http://dx.doi.org/10.15576/GLL/2022.3.45

GLL

Geomatics, Landmanagement and Landscape No. 3 • 2022, 45–57

EFFECT OF THE AGRICULTURE ON THE QUALITY OF GROUNDWATER IN THE ALLUVIAL AQUIFER OF THE TADJENANET AREA (EASTERN ALGERIA)

Abdelhamid Khedidja, Imen Dib

Summary

The region of Tadjenanet is in eastern Algeria in the high plains, characterized by a varied age detritus Mio-Plio-Quaternary. Some geological formations can be an important source of groundwater (alluvial sand, shell limestone, gravel). Its location in semi-arid area involves evaporation pronounced even tilt the balance in a chronic deficit, excluding periods characterized by rainfall events.

Agriculture in the study area is the first socio-economic activity and the largest consumer of water resources. It is therefore necessary to consider for effective water management. Indeed, the combination of hydrogeological and hydro chemical geological mapping, geophysics, harvested from field data and their interpretations can be an excellent tool for deciding the suitability of water for irrigation.

The analysis of the physicochemical data shows an increase in the concentration of nitrates reaching 200 mg · l^{-1}, as well as the analysis by the Richards SAR parameter shows that most groundwater samples are generally suitable for agricultural purposes with 33%, belong characterizing poor quality.

Indeed, the groundwater in the region generally requires prior treatment before consumption and use depending on the type of crop.

The assessment of the quality of the water in the region and its consequences on the soil and the types of crops has enabled the authorities concerned to manage the water supply adequately to preserve and protect this vital source for the future from any risk of contamination.

Keywords

effect • groundwater • salinity • quality • irrigation • Tadjenanet • Algeria

1. Introduction

Water is the most important natural resource, which forms the core of ecological system. Recently there has been overall development in various fields such as agriculture, industry and urbanization. This has led to increase in the demand of water supply which is met mostly from exploitation of groundwater resources. Therefore, the

number of wells increases from one year to another with increasing demand due to the introduction of medium depth drilling and uncontrolled installation of single use wells. This led to poor management of water potential of the region. This requires a thorough study of hydraulic capabilities of the aquifer system of the plain of Tadjenanet, which characterize the upper valley of Oued Rhumel, and the effect of agriculture and the installation of the various industrial units in both cities of Tadjenanet Chelghoum Laid [Asadi 2019, Khedidja 2001]. This may cause a risk of pollution of various kinds, agricultural, industrial and domestic water of groundwater and surface water (dam Oued el Athmania located downstream of the plain). This is compounded by the lack of wastewater treatment plants in the region and that all discharges of wastewater are discharged into the river of Rhumel are no prior treatment. Agriculture in our study area represents the first socio-economic activity and water resource which influences the quality of the waters and thus their suitability for agricultural use [Elgallal et al. 2016, Saadali et al. 2022]. It is therefore necessary to consider for effective water management.

The aim of this work is to determine the physicochemical characteristics of groundwater and to study the suitability of groundwater for consumption and irrigation in the study area through statistical analysis of the salinity parameters of the water [Jasrotia et al. 2018, Ismail et al. 2020].

2. Materials and methods

2.1. Geological and hydrogeological settings

The area explored is part of the western area of the great watershed Kebir Rhumel located in east Algerian. The area is characterized by a semi-arid climate, with a wet and cold winter and a hot, dry summer. Stratigraphic point of view, the formations met are major part of continental and lacustrine origin (Fig. 1). This is basically red clay in which extend lacustrine limestone benches, sandstone and conglomerate, still limited in thickness and extent, with rapid changes in facies. Clays, in some places (Northwest to Dj Ed Dess, south-east and around Dj Grouz Eocene outcrops) have many blocks or gravel or debris flint. The balance sheet is characterized by a flow deficit that extends from July to October, with an annual average of about 501 mm and a surplus equal to 29 mm, or 8% of precipitation.

