INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 14, No. 3, p. 63-70, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Assessment of the groundwater quality used for irrigation: Example of the Plain of Azzaba, North-eastern Algeria

Zineb Bouleghlem*[1], Bachir Saaidia[1], Mohamed Mahia[2], Lamine Sayad[3], Hicham Chaffai[1]

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

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

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

Article published on March 30, 2019

Key words: Water, Irrigation, Azzaba, Mineralisation, Hydrochemistry, Salinity.

Abstract

The Azzaba plain located north-east of Algeria is a plain of primary economic importance. In fact, we find a large surface area of agricultural land therein, whose activity requests huge quantities of water to meet the needs of various cultures. Water intended to agriculture should have physicochemical characteristics tolerable by crops, even under wet climate, the resort to irrigation is necessary for most cultures. The lack of surface water causes for groundwater to be increasingly exploited. A hydrochemical study was conducted; it focused on major elements of groundwater of the plain. Two sampling campaigns were carried out during the periods of high and low waters (April and October 2018). The findings of the study show that groundwater is very mineralised and characterised by average to high salinity, so it is of permissible to poor quality for agriculture.

***Corresponding Author:** Zineb Bouleghlem ✉ geo.bz@live.fr

Introduction

The chemical composition of water depends on the environment in which it is found, this composition plays a key role in the determination of its quality and uses (Zahi & *et al.*, 2013). Too mineralised water causes diverse pedological and agronomic problems, these salts can be harmful to cultures and disrupt their growth, thus resulting in the reduction of their yield (Hadj said, 2007). Most irrigation methods applied are often accompanied by the apparition of sodification, salinisation or alkalinisation process of the soil. The intensity of salinisation process is tributary of the characteristics of the soil that we want to irrigate, the quality of used water, the conditions of its use and notably the drainage system efficiency (Gouaidia & *et al.,* 2013). In Algeria, water has a strategic importance due to its shortage and to a naturally disrupted and unbalanced cycle (Boudjadja & *et al.,* 2003), also to the fact that more than 20 % of the irrigated soils are concerned by the problem of salinity (Douaoui & Hartani, 2007). The study area is known for its agricultural activity, an activity that demands much water in order to meet the needs of a variety of cultures. The fitness of water for irrigation can be estimated not only from the total concentration of salts, but also by the type of salts and ions that constitute it (Ayers & Westcot 1985; Rouabhia & Djabri 2010).

Materials and methods

Study area

The Azzaba plain is located north-east of Algeria with a surface area of 173,43km², a population of 58 992 inhabitants and has a Mediterranean climate, marked by a mean annual rainfall of the order of 629.69 mm and a mean annual temperature of 18.57°C (Bouleghlem & *et al.,* 2016).

The study area is surrounded by mountains; to the north-east Djebel Grebissa and Djebel El Oust, to the north-west Djebel Kef Serrak and Djebel Boufernana, to the south Djebel Ferfour, Djebel Siafa, Djebel Ousfane and Djebel Maksem, to the south-east Kodiet Mra Sma at the limit of the Ain Charchar municipality, to the south west Djebel Demnchaba and Djebel Mekdoua (Fig. 1), (PDAU, 2012).

