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Assessment and Physicochemical Characterization of Groundwater Quality for Irrigation and Drinking Purposes in Bazer Sakhra (Eastern Area of Algeria)

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ABSTRACT

Twenty groundwater samples were collected and then examined for physical (pH, EC, TDS) and chemical (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3) parameters, followed by multivariate statistics to determine the current state of groundwater quality and to assess the suitability of these resources for drinking and irrigation purposes in the Baser Sakhra area localized in Eastern of Algeria. The analysis carried out showed that the cations trend in most of the groundwater samples is on the order of $Ca^{2+}>Na^+>Mg^{2+}>K^+$ and the anions trend is on the order of $HCO_3^- >SO_4^{2-}>Cl^-$. Stabler diagram demonstrated the predominance of Ca^{2+}- HCO_3^- hydro-chemical facies (80%). Moreover, the parameters, such as sodium adsorption ratio, percentage sodium, residual sodium carbonate, permeability index, Kelly's ratio, potential salinity, and magnesium hazard were evaluated for the suitability of groundwater for irrigation. The values obtained in this investigation concluded that most of the groundwater samples are suitable for irrigation. From the other approach, the Water Quality Index (WQI) for drinking was also used in the current study. WQI ranged from 72.46 to 506.426, indicating that 40% of the samples were suitable for drinking however, 60% of them belong to the poor to unsuitable category of drinking water in terms of physicochemical properties, according to the World Health Organization norms.

Keywords: groundwater, drinking water, irrigation water, water quality index, hydro-chemical facies.

INTRODUCTION

Groundwater is becoming highly crucial in the development and utilization of water resources (Subbarao and Reddi Bhaskara Reddy, 2018). It is the main source of domestic, agricultural and industrial water in the many regions (Bounab et al., 2017; Karmegam et al., 2010). The importance of water quality varies based on the amount of water available and the rate of dilution (Arthington et al., 2010). Groundwater accounts for 43% of the world's irrigation water and is better suited for the irrigation purposes than surface water (Kawo and Karuppannan, 2018). However, its use affects soil quality (Oga et al., 2015). In addition, it is clear that the quality of agricultural water has an impact on soil quality and thus on the harvests obtained (Asadi et al., 2020). To avoid the negative impacts on soil quality and plants, it is important to monitor the water quality for irrigation (Panpan et al., 2019). Various determining parameters such as sodium adsorption ratio, percentage sodium, residual sodium carbonate, permeability index, Kelly's ratio, potential salinity and magnesium hazard are used for monitoring and assessing the water quality throughout several countries around the world (Barick and Ratha, 2014; Bouderbala, 2015; Gad et al., 2020; Guettaf et al., 2017; Kshitindra et al., 2020; Nagaraju et al., 2014; N'diaye et al., 2010; Oulai et al., 2017; Panpan et al., 2019; Zaki et al., 2018). On the other hand, the water quality index (WQI) is widely regarded as a reliable method for determining the quality of groundwater for drinking (Masood et al., 2021). This method simplifies the interpretation of multiple parameters of water quality into simple terms (Sadat-Noori et al., 2014). Horton (1965) was the first scientist who introduced the Index WQI in the United States later by Brown (1970). Several researchers demonstrated the efficacy of WQI in assessing water quality for diverse regions around the world (Ewaid and Abed, 2017; Jhariya et al., 2017; Kumar et al., 2016; Leizou et al., 2017; Kawo & Karuppannan, 2018; Portia et al., 2020; Ramya Priya and Elango, 2018; Syeda Urooj et al., 2022; Tirkey et al., 2015). In this regard, the current research aimed at three objectives: (i) to determine the hydrochemical characteristics of groundwater, (ii) to use a variety of methods for the overall assessment and monitoring of groundwater quality for irrigation, and (iii) to assess the water quality for drinking by calculating WQI.

