Hydrogeochemical Quality of Groundwater used for Irrigation in Ziban Region, Algeria

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Abstract. The present study focuses on the hydrogeochemical characteristics of groundwater in order to assess their irrigation suitability. The samples collected from 28 boreholes intended for irrigation chosen from two localities (El Outaya and Ain Naga) in the Ziban region (Algeria), were analyzed for nine different physicochemical water quality parameters (which include EC, pH, Ca^{2+}, Mg^{2+} , Na^{+}, K^{+}, Cl^{-}, $SO_4^{2-}$and HCO_3^{-}). The laboratory results indicate that most of the groundwater samples of the both locations show high value of EC which exceed as per FAO Standards. The classification of hydrochemical facies by Piper diagram shows dominance of chloride and calcium sulfate ($CaSO_4$) and magnesium groundwater type (in Ain Naga) and potassium chloride water type (in El Outaya). The majority of groundwater samples analyzed of the both location are unsuitable for irrigation purpose according to the interpretation of graphical plots such as Wilcox and US Salinity Laboratory for the classification of groundwater. In Ain Naga location, the better class of water quality is C3S1 with only 14.28%.The rest is unsuitable for irrigation C4S1 (71.42%) and C4S2 (14.28%). However, all groundwater samples analyzed of El Outaya location are unsuitable for irrigation with C4S2 (28.57%), C4S3 (28.57%) and C5S3 (42.85%).

Keywords. Groundwater, Hydrogeochemical, Quality, Irrigation suitability, Ziban.

1. Introduction

Water is essential for all aspects of life[1]. In many countries, specifically those located in arid and semi-arid zones, groundwater is the major source of drinking water, domestic and agriculture use[2]. In Algeria, the rapid growth of irrigated agriculture has increased the utilization of water resources; in 2020 the irrigated area increases to 1.4 million hectares[3]. Groundwater is an important natural resource[4], the majority of irrigation water in the Saharan region of Algeria is in underground origin. However, groundwater of phreatic aquifer is always very salty with more than 4 to 5 g / l of dry residue and very often three times more [5]. The problem of the availability of water quality is becoming more and more crucial [6]. All irrigation water contains dissolved mineral salts, but the

DOI: 10.33794/qjas.2022.135796.1081

concentration and composition of the dissolved salts vary depending on the source of the irrigation water [7-10]. Mostly, the irrigation water quality relate to possibility of high salt concentration, sodium hazard, carbonate and bicarbonate hazard, or toxic ions (e.g., B or Cl). The analyses required for determining water quality include EC, soluble anions and cations[1]. Irrigation with groundwater for several decades, currently poses increased problems in the hydraulic and agricultural fields: exhaustion of underground water reserves (given the low recharge of the deep water table), which results in the closure of many boreholes, increased salinity of extracted groundwater (different degrees and types of salinity), salinization of irrigated soils and reduced yields, especially for crops sensitive to salinity as fruit crops [11,12]. In fact salts from irrigation water accumulate in the soil causing an increase in osmotic pressure and can lead to soil salinization [13]. Salts not only decrease the agricultural production of most crops, but also, as a result of their effect on soil physicochemical properties, adversely affect the associated ecological balance of the area [14]. Therefore, knowledge of irrigation water quality is critical to understanding what management changes are necessary for long-term productivity [15]. So monitoring of soil and water quality in irrigated areas is necessary for measuring the sustainability of the production system [16]. The objective of this study is to define the hydrochemical characteristics that control the quality of groundwater to determine their suitability for irrigation purposes of two locations located in the Ziban region.

2. Description of the Study Area

2.1. Location and Climate

This study was carried out in the Ziban region (Biskra) (Figure 1), which is located in the southeast of Algeria (5º 44' 00" N, 35º 51' 00" E). This region is characterized by the arid climate. The highest monthly average temperature is recorded in July (35.0 °C) and the lowest in January (12.7 °C). Average annual rainfall is about 156.9 mm over the last ten years (2009 –2018) [ONM, 2009–2018].

2.2. Agricultural Activities in the Ziban Region

In the agricultural field, the Ziban region is characterized by the predominance of phoeniculture and plasticulture introduced in the 1990s. One of the best arboricultural crops, which best adapts to the soils of the Ziban region is the date palm; it is the primary crop in the Saharan areas. The most marketable variety is the Deglet-Nour. From the viewpoint of soil, the palm tree is not very exigent; it is very tolerant of salinity. The other tree species that can be grown in the Ziban region, (provided certain technical considerations) are the following: Pomegranate, Apricot, Olive, Fig and Grape. The suitability for market gardening is generally good provided that soil work and organic amendments are undertaken. All vegetable crops can be grown in the Ziban region except for those crops that require a fine texture.

Industrial crops, which are suitable for the soil and climate of the Ziban region, are mainly, (Tobacco, Henna, Peanut and Sunflower). Cereal and forage crops, which adapt to the climate of the Ziban region, are durum wheat, soft wheat, barley and Alfalfa. The very coarse texture can affect yields and even limit the suitability of some crops[17].

2.3. Hydrogeology

2.3.1. Potential Water of Resources in Algerian Sahara

The potential water of resources in Algeria is of 17 Billion of m^3 (surface water 10 Billion of m^3, underground water 6.8 Billion of m^3 mainly in the Sahara). Aquiferous system of the north Sahara, extending 1 million km^2, is shared by Algeria,Tunisia, and Libya. The groundwater tables are fed by the winter rains and sometimes by infiltration from the Oueds (Figure 2)[18].