The various geological, geophysical and hydrogeological conducted in the region [Issaadi 1981, CGG 1973, Bensouilah 1995], showed the existence of three permeable geological formations allowing the formation of three aquifers:

- An aquifer whose permeability is related to a crack network characterized by a karst limestone formations circulation in the Cretaceous neritic and all allochtonous south of Setif [CGG 1973, Vila 1980].
- An aquifer in Mio-Pliocene formations, it outcrops over a large part of the land, they are lacustrine limestone, red marl, silt and red sands. All these formations present very variable facies; the set has a thickness of 100 to 150 m.

- A shallow aquifer in the Quaternary alluvium developed at Oued Rhumel which is in destocking phase. In this section we will focus in the second and third aquifer.

This aquifer of great extension occupies almost all of the study area, it stretches from Bir El Arch in the west to Oued Athmania east through Tadjenanet and Chelghoum Laid. This aquifer was formed in sandstone, gravel, sand, silt and lake limestone in which there are passages of clay and marl. The bedrock is formed by Miocene clays and marl [Khedidja 2001]. The power of this aquifer is from rainfall infiltration especially during periods of Oued Rhumel flood, and a side supply.

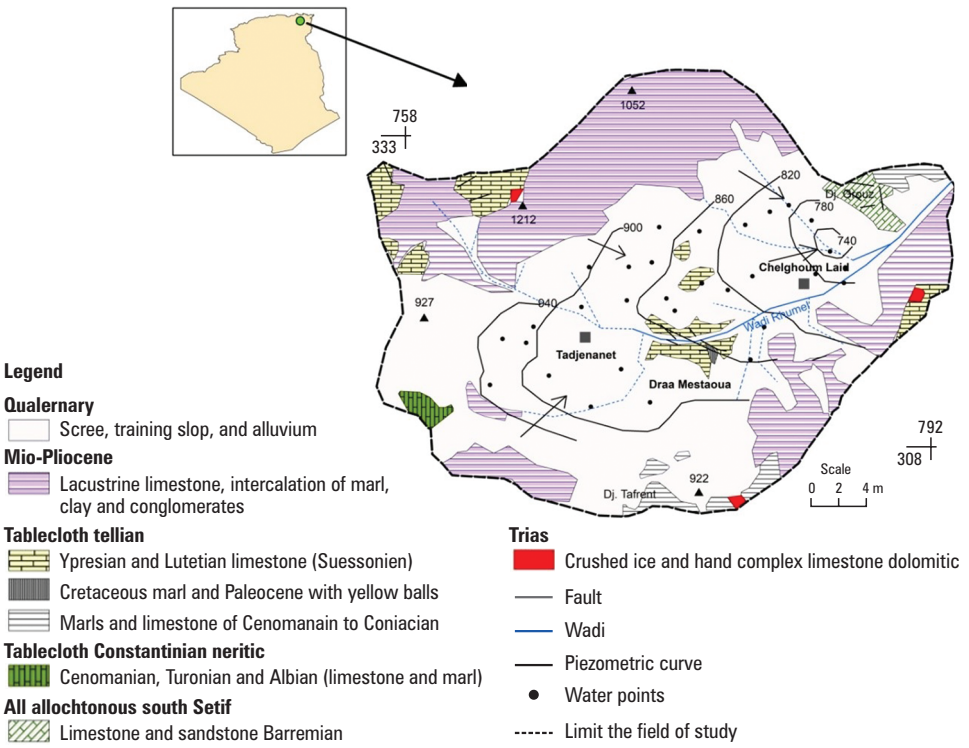

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Fig. 1. Map of the natural conditions of the study area: geology and piezometry (May 2016)

The aquifer studied is characterized by a converging flow is characterized by closed curves piezometric in West–East direction which coincides with the morphology of the bedrock [CGG 1973, Vila 1980]. The piezometric curves are close to the West and to the East reflecting an average hydraulic gradient of the order of 3%, which implies a low permeability. In the center and in the far east of the land, the curves are more spaced reflecting a lower hydraulic gradient of the order of 1%. This low gradient is due to the good characteristic of the field.