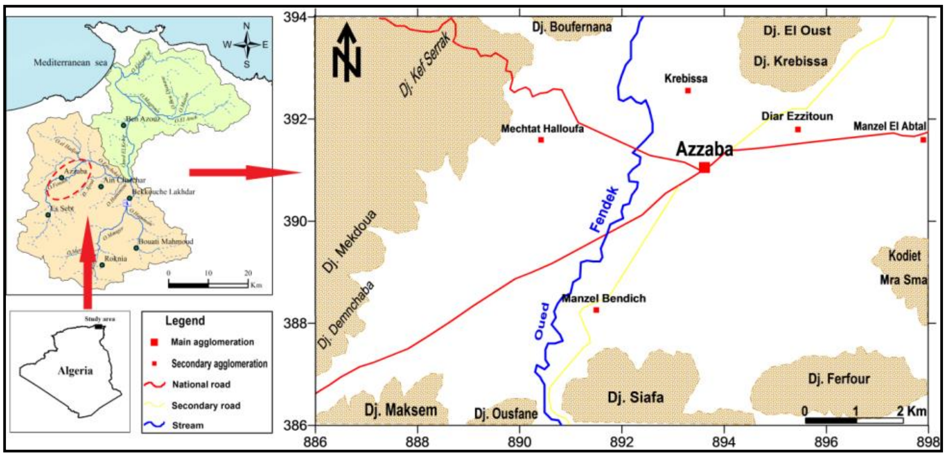


Fig. 1. Geographical location of the study area (Bouleghlem, 2018).

Geology of the area is characterised by autochtonous, composed of deposits of the Kabyle ridge comprising formations, whose age ranges from Triassic to Upper Eocene. We find dislocated deposits of Paleocene (e^1) with sandstones, limestones, limestone microbreccias and breccias, Thanetian-Ypresian (e^{2-3}) formed by quartzitic sandstones and limestones, and Ypresian-Lutetian (e^{3-4}) consisted of conglomerates, limestone microbreccias and sandstone limestone. Allochtonous formed by a series of slices of a diverse composition ranging from Paleozoic metamorphic shale to Oligocene clays (g^2) (Benhamza & *et al.,* 2015). Hydrogeology of the area is marked by two aquifers, Oligocene groundwater made up of fissured sandstones alternating with clay layers, and Paleocene-Eocene deep groundwater localised at sandstones, limestones, breccias conglomerates, fissured and cavernous limestones and Paleocene calcareous sandstones. These two aquifers are separated by impermeable rocks of Paleozoic and Lutetian-Priabonian (Bouleghlem & *et al.*, 2017).

Piezometry

From two campaigns of piezometric surveys, which were performed during the period of high waters (April 2018) and the period of low waters (October 2018) on 11 wells and 3 boreholes, we could realise two water level maps (Fig. 3 and 4).

Hydrochemistry

Two sampling campaigns (April and October 2018) for physicochemical analyses were carried out. The collected samples from 14 water points (11 wells and 3 boreholes) covering the whole study area are kept in a cooler at 4°C (Rodier, 2009) and transported to the laboratory for hydrochemical analysis. Electrical conductivity (EC) was measured in situ; Calcium (Ca^{2+}), magnesium (Mg^{2+}), chlorides (Cl^-) and bicarbonates HCO_3^-) are dosed using volumetric titration; sodium (Na^+) and potassium (K^+) by flame photometer and sulfates (SO_4^{2-}) by means of atomic absorption spectrometer.

In order to control the quality of water intended for an agricultural activity, we used the seven quality parameters such as dry residue (DR), osmotic pressure (π), sodium absorption rate (SAR), sodium percentage (%Na), exchangeable sodium percentage (ESP), potential salinity (PS) and permeability index (PI). In addition to these criteria, we used Richard and Wilcox diagrams.

The primary effect of the total salinity is to reduce the growth of cultures and their production (Rouabhia & Djabri, 2010). It is generally expressed by the global mineralisation or by electrical conductivity (EC) (Alsheikh, 2015). This latter is linked to dry residue (DR) and osmotic pressure (π) by the following formulas:

$$\mathrm{DR\ (mg/l)} = 0{,}7 \times \mathrm{EC\ (\mu S/cm)}$$

$$\pi\ \mathrm{(atm)} = 0{,}00036 \times \mathrm{EC}$$

Soil salinity consists of all salts of sodium chlorides and magnesium sulfates. The potential salinity (PS) would therefore be estimated by the following formula (Doneen, 1962):