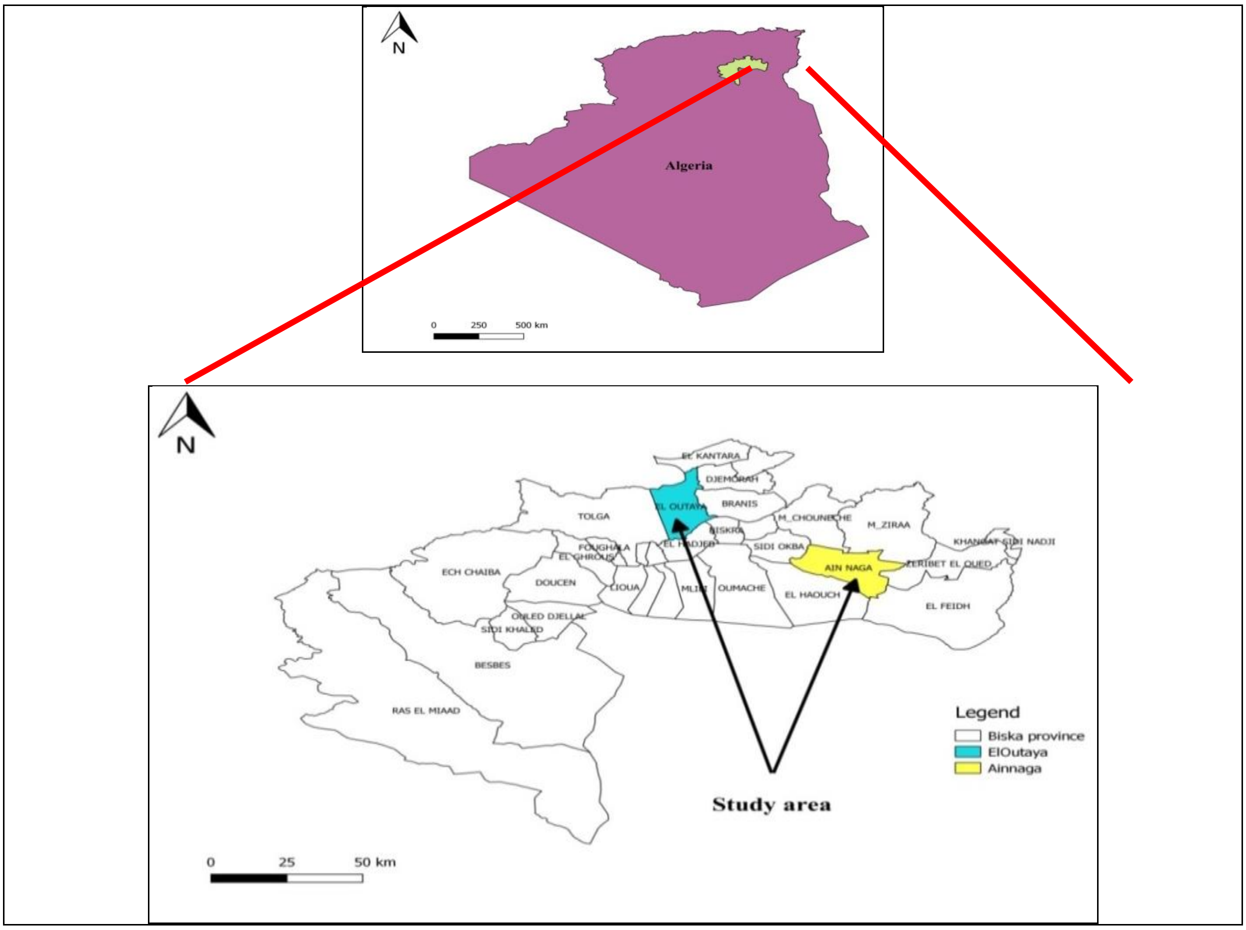

Figure 1. Geographical location of the study area (El Outaya and Ain Naga) in Ziban region.

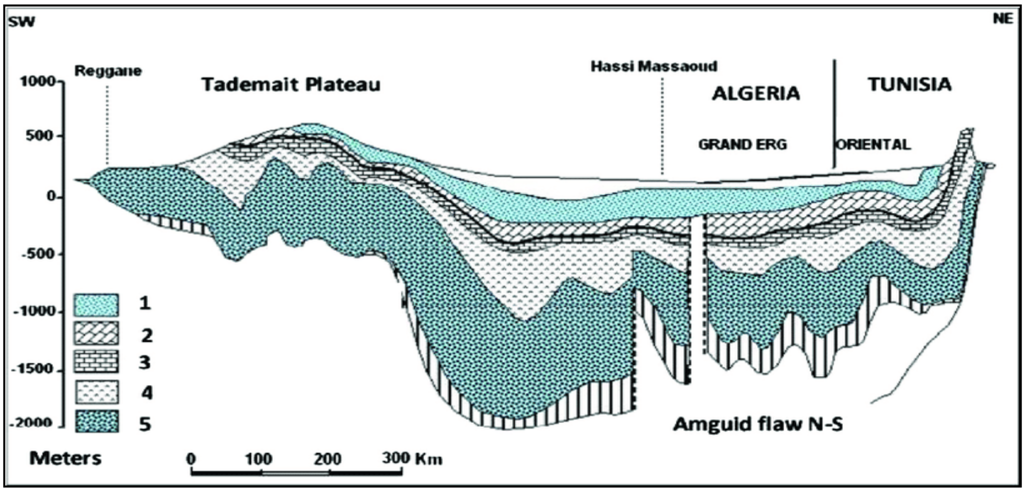

Figure 2. Synthetic hydrogeological section across the septentrional Sahara. 1 Continental terminal aquifer, 2 Lower Senonian, 3 Turonian evaporates, 4 Cenomanian, 5 continental intercalaire aquifer.