MATERIALS AND METHODS

Study area

The studied area is located in the Eastern of Algeria (Fig. 1). The climate of the study area is classified as semi-arid climate, with an annual precipitation ranging from 300 to 420 mm/year, and the average monthly temperature varies between -5 and 40°C. The studied area is located in the alluvial plain of the Mio-Plio-Quaternary consists of nearly flat land with local relief of 5 to 10 m, and the potential evapotranspiration rises to 889 mm (Bencer et al., 2016). These formations are generally found in the central part of the study area and consist of various rocks including sands, clays and gravels. The Villafrachian is composed of lacustrine limestone rocks and is situated in the Bazer Sakhra Lake. The Jurassic formation is constituted of carbonate and Karstic Limestone rocks these formations are situated in Braou and Tnoutit highland in the South of the study area (Fig. 2) (Khemmoudj et al., 2014).

The variability lithologic in the aquifer may have an impact on water composition because of its effect on rock/water interactions and directions of groundwater movement (Demdoum et al., 2015). Shallow groundwater in the study area is found between 5 and 80 meters below the surface. Vertical infiltration of meteoric water and rainwater from various reliefs is an essential factor for the recharge of the aquifer (Bencer et al., 2016). The principal drainage network is constituted by several ephemeral wadis (Djermane, Guitoune, Medjaz and Djehadi).