$$\mathrm{PS} = \mathrm{Cl}^- + \frac{1}{2}\mathrm{SO}_4^{2-}$$

Where all terms are expressed in milliequivalent per liter

For sodium, it was recognised that its concentration in irrigation water has an influence on permeability and infiltration of the soil. The presence of (Na^+) has detrimental effects on the structure of the soils by deflocculation of clay. This effect is interpreted by different authors by computing numerous parameters like SAR:

$$\mathrm{SAR} = \mathrm{Na}/\sqrt{(\mathrm{Ca}+\mathrm{Mg})/2}$$

Sodium percentage is written as:

$$\mathrm{Na\%} = \left[\frac{(\mathrm{Na}+\mathrm{K})}{(\mathrm{Ca}+\mathrm{Mg}+\mathrm{Na}+\mathrm{K})}\right] \times 100$$

Exchangeable sodium percentage is :

$$\mathrm{ESP} = 100 \times \frac{[\mathrm{b(SAR)} - \mathrm{a}]}{1 + [\mathrm{b(SAR)} - \mathrm{a}]}$$

Where a = 0, 0126 and b = 0, 01475

In the above formulas, all of the elements are expressed in milliequivalent per liter. Moreover, the studies of Younsi, 2001 and Debieche, 2002 denoted that soil permeability is dependent on several other factors such as total concentration of water, sodium quantity, bicarbonates concentration and the nature of the soil itself. The three first terms were combined in a single formula, giving what we call permeability index (PI) defined by (Doneen, 1962):

$$\mathrm{PI} = \frac{\mathrm{Na}^+ + \sqrt{\mathrm{HCO}_3}}{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+} + \mathrm{Na}^+} \times 100$$

Where all terms are expressed in milliequivalent per liter.

Results and discussion

Interpretation of water level maps

The observation of water level maps realised in April and October 2018 (Fig. 3) and (Fig. 4), respectively, shows that they have the same pattern. The piezometric contour lines in the two maps indicate that the aquifer follows the topographical model. The spacing of the contour lines increases, going from the south of the aquifer to the north, thus indicating high hydraulic gradient in the south, which becomes low in the north. Arrows showing the flow direction are oriented towards the surface stream (Wadi Fendek).

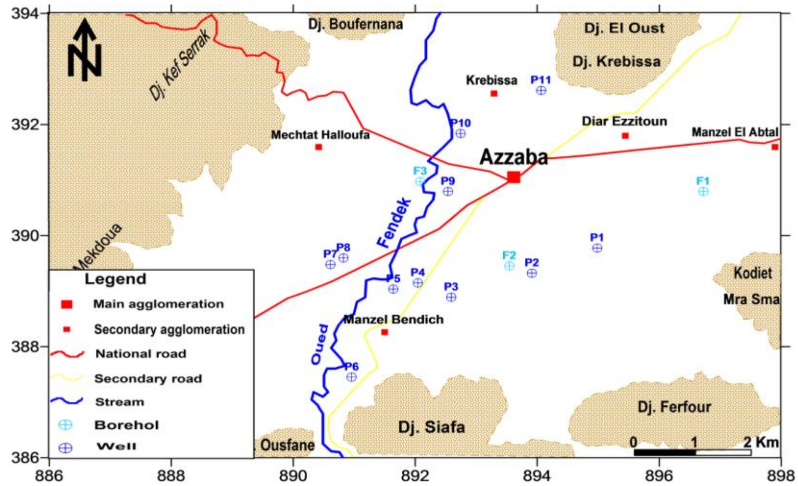


Fig. 2. Water points inventory map of the Azzaba plain (Bouleghlem, 2018).

