015). Hydrochemical characterization of groundwater in lower Kali watershed, Western Uttar Pradesh. Journal of the Geological Society of India, 86(2), 195–210.

Loizidou, M., and Kapetanios, E. G. (1993). Effect of leachate from landfills on underground water quality. Science of the Total Environment, 128(1), 69–81.

Nishanthiny, S. C., Thushyanthy, M., Barathithasan, T., and Saravanan, S. (2010). Irrigation water quality based on hydrochemical analysis, Jaffna, Sri Lanka.

Okogbue, C.0., and Ukpai, S.N. (2013). Geochemical evaluation of groundwater quality in Abakaliki area, Southeast Nigeria . Jordan Journal of Earth and Environmental sciences, 5 (1), 1-8

Piper, A. M. (1944). A graphic procedure in the geochemical interpretation of water analyses. Eos, Transactions American Geophysical Union, 25(6), 914–928.

Ravikumar, P., and Somashekar, R. K. (2013). A geochemical assessment of coastal groundwater quality in the Varahi river basin, Udupi District, Karnataka State, India. Arabian Journal of Geosciences, 6(6), 1855–1870.

Salimaa, D., and Belgacemb, H. (2017). The hydrochemical characterization of the upper plains aquifers: case of the plain of F'kirina Ain-Beïda, Northeastern Algeria. Desalination and Water Treatment, 92, 90–97.

Sarath Prasanth, S. V, Magesh, N. S., Jitheshlal, K. V, Chandrasekar, N., and Gangadhar, K. (2012). Evaluation of groundwater quality and its suitability for drinking and agricultural use in the coastal stretch of Alappuzha District, Kerala, India. Applied Water Science, 2(3), 165–175.

Sarikhani, R., Ghassemi Dehnavi, A., Ahmadnejad, Z., and Kalantari, N. (2015). Hydrochemical characteristics and groundwater quality assessment in Bushehr Province, SW Iran. Environmental Earth Sciences, 74(7), 6265–6281.

Stumm, W., and Morgan, J. J. (2012). Aquatic chemistry: chemical equilibria and rates in natural waters. John Wiley and Sons.

Subyani, A. M., and Al Ahmadi, M. E. (2010). Multivariate statistical analysis of groundwater quality in Wadi Ranyah, Saudi Arabia. JAKU Earth Sci, 21(2), 29–46.

Todd, D. K., and Mays, L. W. (2004). Groundwater hydrology. John Wiley and Sons.

WHO, G. (1984). Guidelines for drinking-water quality. v. 1: Recommendations.-v. 2: Health criteria and other supporting information. v3: Drinking-water quality control in small-community supplies.

WHO, 2017. World health statistics 2017. Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2017. License: CC BY-NC-SA 3.0 IGO.

Wilcox, Lv. (1955). Classification and use of irrigation waters (Issue 969). US Department of Agriculture.