2.2. Materials and means of analysis

The campaign of sampling was conducted during the end of the period of high water (May 2018). Twenty nine (29) samples were taken at water points (wells and drilling) from wells of average depth 40 m and various locations in the study area with an average altitude of 820 m (Fig. 1).Chemical elements analyzes were performed at the laboratory of the treatment plant Batna. Chemicals that were measured are: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-}, NO_2^{-}, NH_4^{+}, PO_4^{3-}. Assay methods used are colorimetry, volume and spectrophotometry [Rodier 1996]. The temperature (T), electrical conductivity (EC) and pH were measured on field using a portable multi-parameter instrument. The accuracy of the chemical analysis was checked by calculating the ion balance errors where the errors were generally less than 8% for all samples. The concentrations were interpreted and calculated with salinity parameters and using the following formula of Sodium adsorption ratio (SAR).

3. Results and discussion

The chemical composition of groundwater depends largely on the type of host rock, the residence time of the hydrodynamic evolution of the depth of the static level and climate. The water quality may also be influenced by human activity in urbanization, industrialization and especially the different agricultural activities.

Another factor that has a considerable effect on the quality of water, especially in arid and semi-arid areas, is increasing groundwater salinity especially for shallow aquifers, resulting in the phenomenon of evaporation [Drever 1997]. The analysis results are summarized in Table 1.

According to the results of analyzes of water chemistry, the groundwater is characterized by a wide variation of chemical elements concentrations: Na^{+} and Cl^{-} (27–331 $mg \cdot l^{-1}$), SO_4^{2-}, Ca^{2+}, Mg^{2+} and HCO_3^{-} (28–1050 $mg \cdot l^{-1}$), NO_3^{-} (14–220 $mg \cdot l^{-1}$), NH_4^{+}, PO_4^{3-}, NO_2^{-} (0.01–2.8 $mg \cdot l^{-1}$). It is noted that the deviation from the average is significant for certain elements such as magnesium, sulphate and nutrients.

3.1. Nitrate

Inputs of nitrogen in organic form in the soil are by anthropogenic amendments, returned to the soil of crop residues and/or restitution of animal waste. The constitution of the stock of mineral nitrogen in the soil is derived from synthetic fertilizer inputs in the form of ammonium nitrate and urea [Macko et al. 1994, Debieche 2002].

The review of the map (Fig. 2) shows that the area most vulnerable to pollution by nitrates are in the central part of the plain, mainly due to the alluvial nature of the terrain that favors immigration nitrogenous elements to the saturated zone under the effect of the intensification of agriculture and excessive pumping. The high content is recorded at the center with a grade of 220 $mg \cdot l^{-1}$. Low concentrations are stored in the southwest part of the land given the high groundwater level and the clayey nature of the roof of the water table, which protects groundwater against infiltration of nitrate ions.

Table 1. Statistical characteristics of the physico-chemical parameters of water in the alluvial aquifer of Tadjenanet (May 2018)

Parameters Statistics	T (°C)	pH	CE $\mu s \cdot cm^{-1}$	Ca^{2+} $mg \cdot l^{-1}$	Mg^{2+} $mg \cdot l^{-1}$	Na^{+} $mg \cdot l^{-1}$	K^{+} $mg \cdot l^{-1}$	HCO_3^{-} $mg \cdot l^{-1}$	SO_4^{2-} $mg \cdot l^{-1}$	Cl^{-} $mg \cdot l^{-1}$	NO_3^{-} $mg \cdot l^{-1}$	NO_2^{-} $mg \cdot l^{-1}$	NH_4^{+} $mg \cdot l^{-1}$	PO_4^{3-} $mg \cdot l^{-1}$
Max	19	8.69	3635	290.6	160.44	133	12.4	500.4	1050	331.25	220	0.04	0.51	2.8
Min	14.9	7.10	733	64.68	31.9	27.1	0.45	125	28	89.95	14	0.02	0.15	0.45
Average	18.9	7.69	2184	149.49	71.55	77.81	7.64	249.55	278.44	197.32	105.7	0.01	0.29	0.99
SD	1.18	0.35	684	67.88	38.44	29.5	2.7	96.14	288.57	78.00	84.86	0.01	0.17	0.5
CV (%)	6.77	4.88	44.42	45.44	54.77	37.33	36.44	38.56	110.44	45.55	78.65	51	74	64.22
Standard WHO (2004)		6.5–8.5	2000	100	51	201	13		252	251	51	0.22	0.41	

CV – coefficient of variation, SD – standard deviation

The low content is stored in the southwestern part by order concentration 14 mg · l^{-1} [Hildebrandt 2008, Khedidja 2013].