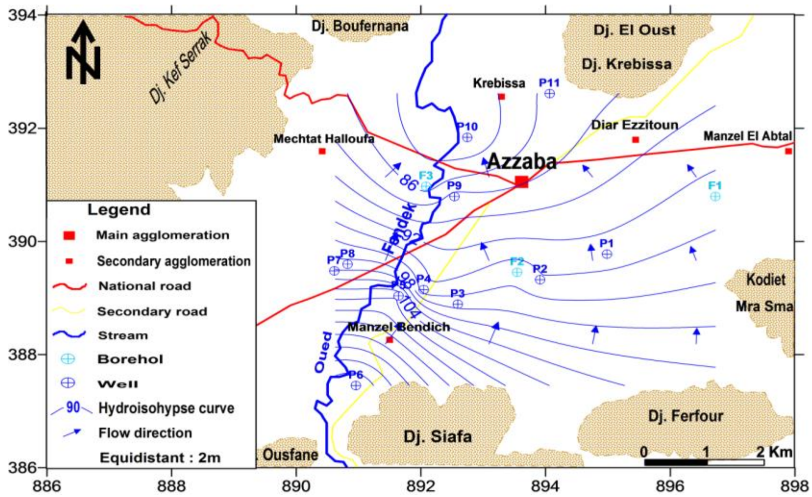


Fig. 3. Piezometric map of the high waters period (April, 2018).

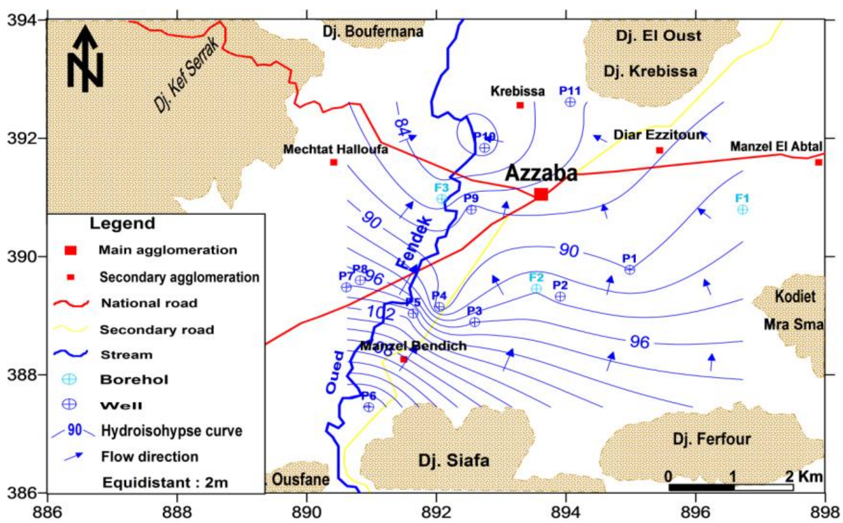


Fig. 4. Piezometric map of the low waters period (October, 2018).

Chemical analyses

Piper diagram (Fig. 12) highlights three major types of chemical facies, namely calcium-bicarbonate, which accounts for 57,14% of samples and appears at points (F1), (F3), (P1), (P4), (P5), (P7), (P8) and (P9); this facies is explained by the fact that the Paleocene-Eocene reservoir is constituted of fissured and cavernous limestones and calcareous sandstones. Sodium-chloride facies (35.71% of samples), which characterises water of borehole (F2) and wells (P2), (P3), (P10) and (P11) having sandstones and Oligocene clays as a reservoir. Chlorides can derive, among others, from dissolution of sodium chlorides of saliferous alluvia. Calcium-sulfate facies accounting for 7.14% of samples is typical of well (P6) water; this facies comes mostly from dissolution of calcium sulfates contained in the evaporitic inclusions and in the alluvia.