Groundwater resources in the Ziban region are represented by three large multilayer aquifers, are as follows (Figure 3):

DOI: 10.33794/qjas.2022.135796.1081

- Phreatic aquifer; this water table is generally located in alluvial accumulations; it is fed mainly by water from precipitation, infiltration from wadis and irrigation water. The depth of this sheet is between 20 and 100 m.
- Terminal Complex aquifer (CT); in this pocket of groundwater, there are two superimposed aquifers:
- Sand sheet: it is made up of alternating levels of clay, sand and pebbles from the Mio-Pliocene age, it covers a large area of the Ziban region. This water table is heavily exploited in the eastern part of the Ziban region. Its depth varies from 100 to 900 m.
- Limestone layer: this layer is essentially made up of fissured limestone from the Eocene and Senonian ages; it is most in demand in the palm groves of Ziban; the latter is called "Tolga tablecloth". Its depth varies from 100 to 130 m.
- The Continental Intercalary aquifer (CI); It is a very important reservoir, made up mainly of sandstone and marl of Albian and Barremian age. Its operation is very expensive due to its depth, which exceeds 2000 m, the water temperature can exceed 60 ° C [19].

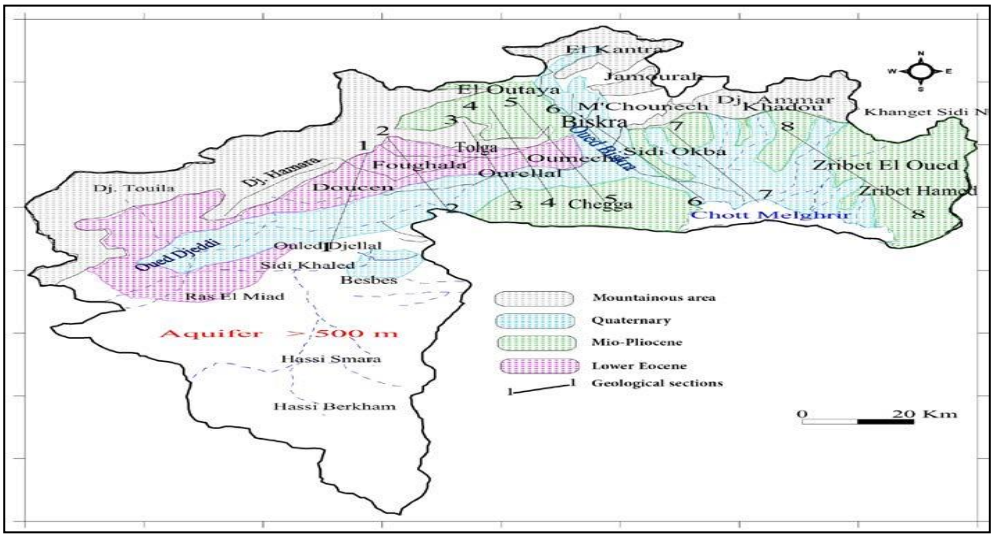

Figure 3. Schematic representation of the extension of the main exploited aquifers in Ziban region.

3. Materials and Methodology

3.1. Sampling Procedures and Analysis

According to the study carried out by A.N.R.H (2008) and the specificity of each region given the availability of boreholes in operation, we have selected two localities, Ain Naga and El Outaya in Ziban region, which show a great tendency concerning the evolution of electrical conductivity of groundwater used for irrigation. In this study, we recorded the coordinates of the sampled water points using a GPS (Model Garmin Oregon 650). Groundwater samples were monitored from twenty-eight (28) boreholes in total intended for the irrigation of agricultural land chosen from selected location (ElOutaya and Ain Naga) during 2016 (Summer season). Figure 1 represents the study area and groundwater samples in Ziban region. Before we collect a groundwater sample, we must purge the well to remove any stagnant water in the well casing and to ensure that at least 95 percent of the water sample originates from the aquifer formation being sampled. Preservation usually also includes cooling the sample to 4°C (40°F) [20]. At the time of sampling, for chemical analysis, each sample bottle will first be rinsed 3 times with the water to be analyzed, and then filled to the brim. The cap will be placed in such a way that there are no air bubbles and that it is not ejected during transport. The use of disposable glass or plastic vials has grown widely, due to their ease of transport and the possibility of their single use given their competitive price[21]. At the laboratory, the samples are logged in, given sample ID numbers, and kept cool until they can be analyzed [20].The groundwater samples collected were analyzed and characterized in the laboratory of the Agricultural Sciences

Department at the University of Biskra (Algeria) for nine different physicochemical water quality parameters (which include EC, pH, Ca^{2+}, Mg^{2+} , Na^{+}, K^{+}, Cl^{-}, $SO_4^{2-}$and HCO^{3-}) adopting standard procedures [21] Electrical conductivity (EC) and pH are measured in situ using a multi-function instrument. Flame-spectrometer (JENWAY) was used to measure sodium and potassium levels. Ca^{2+} and Mg^{2+} were measured by using complexometric method with EDTA. SO_4^{2-} were analyzed by using UV-Spectrophotometry. Cl^{-} and HCO_3^{-} are measured by using volumetric method. The evaluation of the results obtained is given according to the FAO Standards, guidelines for interpretation of water quality for irrigation [22]. DIAGRAMMES software (version 5.1, 2013) was used to calculate the ionic balance, to classify the water (chemical facies, irrigation class) and to construct in particular the different diagrams (Piper, Schoeller-Bercaloff and Riverside diagram). Descriptive statistics were determined using XLSTAT (version 14, 2009).