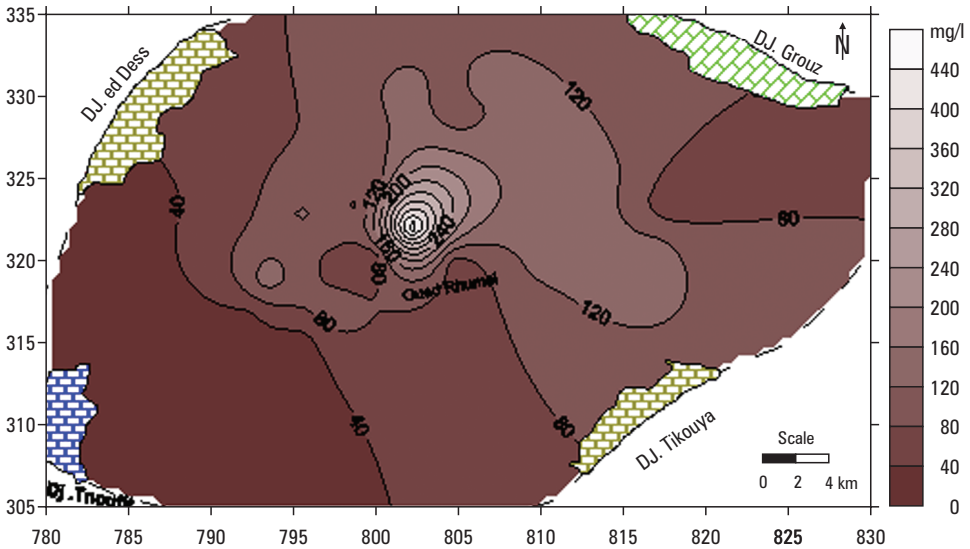

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Fig. 2. Map of nitrates

3.2. Spatial evolution of nitrogen forms

Examining the figure of evolution of different nitrogen form in the western profile of the flow, allowed us to see that the appearance of nitrite and ammonium in water begins from a threshold an average nitrate levels higher than 100 mg/l in the central part of the field study, the low water concentrations of these elements is due to the reducing conditions of the less developed nitrated form [Saadali et al 2020] . Phosphates become important in the eastern part, related to the use of the type of chemical NPK and domestic and industrial discharges downstream of the city of Tadjenanet (Fig. 3).

3.3. Relationships between nitrate concentration and depth of water

The spatial distribution of the concentrations of nitrates on five wells of orientation according to the direction of flow of groundwater West–East according to the depth of the water in the wells allowed us to note that the rate of nitrates in the water is negatively correlated with the depth of the water [Mebarkia et al. 2017]. The high concentrations of which characterize the wells which are in agricultural areas and have experienced an intensification of the use of fertilizers, which eases the immigration of nitrogenous products to the superficial aquifer [Zakaria et al. 2021] (Fig. 4).

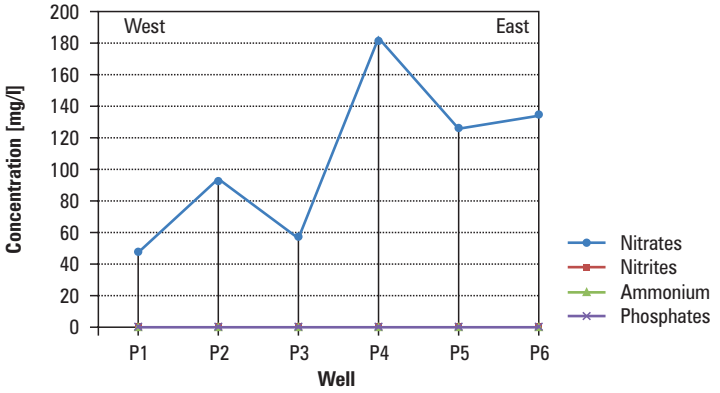

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Fig. 3. Spatial evolution of nitrogen forms and phosphates as the flow axis