Suitability of groundwater for irrigation

The most important factors, involved in water quality for irrigation are computed in order to better define the Azzaba plain groundwater suitability for irrigation, according to the classification used nowadays. The plot of the different parameters of Table 1 and 2 on Richard (1954) and Wilcox (1948) diagrams, allows for an interpretation that leads to situate the types of water and thus the various uses (culture varieties). Richard diagram (Fig. 6) reveals three classes that are presented as follows: good, allowable and poor. Each of these classes has its properties. The Table 3 provides the findings of the diagrams interpretation. Wilcox diagram related to sodium percentage and conductivity (Fig. 7), shows that the plain water exhibits the same properties over time (Table 4). The EC high values are of the order of 3000µS/cm, thus matching high salinity owing to leaching of geological formations. The conductivity average value is of the order of 1655µS/cm in April 2018 (period of high waters) and 2153µS/cm in October 2018 (period of low waters), indicating that the Azzaba area groundwater is of allowable to poor quality. However, the mean value of SAR equal to 1.97 meq/l (April and October 2018), shows a low risk of sodification (Table 5). The PI values obtained are lower than 75% and greater than 25% (Table 1and 2). Therefore, all groundwater of the study area is grouped into the class of good permeability water (Hadji & *et al.,* 2013, Venkateswarana & *et al.,* 2015).

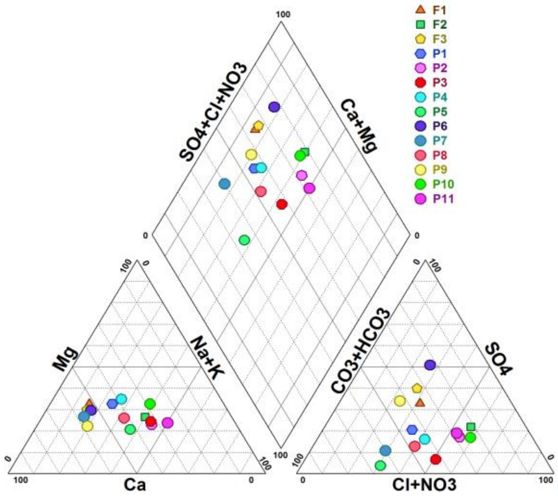
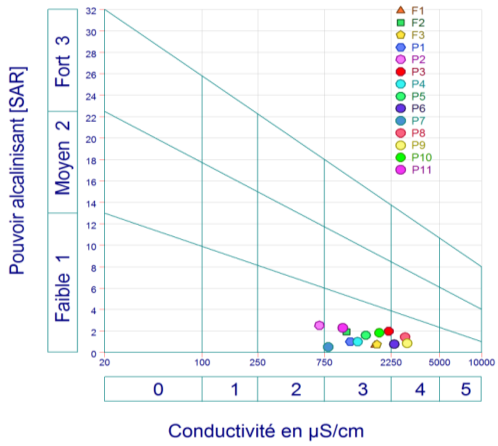
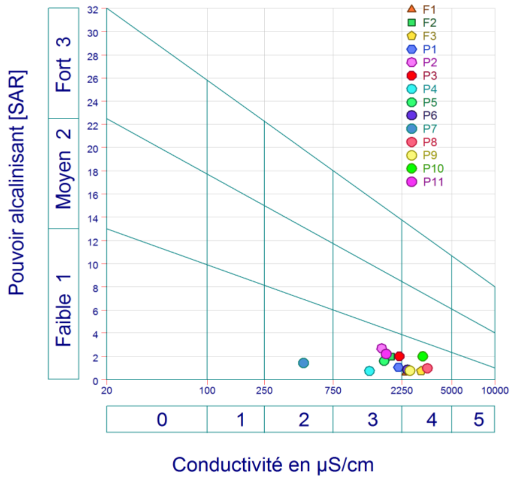


Fig. 5. Piper diagram.



High waters period (April, 2018).



Low waters period (October, 2018).

Fig. 6. Diagrams of Richards (1954). Periods April and October 2018.

Table 1. Quality parameters of Irrigation water (April 2018).