4. Results and Discussion

4.1. Irrigation Water Quality

4.1.1. El Outaya Location

The Table 1 represents the different physicochemical parameters of groundwater samples analyzed of El Outaya location, and also some statistical parameters including minimum, median, average, and standard deviation. The results obtained show high values of the electrical conductivity (2.92 to 8.04 dS /m) which indicates very high to excessively category of salinity of water using the classification of Durand presented in the table 3[23]. 92.86% of the samples analyzed are more than the acceptable limit admissible by the FAO Standards which is 3 dS/m. According to the F.A.O Standards, the normal range of the pH for irrigation water is between [6.5 and 8.4]. So, 100% of the groundwater samples are within the normal range for irrigation with values ranging from 7.32 to 7.62, this pH is slightly alkaline due to the presence of small amounts of bicarbonates[24]. Among the cations, sodium is generally dominant in the waters of the Sahara, constituting 50% of the total. For anions, chlorides and sulfates are the most abundant [25]. The majority of the analyzed samples in this analysis show the following order of major cation abundance: ($Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$) (Figure.4) and major anions abundance: ($Cl^{-} > SO_4^{2-} > HCO_3^{-}$) (figure.5). According to the F.A.O Standards; calcium of 7.14% of samples analyzed exceeds the permissible limit (20 meq/l). 100 % of analyzed groundwater samples are more than the acceptable limit for magnesium (5 meq / l). The majority of the groundwater samples (85.72 %) are more than the acceptable limit (0.05 meq /l) for potassium. Sodium in all samples analyzed is under the permissible limit (40 meq /l). In addition, the anions results show that 57.14% of analyzed samples exceed the permissible limit for chloride (30 meq/l) set by F.A.O Standards. Also, sulfate concentration in 7.14% of analyzed samples exceeds the permissible limit (20meq/l). Bicarbonates in all samples analyzed don't exceed the permissible limit (10 meq/ l).

Table 1. Statistical of the analyzed parameters of groundwater samples in El Outaya location.

Variables	Minimum	Maximum	Average	Standard deviation
pH	7.320	7.620	7.468	0.079
EC (dS/m)	2.920	8.040	4.766	1.288
Na (meq/l)	18.030	37.690	28.013	6.448
K (meq/l)	0.020	7.079	0.575	1.872
Ca (meq/l)	8.600	21.400	13.600	3.276
Mg (meq/l)	8.600	32.200	14.214	5.860
Cl (meq/l)	16.000	53.300	29.021	9.672
SO4 (meq/l)	7.200	26.070	12.835	4.836
HCO_3 (meq/l)	2.750	4.250	3.768	0.421

Table 3. Evaluation of irrigation water quality.

Electrical conductivity (µS/cm)	Concentration (g/l)	Evaluation of DURAND for Algeria
EC < 250	< 0.2	Not saline
250<EC<750	0.2 - 0.5	Medium salinity
750<EC<2250	0.5 - 1.5	High salinity

DOI: 10.33794/qjas.2022.135796.1081

Electrical conductivity (µS/cm)	Concentration (g/l)	Evaluation of DURAND for Algeria
2250<EC<5000	1.5 - 3	Very high salinity
5000<EC<20000	3 - 7	Excessive salinity

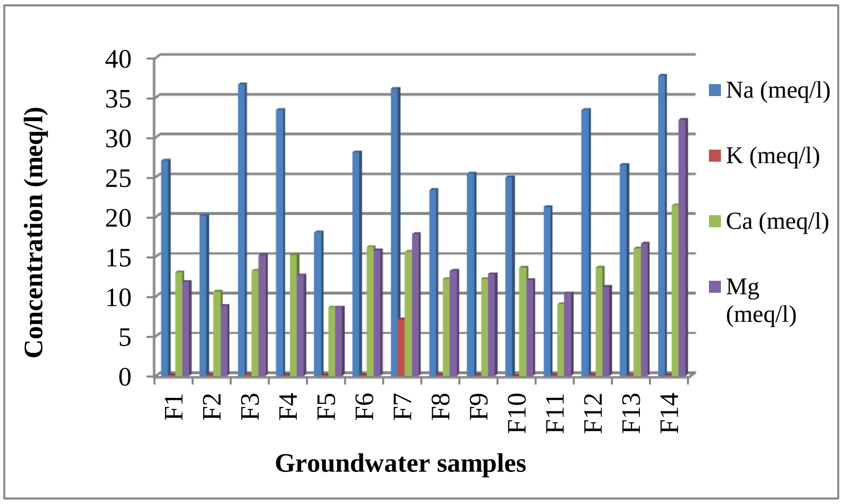

Figure 4. Cations value of groundwater samples.

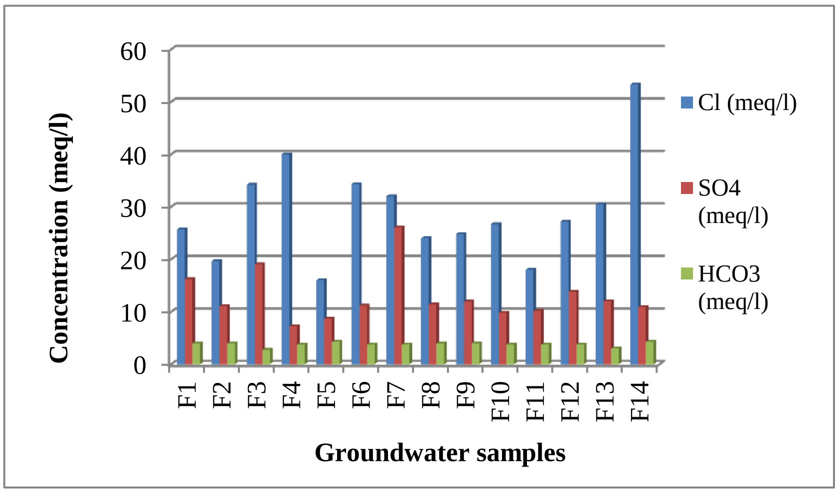

Figure 5. Anions value of groundwater samples.