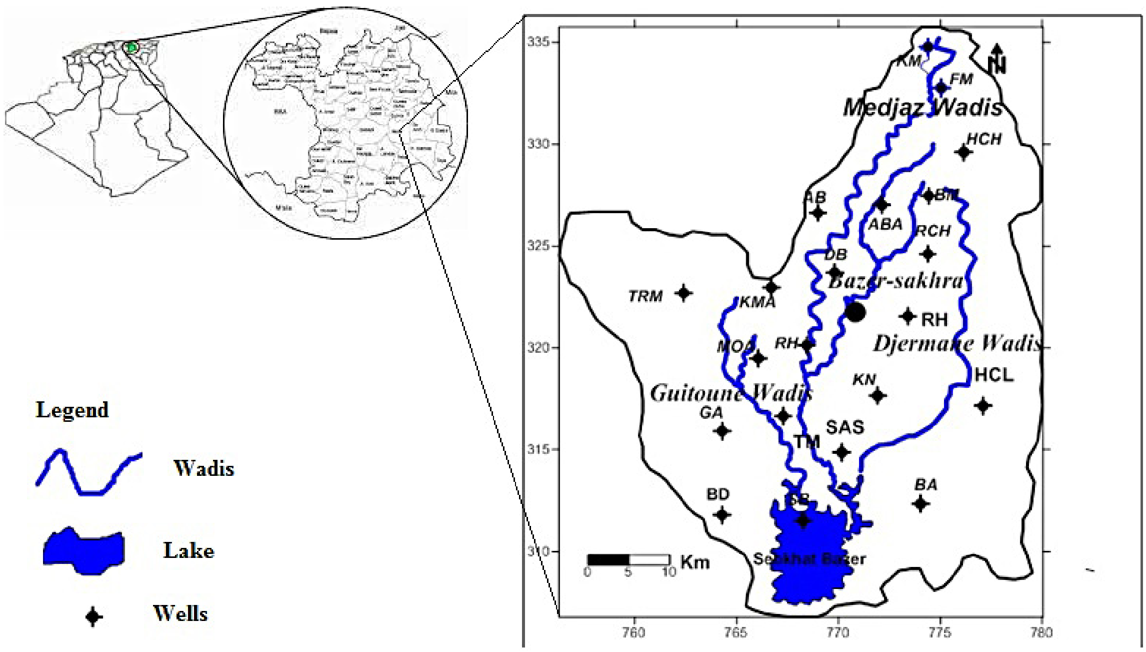

Figure 1. Location of the studied site and the groundwater sampling location

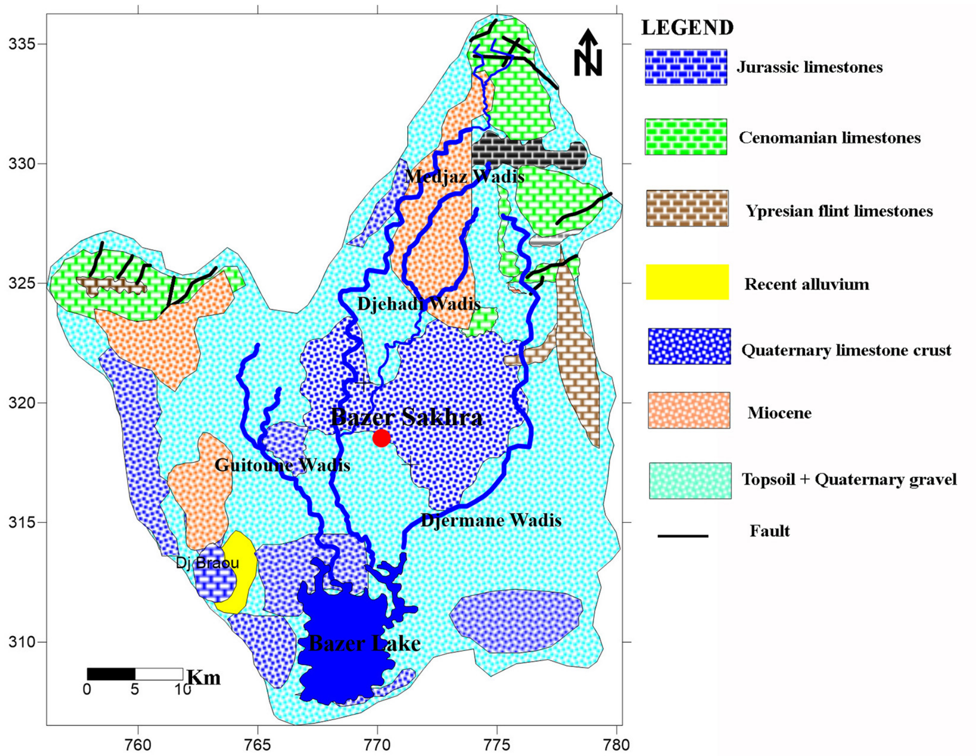

Figure 2. Geological map of the studied area (Khemmoudj et al., 2014)

Data and methods

The data in this study is based on the groundwater samples taken from private wells of the Bazer Sakhra area. A total of twenty samples (Fig. 1), were collected into new polyethylene bottles. All bottles were carefully labeled, numbered, and stored at a low temperature of 4°C. A multiparameter WTW.2000 was used in situ to measure electrical conductivity (EC), temperature (T), and pH parameters, The major ions (calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), and chloride (Cl^{-})) were analyzed in the laboratory. These parameters were determined using standard techniques recommended by Rodier (1996). Calculating ion-balance errors confirmed the precision of the chemical analysis, in which the errors were usually less than 10%. Table 1 shows the hydrochemical data and statistical summary of the water samples, which were compared to the water guideline values suggested by the World Health Organization (WHO 2011). The results of the physicochemical analyses were visualized by the use of statistical analysis (with Microsoft Excel Stats software). The approach used determines dominant anions and water type was established from Diagram's software 6.76 version and the illustration of index water quality (for irrigation and drinking) using surfer11 software via production of maps.

Irrigation groundwater quality

The quality groundwater for irrigation purposes was evaluated and discussed by determining several parameters, such as percentage sodium (%Na^{+}), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), permeability index (PI), Kelly's ratio (KR), potential salinity (PS) and magnesium hazard (MH) (Abdourazakou Maman and Arzu, 2022; Asadi et al., 2020; Kawo and Karuppannan, 2018; Panpan et al., 2019). These irrigation parameters were calculated as follows:

%Na^{+} was calculated using Eq. 1:

$$\%Na^{+} = (Na^{+} + K^{+}) \times \frac{100}{Ca^{2+} + Mg^{2+} + + Na^{+} + K^{+}} \quad (1)$$

Sodium adsorption ratio (SAR) – was calculated using the Eq. 2:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad (2)$$

RSC was computed using Eq. 3:

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

MH was calculated using Eq. 4:

$$MH = \frac{Mg^{2+}}{(Ca^{2+} + Mg^{2+})} \times 100 \quad (4)$$

KR was computed using Eq. 5:

$$KR = \frac{Na^+}{(Ca^{2+} + Mg^{2+})} \quad (5)$$

PI was computed using Eq. 6:

$$PI = Na^+ + \frac{\sqrt{HCO_3^-}}{(Ca^{2+} + Mg^{2+} + Na^+)} \times 100 \quad (6)$$

PS was calculated using Eq. 7:

$$PS = Cl^- + \sqrt{SO_4^{2-}} \quad (7)$$

In these equations, all ionic concentrations were represented in mill equivalents per liter.