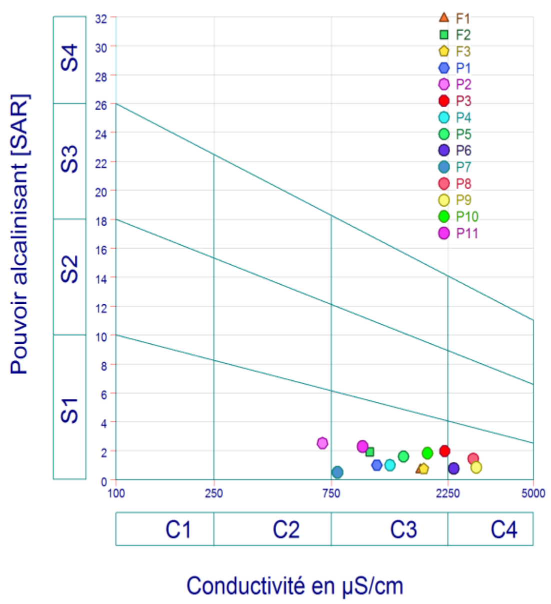
Water points	EC (µS/cm)	DR (mg/l)	π (atm)	SAR (méq/l)	Na (%)	ESP (%)	PS (méq/l)	PI (%)
F1	1728	1209.6	0.62	0.95	15.38	0.14	7.37	30.28
F2	1074	751.8	0.39	2.76	40.10	2.72	8.53	51.64
F3	1787	1250.9	0.64	1.01	15.84	0.23	7.61	29.08
P1	1150	805	0.41	1.41	24.35	0.81	5.21	42.61
P2	693	485.1	0.25	3.56	44.42	3.83	10.12	55.79
P3	2170	1519	0.78	2.8	43.50	2.78	5.53	61.21
P4	1300	910	0.47	1.46	26.76	0.88	5.45	46.30
P5	1480	1036	0.53	2.27	37.32	2.04	3.41	58.17
P6	2370	1659	0.85	1.13	17.42	0.41	8.31	28.60
P7	795	556.5	0.29	0.73	16.34	-0.19	2.82	38.89
P8	2840	1988	1.02	1.99	32.25	1.64	5.52	50.00
P9	2930	2051	1.05	1.24	19.92	0.57	5.57	36.70
P10	1846	1292.2	0.66	2.58	38.99	2.47	8.54	51.94
P11	1008	705.6	0.36	3.27	50.34	3.42	6.23	64.08

Explanations: EC = electrical conductivity, DR = dry residue, π = osmotic pressure, SAR = sodium absorption ratio, Na % = sodium percentage, ESP= Exchangeable sodium percentage, PS= potential salinity, PI = permeability index.

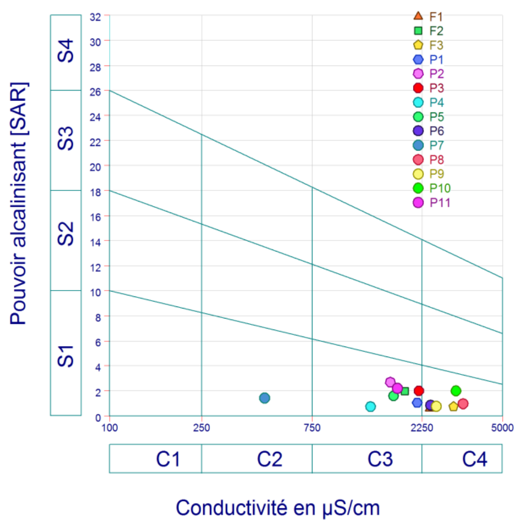
Table 2. Quality parameters of Irrigation water (October 2018).

Water points	EC (µS/cm)	DR (mg/l)	π (atm)	SAR (méq/l)	Na (%)	ESP (%)	PS (méq/l)	PI (%)
F1	2420	1694	0.87	0.86	16.48	0.01	8.22	27.91
F2	1887	1320.9	0.68	2.8	40.06	2.77	9.32	50.56
F3	3070	2149	1.11	1.06	18.40	0.29	8.27	29.91
P1	2140	1498	0.77	1.48	25.48	0.91	5.91	40.41
P2	1635	1144.5	0.59	3.83	50.76	4.19	8.87	61.27
P3	2170	1519	0.78	2.89	43.76	2.90	7.51	55.95
P4	1344	940.8	0.48	1.05	23.55	0.28	4.13	44.21
P5	1690	1183	0.61	2.29	34.92	2.06	6.17	50.12
P6	2450	1715	0.88	1.21	17.83	0.51	9.50	27.11
P7	467	326.9	0.17	2.04	40.55	1.71	2.82	64.69
P8	3380	2366	1.22	1.36	26.16	0.73	4.16	43.54
P9	2582	1807.4	0.93	1.12	19.06	0.38	5.59	35.42
P10	3150	2205	1.13	2.86	40.09	2.87	7.61	53.04
P11	1758	1230.6	0.63	3.1	45.87	3.20	7.63	58.63