4.1.2. Ain Naga Location

The statistical data of the physical and chemical parameters of groundwater samples of Ain Naga location are presented in table.2. EC of the samples analyzed vary between (2.090 to 4.5 dS/cm), which indicates water with high to very high salinity[23]. 64.29% of the samples analyzed are more than the acceptable limit set by the FAO Standards. pH of irrigation water is within the normal range for irrigation according to the F.A.O Standards with values ranging from 7.31 to 7.62. The trend of major cations of the most analyzed samples (Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}) (Figure.1) and major anions (SO_4^{2-} > Cl^{-} > HCO_3^{-}) (Figure.2). According to the standards for irrigation water set by F.A.O Standards; 42.86% of the samples analyzed are more than the acceptable limit for calcium. 100% of the samples are more than the acceptable limit for magnesium. Potassium of the majority of samples (78.57%) exceeds the permissible limit. All samples analyzed under the permissible limit for sodium. Concerning anions results, 28.57% of samples analyzed exceed the permissible limit for sulfate. Cl^{-} of all samples analyzed under the permissible limit (30 meq / l). 100% of samples analyzed don't exceed the permissible limit for bicarbonates (10 meq / l).

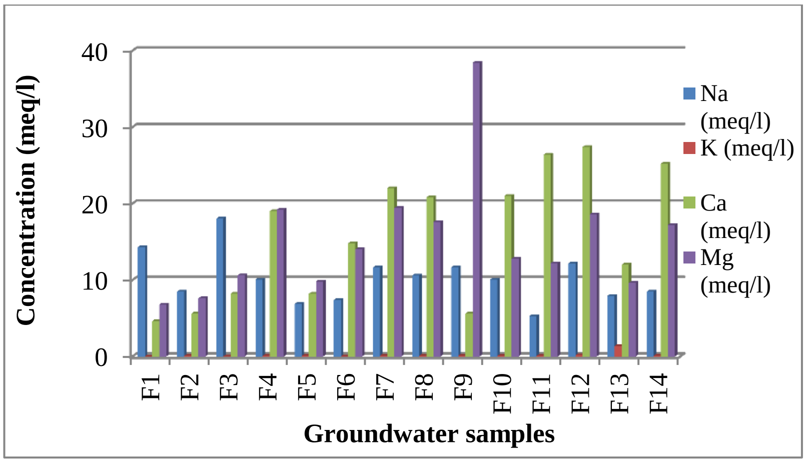

Figure 6. Cations value of groundwater samples.

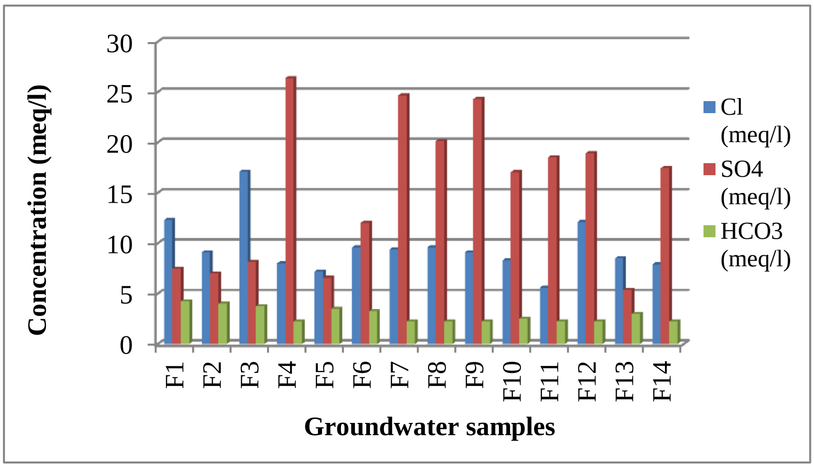

Figure 7. Anions value of groundwater samples.

Table 2. Statistical parameters of groundwater samples in Ain Naga location.

Variable	Minimum	Maximum	Average	Standard deviation
pH	7,310	7,620	7,455	0,098
EC (dS/m)	2,090	4,500	3,226	0,724
Na (meq/l)	5,270	18,030	10,209	3,293
K (meq/l)	0,013	1,379	0,172	0,350
Ca (meq/l)	4,600	27,400	15,771	8,323
Mg (meq/l)	6,800	38,400	15,271	7,939
Cl (meq/l)	5,600	17,100	9,557	2,779
SO4 (meq/l)	5,370	26,375	15,289	7,406
HCO_3 (meq/l)	2,250	4,250	2,857	0,751

The table.3 illustrates the correlation matrix between the physicochemical parameters used in this analysis. The high correlations were noted between electrical conductivity and major ions [Cl^- (0.868), Na^+ (0.812)] and the median correlations with magnesium (0.550). It means that these ions are responsible for the high EC found in groundwater samples. Na^+ shows strong correlation with Cl^- (0.946) and average correlation with HCO_3^- (0.520). It indicates that Na^+ concentration observed in water have the same direction of evolution with Cl^- and HCO_3^- concentration, suggesting a common source of origin [26]. Ca^{2+} and Mg^{2+} show average correlation with SO_4^{2-} [(0.502), (0.566)] respectively, indicating that Ca^{2+} and Mg^{2+} ions are coming from a dissolution of sulfated minerals [27]. Chloride indicates average correlation with bicarbonate (0.525).

Table 3. Correlation matrix (Pearson) of the analyzed parameters of the groundwater samples for the two locations (ElOutaya and Ain Naga).