Drinking water quality

The Water Quality Index was used to evaluate the quality of the water for human consumption based on the pH, EC, TDS parameters and major ions (Ewaid and Abed, 2017; Guettaf et al., 2017). WQI summarizes large amounts of water quality data in simple terms (e.g. excellent, good, poor, etc.) and generates a score that describes the suitability of water for drinking purpose (Ewaid and Abed, 2017; Sahu and Sikdar, 2008; Syeda Urooj et al., 2022). According to Sahu and Sikdar (2008), WQI was calculated as follows:

1. Allocation of weight (w_i) to each parameter based to their impact and importance with WHO (2011) global drinking water quality. The parameters were weighted based on their importance in determining the water quality. The minimum weight 2 is assigned to the parameters classified as non-dangerous: Ca^{2+}, Mg^{2+}, Na^+, and K^+. The highest weight of 5 was assigned to the parameters that have the main effect on quality water (total dissolved solids and NO_3^-). Other parameters such as pH, EC, HCO_3^-, SO_4^{2-} were assigned weights between 3 and 4 based on their importance in determining the water quality (Table 2) (Guettaf et al., 2017; Sahu and Sikdar, 2008).
2. Calculation of relative weight (W_i) using Eq. 8.

$$Wi = \frac{Wi}{\sum_{i=1}^{n} Wi} \quad (8)$$

where: W_i – relative weight,
w_i – weight of each parameter,
n – number of parameters.

3. Allocation of quality rating scale (qi) for each parameter based Eq. 9.

$$qi = \left(\frac{Ci}{Si}\right) \times 100 \quad (9)$$

where: q_i – quality rating,
C_i – concentration of each chemical parameter,
S_i – WHO (2011) drinking water standard for each parameter.

4. Finally, WQI was computed using Eqs.10 and 11.

$$SIi = Wi\, qi \quad (10)$$

$$WQI = \sum_{i=1}^{n} SIi \quad (11)$$

where: SI_i – sub-index of i^{th} parameter,
q_i – rating based to the concentration of i^{th} parameter,
n – number of parameters.

According to Sahu and Sikdar (2008), the WQI values are classified into five groups (Table 3).

RESULTS AND DISCUSSION

Hydrochemistry of the groundwater samples

The mean, standard deviation (SD), minimum (Min) and maximum (Max) values of the 11 physicochemical parameters of 20 groundwater samples were measured and presented in Table 1.

These results indicate that the tendency of cations in the most of groundwater samples in the study area is in the order of $Ca^{2+}>Na^+>Mg^{2+}>K^+$, which represent 70% with calcium as a dominant cations, whereas the order of the cations is $Na^+>Ca^{2+}>Mg^{2+}$ in the SB, TM, RM, GA, BD samples represents 25% with sodium as the dominant cation. The order of the cations in the sample SAS is $Ca^{2+}>Mg^{2+}>Na^+$ with calcium as the dominant cation.

The tendency of anions is in the order of $HCO_3^- >SO_4^{2-}>Cl^-$ represent 50% followed by $HCO_3^- >Cl^-> SO_4^{2--}$, the bicarbonate is the dominant

Table 1. Statistics of the various physicochemical parameters

Parameter	Symbol	Min	Max	Mean	WHO (2011)
pH	pH	6.70	9.30	7.77	6.5–8.5
Electrical conductivity	EC	463.00	6844.00	1353.80	1000
Total dissolved solids	TDS	324.00	478.00	939.65	500
Bicarbonate	HCO_3^-	127.00	657.60	328.95	120
Chloride	Cl^-	22.86	2750.40	236.82	250
Sulphate	SO_4^{2-}	40.72	292.01	92.27	250
Calcium	Ca^{2+}	56.40	785.50	138.91	75
Magnesium	Mg^{2+}	15.00	64.00	29.75	50
Sodium	Na^+	12.00	1300.00	142.30	200
Potassium	K^+	7.00	135.00	23.95	12
Nitrate	NO_3^-	5.40	109.20	35.04	50