Explanations: EC = electrical conductivity, DR = dry residue, π = osmotic pressure, SAR = sodium absorption ratio, Na % = sodium percentage, ESP= Exchangeable sodium percentage, PS= potential salinity, PI = permeability index.



High waters period (April, 2018).



Low waters period (October, 2018).

Fig.7. Diagrams of Wilcox (1948). Periods April and October 2018.

Table 3. Results obtained after interpretation of Richards diagrams.

Degree	Class	Study site April	Study site October
2	Good	P2	P7
3	allowable	F1, F2, F3, P1, P3, P4, P5, P7,P10, P11	F2, P1, P2, P3, P4, P5, P11
4	poor	P6, P8, P9	F1, F3, P6, P8, P9, P10

Table 4. Results obtained after interpretation of Wilcox diagrams.

Class	Quality	Characteristics	Study site April	Study site October
C2-S1	Good	Water can be used without special measures to irrigate moderately salt-tolerant crops on soils with good permeability	7.14 %	7.14 %
C3-S1	allowable	Water suitable for irrigation of salt-tolerant crops on drained soils; changes in salinity, however, must be controlled	71.42 %	50 %
C4-S1	poor	Water unsuitable for irrigation but may be used under certain conditions: high soil permeability, good leaching plants, highly tolerant to salt	21.42 %	42.85 %

Table 5. Descriptive statistics of calculated parameters in high water period (April 2018) and low-water period (October 2018).

Water points	EC (µS/cm)	DR (mg/l)	π (atm)	SAR (méq/l)	Na (%)	ESP (%)	PS (méq/l)	PI (%)
Min	467	326.9	0.17	0.73	15.38	-0.19	2.82	27.11
Max	3380	2366	1.22	3.83	50.76	4.19	10.12	64.69
Mean	1904	1332.85	0.69	1.97	30.92	1.59	6.63	46

Explanations: EC = electrical conductivity, DR = dry residue, π = osmotic pressure, SAR = sodium absorption ratio, Na % = sodium percentage, ESP= Exchangeable sodium percentage, PS= potential salinity, PI = permeability index.

Conclusion

As part of this work, we attempted to evaluate the quality of groundwater used for irrigation in the Azzaba plain during the observation period April and October 2018. The interest of this research is due to the problem seen by the area, which is groundwater quality, the lack of surface water as well as the heavy demand for water as a result of increasing agriculture activity. The analysis of all parameters characterizing salinity, during the observation period, made it possible to evaluate the quality of this water by means of conventional methods. This evaluation revealed that water is of average to high salinity. According to SAR average value, which remains lower than 4 meq/l, groundwater exhibits a low risk of alkalinisation and could be used for irrigation.

The comparison of the two diagrams of distribution of SAR and Na% revealed a similar distribution of the classes of suitability for irrigation. It is clear from this classification that, overall, water of the area is fit for irrigation of salt-tolerant crops on well-drained soils, the evolution of salinity should however be controlled. We note that some water points contain water which is only fit for irrigation of certain salt well-tolerant crops.

References

Alsheikh A. 2015. Irrigation water quality evaluation of Aldelam groundwater. Original Journal of Chemistry. Vol. 31. No. (3) p. 1759-1766.

Ayers S, Westcot D W. 1985. Water quality for agriculture. FAO Irrigation and Drainage paper. No. 29. Rev 1. Rome. FAO. ISBN 92-5-102263-1 pp. 174.