Variables	pH	EC (dS/m)	Na (meq/l)	K (meq/l)	Ca (meq/l)	Mg (meq/l)	Cl (meq/l)	SO4 (meq/l)	HCO_3 (meq/l)
pH	1	0,037	0,235	0,251	-0,495	-0,040	0,218	-0,165	0,393
EC (dS/m)		1	0,812	0,270	0,369	0,550	0,868	0,268	0,105
Na (meq/l)			1	0,281	-0,093	0,119	0,946	-0,057	0,520
K (meq/l)				1	0,022	0,070	0,172	0,334	0,085
Ca (meq/l)					1	0,287	-0,003	0,502	-0,613
Mg (meq/l)						1	0,207	0,566	-0,401
Cl (meq/l)							1	-0,171	0,525
SO4 (meq/l)								1	-0,676
HCO_3 (meq/l)									1

Values in bold are different from 0 at a significance level alpha = 0.05

4.2. Hydrogeochemical Assessment of Groundwater Quality

4.2.1. Piper Diagram

The trilinear diagram of PIPER is a schematic description of the chemistry of water samples. (Figure.8) makes it possible to locate the geochemical facies of groundwater in the study area. This diagram does not take into account the quantities but the proportions of the different elements. Piper diagram indicates two main facies of water in El Outaya location; ~64% groundwater samples are showing sodium and potassium chloride (or sodium sulfate) water type hydrogeochemical facies, ~36 % groundwater samples indicate chloride and sulfated calcium and magnesium groundwater type hydrogeochemical facies due to water–rock interaction in the study area [28]. However, in Ain Naga location ~93% groundwater samples classified under chloride and sulfated calcium and magnesium groundwater type hydrogeochemical facies and rest classified under sodium and potassium chloride water type hydrogeochemical facies.

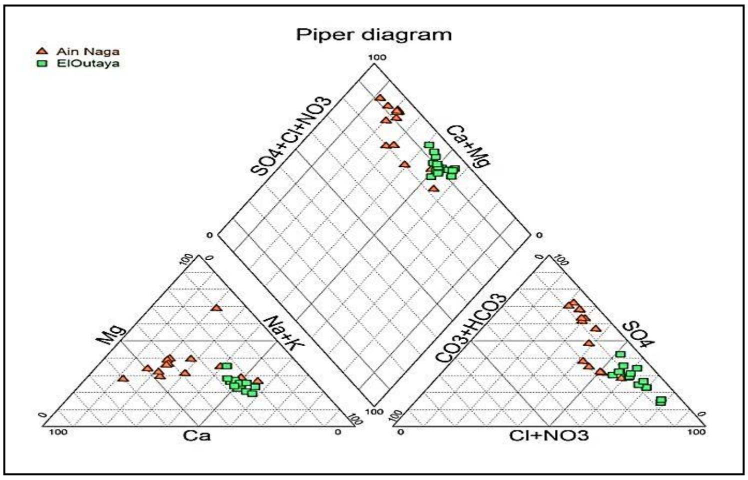

Figure 8. Piper diagram of groundwater samples (ElOutaya and Ain Naga).

4.2.2. Schoeller Diagram

The Schoeller diagram is a representation of the different proportions of ions (cations and anions) in meq/l. (Figure.9). In El Outaya location Schoeller diagram indicates the importance of chloride and sodium potassium in the different groundwater samples with the dominance of chloride anion for all samples and the dominance of sodium potassium for the cations with ~64% groundwater samples and rest indicated under the category no dominant cation. In Ain Naga location, the projection of cations and anions on the Schoeller diagram shows the dominance of the sulfate anion for ~57% of the groundwater samples analyzed. This diagram also indicates ~79% groundwater samples analyzed have no dominant cation.

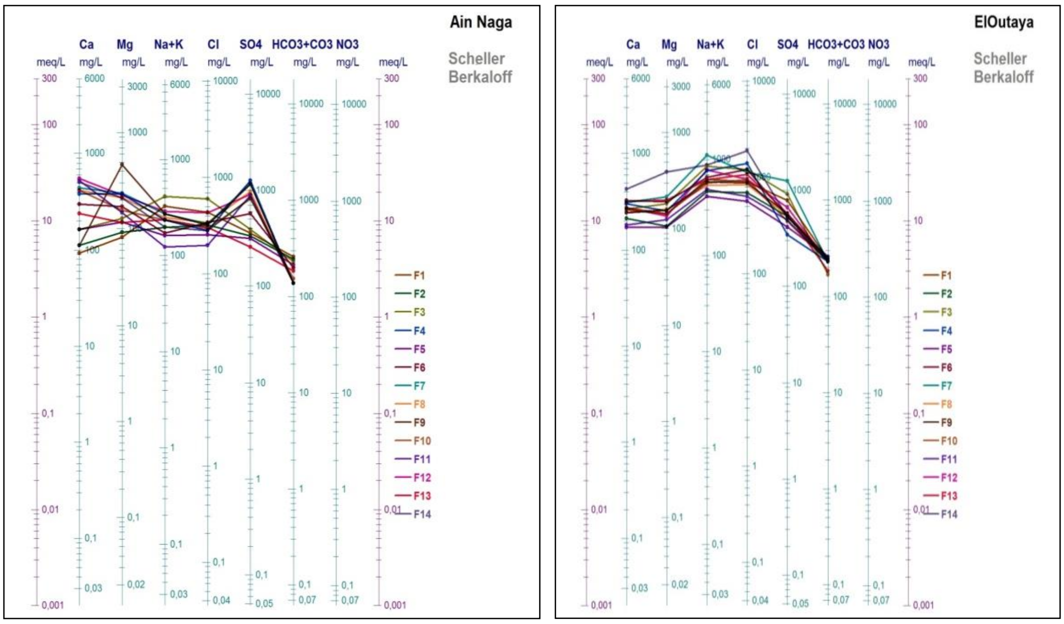

Figure 9. Schoeller diagram of groundwater samples (El Outaya and Ain Naga).

4.2.3. Sodium Adsorption Rate (SAR)

The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as sodium adsorption ratio (SAR). It is an important parameter for determining the suitability of irrigation water, because it is a measure of alkali/sodium hazard for crops[29]. This ratio is calculated by the equation (1):

$$SAR = \frac{Na+}{\sqrt{(Ca2++Mg2+)/2}} \quad (1)$$

The SAR values in El Outaya location range from 6 to10 while in Ain Naga location the SAR values of groundwater range from 1.20 to 5.99. All the groundwater samples are of excellent quality in the both locations, except one sample in El Outaya location which fall under good category of irrigation water quality. Since none of the samples exceeded the SAR value of 10 (Table.4).