Min: minimum; Max maximum; WHO: World Health Organization

Table 2. The allotted *wi* and *Wi* values for each parameter

Parameters	WHO 2011	Weight (w_i)	Relative weight (W_i)
pH	6.5–8.5	4	0.111
EC	1000	4	0.111
TDS	500	5	0.139
HCO_3^-	120	3	0.083
Cl^-	250	3	0.083
NO_3^-	50	5	0.139
SO_4^{2-}	250	4	0.111
Ca^{++}	75	2	0.055
Mg^{++}	50	2	0.055
Na^+	200	2	0.055
K^+	12	2	0.055
n =11		Ʃ = 36	Ʃ = 0.997

Table 3. Scores of *WQI* index (Sahu and Sikdar, 2008)

Range of WQI	Water quality
< 50	Excellent
50–100	Good
100–200	Poor
200– 300	Very poor
> 300	Unsuitable

anion in 80% of the groundwater samples, whereas the order of anions is $Cl^- > HCO_3^- > SO_4^{2--}$ in the GA, RM, SB samples and in TM sample the order of anions is $Cl^- > SO_4^{2-} > HCO_3^-$ with chloride as the dominant anion (Fig. 3) and (Table 4). Stabler (1944) diagram (Fig. 3) and (Table 4) show that HCO_3–Ca^2 type of water was predominant in the majority of samples (80%). Nearby of the study area, evaluation of groundwater quality in the El Eulma area also revealed the dominance of HCO_3^-–Ca^{2+} water type (Belkhiri and Mouni, 2012). The main ion series of the major elements in the collected groundwater samples reaches the following orders:

$HCO_3^- > SO_4^{2-} > Cl^-$ / $Ca^{2+} > Na^+ > Mg^{2+}$
(approximately 45% of the analyzed water samples);

$HCO_3^- > Cl^- > SO_4^{2--}$/ $Ca^{2+} > Na^+ > Mg^{2+}$
(approximately 25% of the analyzed water samples);

$HCO_3^- > Cl^- > SO_4^{2-}$/ $Na^+ > Ca^{2+} > Mg^{2+}$
(approximately 5% of the analyzed water samples);

$HCO_3^- > SO_4^{2-} > Cl^-$/ $Ca^{2+} > Mg^{2+} > Na^+$
(approximately 5% of the analyzed water samples);

$Cl^- > HCO_3^- > SO_4^{2-}$/ $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$
(approximately 15% of the analyzed water samples);

$Cl^- > SO_4^{2-} > HCO_3^-$/$Na^+ > Ca^{2+} > Mg^{2+}$
(approximately 5% of the analyzed water samples).

Table 1 presents the descriptive statistics of the physicochemical characteristics of the groundwater in the current study. The results thus obtained were compared with the standard guideline values, as recommended by the WHO (2011) for drinking water. The pH value ranges between 6.7 and 9.3, these results show that the most groundwater samples are of alkaline nature, around 90% of water samples were found to be under the WHO (2011) permissible standard. The EC values of groundwater samples vary from 463 to 6844 µS/cm 55% of water samples were found within the acceptable limit (1000 µS/cm) prescribed by WHO (2011), indicating a significant variation in the mineralization. The TDS values ranged from 324 to 47811 mg/l, with a mean value of 939 mg/l. 80% of the water samples were found to exceed the desirable limit (500 mg/l) according to the WHO