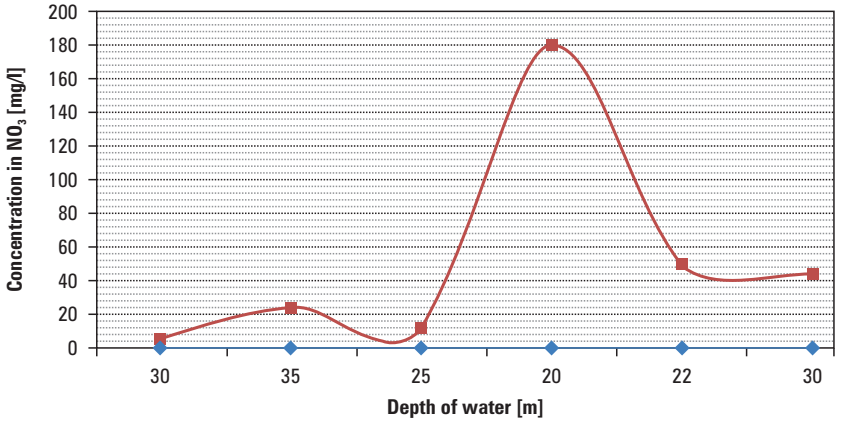

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Fig. 4. Relationships between nitrate concentration and depth of water

3.4. Chemical facies water

From calculations of quantities in reaction (conversion concentrations with meq/L) and classification of ions (ionic form) hydro chemical data collected 29 water points in the plain of Tadjenanet Chelghoum Laid, allowed us to identify five facies.

- Calcium sulfate facies.
- Calcium chloride facies.
- Calcium bicarbonate.
- Magnesium chloride facies.
- Magnesium sulfate facies.

Which the calcium sulfate facies are the most dominant with 36% of samples analyzed, to assess the chemical profile of the water, several treatment techniques based on the establishment of classification diagram is used, as well as methods of statistical treatment, to better understand the water features studied [Piper 1944].

The analysis results worn on the Piper diagram confirms the common origin of these waters. They are grouped into a single pole influenced by the dissolution of evaporite formations. This solution has generated several chemical elements, including sulfates, chlorides, calcium, magnesium. In going from west to east the waters tend to pole sulfated anionic. All water points stood for the triangle related to cations begin in the middle (mixed part) have a tendency toward calcium pole (Fig. 5).

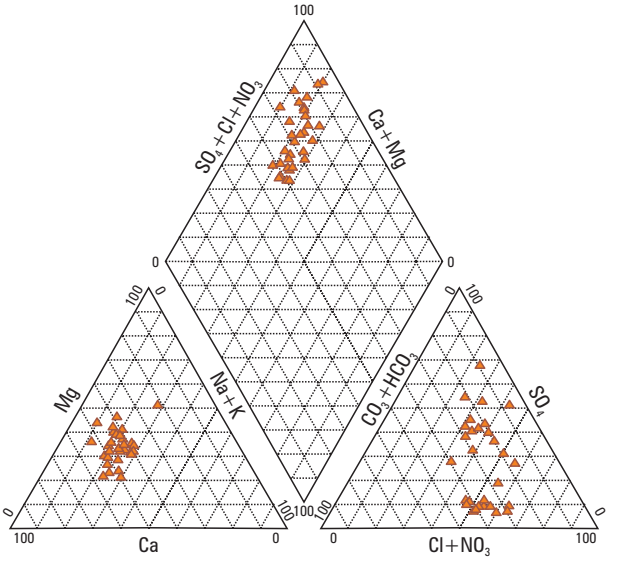

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Fig. 5. Piper diagram

3.5. Suitability water for irrigation

Irrigation with water rich in salts may cause sodium fixing the complex soil adsorbent. The intensity of the salinization process depends on the characteristics of the soil, water quality, conditions of employment and in particular the efficiency of the drainage system. The drought of the last decade has created an agricultural deficit (demonstrated by the water balance calculations) following high evapotranspiration, influencing the water salinity. To investigate the ability of underground waters of the aquifer for irrigation, we made use classification methods Richards, the most often used.