Table 4. Irrigation water quality classification.

Water class	Sodium adsorption ratio-SAR- (meq/l)	Number of samples in El Outaya location	Number of samples in Ain Naga location
Excellent	<10	13	14
Good	10-18	1	Nil
Fair/Medium	18-26	Nil	Nil
Poor/Bad	>26	Nil	Nil

The combined effect of EC and SAR on plant growth is shown graphically by the United States Salinity Laboratory (USSL), which is widely used for classification of water quality for irrigation[30]. Sodium-hazard expressed usually in terms of the sodium adsorption ratio (SAR). The continuous uses of groundwater possessing high SAR for the irrigation can cause the breakdown in the physical structure of the soil [29]. The salinity-hazard expressed on the basis of EC. The groundwater having high salt concentration through various sources (both anthropogenic and geogenic) causes an increase

DOI: 10.33794/qjas.2022.135796.1081

in the salinity. High salinity causes lysis of the plant cell, finally death of cells [31]. The plot of groundwater sampled data on the U.S salinity diagram (Figure.10) shows that the groundwater samples fall analyzed in El Outaya location indicates 28.57% of groundwater is classified under the class of C4S2. This water category is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances, irrigation water must be applied in excess to provide considerable leaching, and very sal-tolerant crops should be selected[30]. Additionally, this diagram shows 28.57% of samples analyzed fall under the class of C4S3, indicates groundwater unsuitable for irrigation while 42.85% of groundwater falls under category of C5S3, indicate unsuitable for irrigation. The analytical data plotted on the U.S Salinity Diagram illustrates that 14.28% groundwater samples in Ain Naga location falls under the category of C3S1, indicates groundwater can be used for irrigation considering sodium-hazard, but permissible with the restriction for the purpose of irrigation considering salinity-hazard [31]. This diagram also shows 71.42% of samples analyzed classified under the class of C4S1 and 14.28% groundwater fall under category C4S2.They indicates water unsuitable for irrigation under ordinary conditions. The high salinity in shallow aquifer makes difficult for salinity management because water consumed by plants, released in the atmosphere by evaporation and dissolved salts left in soil further increases its salinity[31].

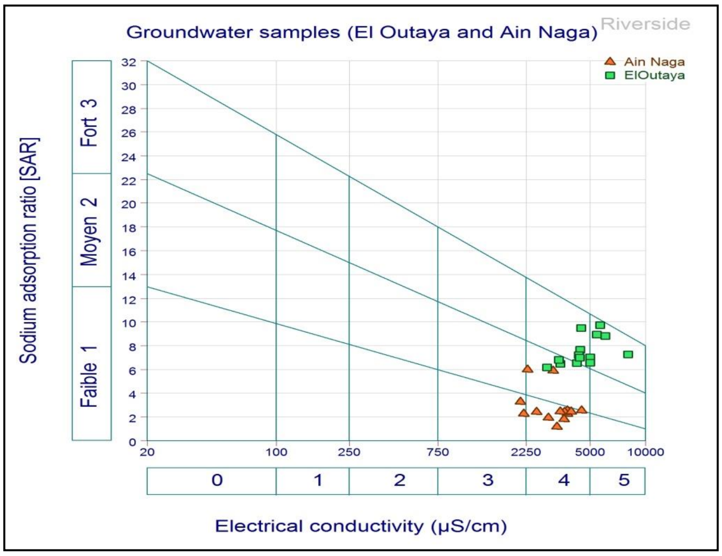

Figure 10. Irrigation water quality assessment based on United States Salinity Laboratory (USSL).

4.2.4. Sodium Percentage

The Wilcox (1955) uses Na% and EC (Figure. 11) to classify groundwater and it can be divided into five categories. The percent sodium is obtained by using the equation given below Eq (2), where all the concentrations units are in meql/1. Generally, the Na% should not exceed 60% in water which is used for irrigation use [32]. In the present study, The Na% values of groundwater samples in El Outaya location ranged from 41.25% to 57.32% while the calculated values of percent sodium of groundwater samples in Ain Naga location range from 12.00% to 55.63% (Table 5).

$$Na\% = [Na^{+}/ (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})]*100 \quad (2)$$

The Wilcox diagram illustrates that 92.86% of the groundwater samples in El Outaya location fall in the category of unsuitable for irrigation and 7.14% samples fallen into doubtful range for irrigation purposes. However, the plot of analytical data on the Wilcox (1955) (Figure.11) indicates that 64.29% of groundwater samples in Ain Naga location range in the region of unsuitable for irrigation and remaining 35.71% are doubtful for irrigation. Irrigation with waters of doubtful to unsuitable category, generally gives low crop yield due to presence of excess sodium salts which reduces the intake of soil nutrients [2].

DOI: 10.33794/qjas.2022.135796.1081

Table 5. Suitability of groundwater for irrigation based on sodium percent (Na %).