Figure 3. Stabler diagram illustrating major ionic dominance in the samples

Table 4. Hydrochemical parameters and water types in the studied area

Well N°	Well name	Ion sequence	Water type
1	BD	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
2	FM	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
3	HCH	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
4	BM	$HCO_3^- > SO_4^{--} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
5	KM	$HCO_3^- > Cl^- > SO_4^{2-} / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
6	SB	$Cl^- > HCO_3^- > SO_4^{2-} / Na^+ > Ca^{2+} > K^+ > Mg^{2+}$	Cl^- Na^+
7	RH	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
8	BA	$HCO_3^- > Cl^- > SO_4^{2-} / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
9	KMA	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
10	MOA	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
11	TM	$Cl^- > SO_4^{2-} > HCO_3^- / Na^+ > Ca^{2+} > Mg^{2+}$	Cl^- Na^+
12	MN	$HCO_3^- > Cl^- > SO_4^{2-} / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
13	RCH	$HCO_3^- > Cl^- > SO_4^{2-} / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
14	RM	$Cl^- > HCO_3^- > SO_4^{2-}$–/ $Na^+ > Ca^{2+} > Mg^{2+}$	Cl^- Na^+
15	CHL	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
16	TRM	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}
17	SAS	$HCO_3^- > SO_4^{2-} > Cl^- / Ca^{2+} > Mg^{2+} > Na^+$	HCO_3^- Ca^{2+}
18	GA	$Cl^- > HCO_3^- > SO_4^{2-} / Na^+ > Ca^{2+} > Mg^{2+}$	Cl^- Na^+
19	BD	$HCO_3^- > Cl^- > SO_4^{2-}$–/$Na^+ > Ca^{2+} > Mg^{2+}$	HCO_3^- Ca^{2+}
20	ABA	$HCO_3^- > Cl^- > SO_4^{2-}$ $Ca^{2+} > Na^+ > Mg^{2+}$	HCO_3^- Ca^{2+}

(2011). The maximum concentration of Ca^{2+} and Mg^{2+} are 785.5 and 64 mg/l, respectively. The current values of Ca^{2+} and Mg^{2+} are greater than 288.6 and lower than 74.13 mg/l, respectively, according to a research published in the El Eulma city to assess the groundwater quality (Belkhiri and Mouni, 2012). According to WHO (2011), only one sample (SB) is higher than the acceptable limit for the Mg parameter (50 mg/l) however, 80% of groundwater samples are higher than the permitted limit for the Ca parameter (75 mg/l). The concentration of Ca^{2+} and Mg^{2+} in the groundwater can be due to the presence of dolomite and limestone in the sedimentary rocks (Bencer et al., 2016). Na^{+} varied from 12 mg/l to 1300 mg/l with the mean value of 142.3 mg/l; the highest concentration is observed in the SB sample. Except for two groundwater samples (SB and GA), all samples fall within the WHO guidelines (200 mg/l). In El Eulma city, the researchers have reported a mean value of 379 mg/l (Belkhiri and Mouni, 2012). Other results (137–638 mg/l) were found in the Ain Djacer area (Bencer et al., 2016). The potassium concentration is between 7 and 135 mg/l, only 50% of samples fall within the WHO guidelines (12 mg/l). However, lower values 4.54 mg/l, 2 to 13 mg/l, and 2.2 to 19.8 mg/l were found in El Eulma city (Belkhiri and Mouni, 2012), Ain Djacer area (Bencer et al., 2016), and El Eulma Basin (Demdoum et al., 2015), respectively. The concentration of bicarbonate (HCO_3^-) varied from 127 to 657.60 mg/l; all the samples values exceeded the acceptable limit of HCO_3^- for water drinking (120 mg/l) according to the WHO (2011). Similar results: 164.7 to 387.9 mg/l, 238 to 342 mg/l, and 108 to 418 mg/l were obtained in Ain Azel plain (Belkhiri & Narany, 2015), Ain Djacer area (Bencer et al., 2016), and El Eulma Basin (Demdoum et al., 2015), respectively. Belkhiri and Mouni, (2012), Bencer et al. (2016), Demdoum et al. (2015) have all shown that the high concentrations of HCO_3^- in water can be due to the dissolution of carbonate minerals and to the diffusion of carbon dioxide in the atmosphere. The chloride concentration varied from 22.86 to 2750.4 mg/l, with a mean value of 236. 82 mg/l. The higher Cl^- contents are noticed in the SB and GA groundwater samples with a concentration of 2750.4 and 580 mg/l respectively. Almost 42% of the samples exceeded the recommended limit of Cl^- for potable water (250 mg/l) (WHO, 2011). Another study on multi-tracer investigation of groundwater in the El Eulma basin shows that the concentration of chloride ranged from 160 to 891mg/l (Demdoum et al., 2015). The source of Cl in groundwater is probably caused by the dissolution of evaporate rocks, halite, and old saltwater infiltrated in sediment (Bencer et al., 2016; Demdoum et al., 2015). The SO_4^{2-} concentration ranged from 40.72 to 292.01 mg/l, with the mean value of 92.273 mg/l only 10% of the samples exceeded the desirable limit of SO_4^{2-} for drinking water (250 mg/l) (WHO, 2011). However, higher values (345 to 660 mg/l) were found in Ain Azel plain (Belkhiri and Narany, 2015). The presence of sulfate ions in the groundwater probably could be attributed to sedimentary rocks like $CaSO_4$ and $CaSO_4$, $2H_2O$. Moreover, sulfate addition to groundwater may have resulted from the degradation of organic matter in the soil, as well as the addition of soluble sulfates in fertilizers used in heavily cultivated lands (Belkhiri and Mouni, 2012). The current study shows that an average concentration of 35.041 mg/l of NO_3^- is present in the groundwater samples and ranged from 5.4 to 109.2 mg/l; almost 25% of the samples exceeded the desirable limit of NO_3^- for drinking water (50 mg/l) (WHO, 2011). The high NO_3^- concentration is attributed to the intensive agriculture, industrial activities, and urban development (Bounab et al., 2017).