Salinity can cause substantial adverse effects due to the binding of sodium sodium chloride salts by soil colloids. Sodium then exerts a harmful effect on vegetation, indirectly, by degrading the physical properties of the soil [Richards 1954]. Due to this

action, the soil becomes compact and asphyxiating for plants [Todd 1980]. When the concentration of Na^+ ions in a soluble state in the soil is important, these ions often replace Ca^{2+} in the absorbing complex. Water loaded with salts can cause this. The risk is determined from the value of absorbable sodium "Sodium Absorption Ratio" (SAR). For the same conductivity, the risk is even greater than the coefficient is higher [Abdel et al. 2018].

SAR is defined by the following relationship:

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

where: Na^+, Ca^{2+} and Mg^{2+} are expressed in meq/l.

The SAR values range from 12 to 25 and according to the classification of Richards (Table 2), all samples belong to good to bad categories.

Table 2. Classification of water samples of groundwater for irrigation based on EC, SAR

Water Quality	Electrical conductivity [$\mu S \cdot cm^{-1}$]	Sodium adsorption ratio [SAR]	Collected samples [%]
Excellent quality	< 250	<10	–
Good quality	250–750	10–18	33
Doubtful quality	750–2250	18–26	77
Unsuitable	> 2250	> 26	0

These chemicals are used in combination with the electrical conductivity of the water.

The postponement of SAR values depending on the electrical conductivity (Fig. 6) this reflects that the groundwater in the study area, belongs to two classes. The results show that most groundwater samples 67% belong to the category C3S1, which is generally suitable for agricultural purposes with 33%, belong to C4S1 characterizing poor quality. Thus, groundwater in the study area can be used without risk for soils with high salinity risk in the eastern part and low sodicity risk [Sridharanet al. 2017, Mandal 2019].

This water is suitable for irrigation of salt-tolerant crops on well-drained land. So, we can say that the groundwater in the study area can be used without risk to soil with high salinity risk in the eastern part and a risk of low Sodicity. This water is suitable for irrigation of salt-tolerant crops on well-drained soils [Wu et al. 2014].

Admissible quality waters occupy almost the entire ground as poor-quality water is located in the middle and around of wadi Rhumel and north of Tadjenanet (Fig. 7).

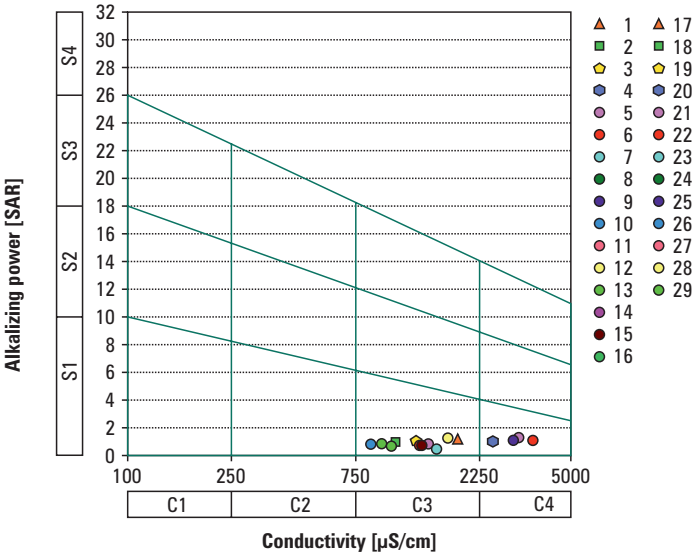

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Fig. 6. Classification of water for irrigation according to the SAR method