Benhamza M, Laraba A, Picard-Bonnaud F. 2015. Contamination par les micropolluants métalliques des eaux souterraines de la région d'Azzaba, Nord-est Algérien. Larhyss Journal, pages 149-157.

Boudjadja A, Messahel M, Pauc H. 2003. Ressources hydriques en Algérie du Nord. Revue des sciences de l'eau, Québec, Canada, Vol.**16,** N°3, 285-304.

Bouleghlem Z, Kahal A, Saadia B. 2016. Evaluation et exploitation des ressources en eau dans la région d'Azzaba (Nord Est Algérien). 2nd International Conference on Water Resources (ICWR), 21-22 Novembre 2016, Ouargla, Algérie.

Bouleghlem Z, Saadia B. 2017. Contexte géologique et hydrogéologique de la région d'Azzaba (Nord Est Algérien). 3rd National Scientific Days (JSNE3), 20-21 Novembre 2017, Skikda, Algérie.

Debieche TH. 2002. Evolution de la qualité des eaux (salinité, azote et métaux lourds) sous l'effet de la pollution saline, agricole et industrielle. Thèse de doctorat. Univ. de franche comté. 199p.

Doneen LD. 1962. The influence of crop and soil on percolating water. Proc.Biennial Conf. on groundwater recharge. P10.

Douaoui A, Hartani T. 2007. Impact de l'irrigation par les eaux souterraines sur la dégradation des sols de la plaine du Bas-Chéliff. Actes de l'atelier régional SIRMA. Tunis.

Gouaidia L, Guefaifia O, Boudoukha A, et Hemila ML. 2013. Evaluation de la salinité des eaux souterraines utilisées en irrigation et risques de dégradation des sols : Exemple de la plaine de Meskiana, nord-est algérien. Geo-Eco-Trop P. 81-92

Hadji F, Guasmi I, Djabri L. 2013. Suitability of surface water from Mouillah Wadi of Algeria for irrigation purposes. In: Developments in soil salinity assessment and reclamation. Eds. S. Shahid, M. Abdelfattah, F. Taha. Dordrecht. Springer. DOI 10.1007/978-94-007-5684- 7_47.

Hadj-Said S. 2007. Contribution à l'étude hydrogéologique d'un aquifère en zone côtière: cas de la nappe de Guerbes.PhD Thesis. Annaba. University of Annaba pp. 180.

PDAU. 2012. Plan directeur d'aménagement et d'urbanisme de la commune d'Azzaba.

Richards LA. 1954. Diagnosis and improvement of saline and alkali soils. Washington D.C. USDA. Agricultural Handbook. No. 60 pp. 160.

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

Rouabhia AEK, et DJABRI L. 2010. L'irrigation et le risque de pollution saline, exemple des eaux souterraines de l'aquifère miocène de la plaine d'El Ma El Abiod. Larhyss Journal, ISSN 1112-3680, n°08, pp. 55-67.

Venkateswarana S, Satheeshkumar S, Ayyandurai R. 2015. Suitability of groundwater resources for irrigation in the Upper Gadilam River Basin Villupuram District, Tamil Nadu, India. Vol. **08**, No. 02 p. 292–300.

Wilcox LV. 1948. The quality of water for agricultural use.Washington, DC. USDA. Technical Bulletin. Vol. **962,** pp. 40.

Younsi A. 2001. Méthodologie de mise en évidence des mécanismes de salures des eaux souterraines côtières en zone semi-aride irriguée. Chaouia côtière, Maroc. Thèse de doctorat d'état, Université Chouaib Doukkali, El Jadida, Maroc.

Zahi F, Djamai R, Chaab S, Djabri L, Drouiche A et Medjani F. 2013. Dynamique de la nappe et qualité physico-chimiques des eaux souterraines du lac Fetzara (Nord-Est Algérien), Rev. Sci. Technol., Synthese **26,** 86- 95.