Water class	Range	Number of samples in El Outaya location	Percentage of samples in El Outaya location	Number of samples in Ain Naga location	Percentage of samples in Ain Naga location
Excellent	<20	Nil	Nil	2	14.29
Good	20-40	Nil	Nil	10	71.43
Permissible	40-60	14	100	2	14.29
Doubtful	60-80	Nil	Nil	Nil	Nil
Unsuitable	>80	Nil	Nil	Nil	Nil

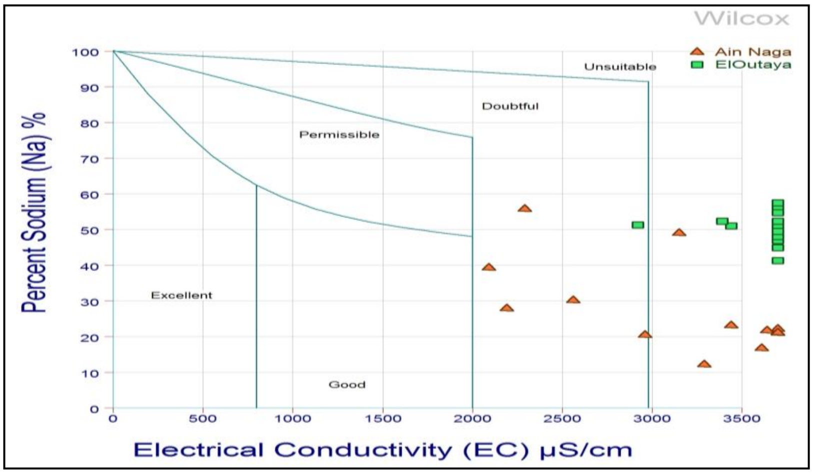

Figure 11. The Wilcox (1955) based classification of groundwater from (El Outaya and Ain Naga).

4.2.5. Residual Sodium Carbonate (RSC)

The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the suitability of groundwater for irrigation. This can be expressed as residual sodium carbonate (RSC) [29].When the total of carbonates and bicarbonates is in excess of calcium and magnesium, there may be possibility of complete precipitation of Ca^{2+} and Mg^{2+} ions [32]. The RSC is obtained by the following Eq.3:

$$RSC = (CO_3^{2-} + HCO_3^{-}) – (Ca^{2+} + Mg^{2+}) \quad (3)$$

The RSC values of groundwater samples in El Outaya location range from -49.35 to -12.95, whereas in Ain Naga location the calculated RSC of groundwater samples range from -43.75 to -7.15. According to RSC classification 100% of groundwater samples in the both location (El Outaya and Ain Naga) falls in the safe (RSC < 1.25 meq/l) categories for irrigation purposes (Table 6).

Table 6. Residual sodium carbonate classification.

RSC (meq/l)	Water category	Number of samples in El Outaya location	Percentage of samples in El Outaya location	Number of samples in Ain Naga location	Percentage of samples in Ain Naga location
< 1.25	Safe	14	100	14	100
1.25 to 2.5	Marginally suitable	Nil	Nil	Nil	Nil
> 2.5	Unsuitable	Nil	Nil	Nil	Nil

Conclusion

The present study focuses on the hydrogeochemical characteristics that control the quality of groundwater in order to determine their suitability for irrigation purposes in the study area. The laboratory results indicated that most of the groundwater samples of the both locations show high value of EC which exceed the permissible limit admissible by the FAO Standards. The trend of major cations and anions of the most analyzed samples was as follows: $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$ and $Cl^{-} > SO_4^{2-} > HCO_3^{-}$ (in El Outaya location), $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $SO_4^{2-} > Cl^{-} > HCO_3^{-}$ (in Ain

DOI: 10.33794/qjas.2022.135796.1081

Naga location). According to the Na%, SAR and RSC, all the groundwater samples of the both location are suitable for the irrigation purpose. Various diagrams have been plotted to identify the quality and suitability of groundwater for irrigation purposes. Piper trilinear diagram demonstrates two main facies of water in El Outaya location; ~64% groundwater samples are showing sodium and potassium chloride water type hydrogeochemical facies, ~36 % groundwater samples indicate chloride and sulfated calcium and magnesium groundwater type hydrogeochimical facies. However, in Ain Naga location ~93% groundwater samples classified under chloride and sulfated calcium and magnesium groundwater type hydrogeochimical facies and rest classified under sodium and potassium chloride water type hydrogeochemical facies. The groundwater in Ziban region has salinity often unusable for irrigation. The plot of data on the US Salinity Laboratory diagram reveals that the better class of water quality in Ain Naga location is C3S1with only 14.28%. The rest is unusable for irrigation C4S1 (71.42%) and C4S2 (14.28%). All groundwater samples analyzed of El Outaya location are unsuitable for irrigation with C4S2 (28.57%), C4S3 (28.57%) and C5S3 (42.85%). According to the Wilcox irrigation water classification, 92.86% of the groundwater samples in El Outaya location fall in the category of unsuitable for irrigation and 7.14% samples fallen into doubtful range for irrigation purposes. However, in Ain Naga location the plot of analytical data on the Wilcox diagram indicates that 64.29% of groundwater samples range in the region of unsuitable for irrigation and remaining 35.71% are doubtful for irrigation. Statistical analysis denotes a positive correlation between some physicochemical parameters. The high correlations were noted between electrical conductivity and major ions [Cl^- (0.868), Na^+ (0.812)] and the median correlations with magnesium (0.550). Na^+ shows strong correlation with Cl^-(0.946) and average correlation with HCO_3^-(0.520). Ca^{2+} and Mg^{2+} show average correlation with SO_4^{2-} [(0.502),(0.566)]respectively. Chloride indicates average correlation with bicarbonate (0.525).
Based on this study results, it is recommended to monitor groundwater quality and soil salinity. Salinity management requires the leaching of excess salts from the root zone to decrease the salinity particularly if the applied water classified under a poor quality. Creating adequate soil drainage, selecting salt-tolerant crops, and using reverse osmosis to remove salts from the water are also recommended. All of these recommendations are intended to ensure sustainable agriculture in the study area.

Acknowledgements
The authors wish to thank the laboratory of Agricultural Sciences Department (University of Biskra, Algeria) for providing analytical laboratory to this study and Mr. CHIKHI Saad for helping during the collection of groundwater samples. The authors also wish to thank Dr. HIOUANI Fatima and Dr. GUIMEUR Kamel for their help in the preparation of this study.

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