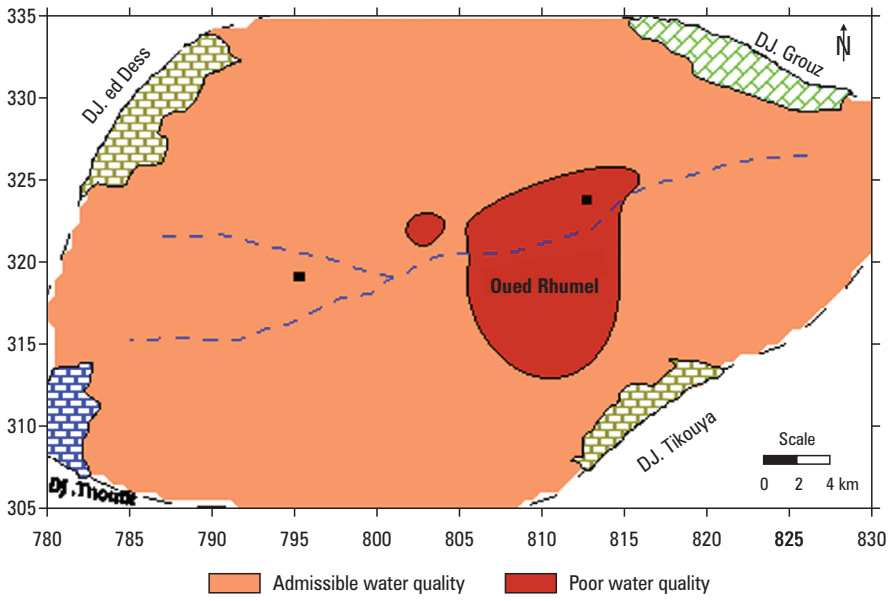

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Fig. 7. Map of water quality for irrigation according to the method of Richard

4. Conclusion

The study of the chemistry of the alluvial aquifer of Tadjenanet area, allowed us to conclude that the hydro chemical behavior is characterized by a high variability in space. The mineralization increases gradually from west to east coinciding with the main direction of groundwater flow. The waters are characterized by low salinity to the west near the mountains of Jebel ed Dess and Djebel Tnoutit, while they are in the center and east, a high mineralization near the town of Chelghoum Laid long the Oued Rhumel.

Electrical conductivity with large variations from one area to another and varies between 733 $\mu S \cdot cm^{-1}$ and 3635 $\mu S \cdot cm^{-1}$ with an average of 2184 $\mu S \cdot cm^{-1}$.

The spatial distribution of concentrations of chemical elements allowed out three main types of chemical profile, calcium sulphate facies , calcium chloride facies and calcium bicarbonate with a low degree facies magnesium chloride and magnesium sulfate, including calcium chloride-calcium bicarbonate facies appeared in west, and the calcium sulfate facies at the center of the field of study where the waters have very high values of electrical conductivity, which is explained by the acceleration of evaporate rocks dissolution phenomenon and the effect base exchange between the alkali metal and alkaline earth metal.

Statistical analysis of the physic and chemical data of all water points has shown the existence of two original chemical pollutants of various kinds in the waters of the alluvial aquifer with high concentrations of chemical elements, the one is due to the effects of pollution by the natural effect of salinity where the high concentration of water in chemical elements of Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}.

The second type of anthropogenic pollutants is marked by the high concentration of nitrate mainly due to the intensive use of chemical fertilizers in agriculture. Concerning the suitability of these waters for irrigation, we find that the waters of the western zone of the study area can be used safely on the ground, with a risk of salinization, in center and east of the land of study with water suitable for irrigation of salt-tolerant crops on well-drained soils.

According to this study of the effect of agriculture on the quality of the region's waters, and taking into account the most important economic activity in the region is agriculture, with the main crops being wheat and potatoes, our perspective must therefore be the object of particular attention in the groundwater monitoring program, especially with regard to contamination by nutrients, in order to guide the design and implementation of the control operations necessary to preserve this vital resource through the use of geomatics techniques.

Acknowledgements

We would like to thank the water resources management and mobilization laboratory of the Institute of Earth and Universe Sciences of the University of Batna 2.

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PhD Abdelhamid Khedidja
University of Batna 2, Algeri, Algeria
Earth Science and Univers
Laboratory of Mobilization and Resources Management
e-mail: khedi73@yahoo.fr

PhD Imen Dib
University of Setif 1, Algeria
Earth Science, Laboratory of Applied Research in Engineering Geology
e-mail: dib.imen@yahoo.fr