Water quality characteristics for irrigation purposes

The major ion chemistry of groundwater was analyzed and 7 parameters are widely used for evaluating the suitability of water for irrigation purposes. The results (minimum, maximum, and mean) for every parameter are listed in Table 5.

Table 5. Statistics of the several groundwater parameters for irrigation

Variable	Min	Max	Mean
$\%Na^+$	8.640	63.020	33.970
KR	0.050	1.655	0.539
SAR	0.240	11.980	2.372
MH	11.847	48.342	31.199
PI	26.946	75.387	52.314
PS	1.260	80.625	7.640
RSC	-44.300	-5.011	-9.200

Percentage sodium

The percentage of sodium is a key parameter for determining the suitability of water for irrigation. Guettaf et al. (2017). Subbarao and Reddi Bhaskara (2018) have noticed that the process of Na in water exchanged for Ca and Mg in soil reduces permeability and eventually results in soil with poor internal drainage. In this study, the $\%Na^+$ values of samples ranged from 8.64 to 63.02 with mean of 33.97 (Table 5). According to the $\%Na^+$, Wilcox (1955) classified the irrigation water into 5 classes (Table 6). According to this categorization, 95% of samples fall into the "excellent" and "permissible" categories (Table 6). Wilcox diagram (Wilcox, 1955), relating between sodium percentage and electrical conductivity values reveals that all groundwater samples fall into the "excellent" to "permissible" categories except one

Table 6. Classification of groundwater quality for irrigation suitability

Parameter	Range	Water Quality	Number of samples	% of samples
$\%Na^+$ (Wilcox, 1955)	< 20 20-40 40-60 60-80 >80	Excellent Good Permissible Doubtful Unsuitable	6 8 5 1 0	30 40 25 5 0
RSC (Ragunath, 1987)	< 1.25 1.25-2.5 >2.5	Good Doubtful Unsuitable	20 nil nil	100% 0 0
KR (Kelly, 1940, 1963)	< 1 > 1	Suitable Unsuitable	17 3	85 15
PI (Doneen, 1964)	> 75 75 < PI < 25 < 25	Excellent Good Injurious	1 19 nil	5 95 0
PS (Doneen, 1964)	< 3.0 3.0–5.0 > 5.0	Excellent to good Good to Injurious Injurious to Unsatisfactor	13 03 4	65 15 20
SAR (meq/l) (Richards, 1954)	< 10 10–18 18–26 > 26	Excellent (Low sodium water S1) Good (Medium sodium water S2) Doubtful (High sodium water S3) Unsuitable (Very high sodium S4)	19 1 nil nil	95 5 0 0
MH (Szaboles, & Darab, 1964)	< 50 > 50	Suitable Unsuitable	20 nil	100 0

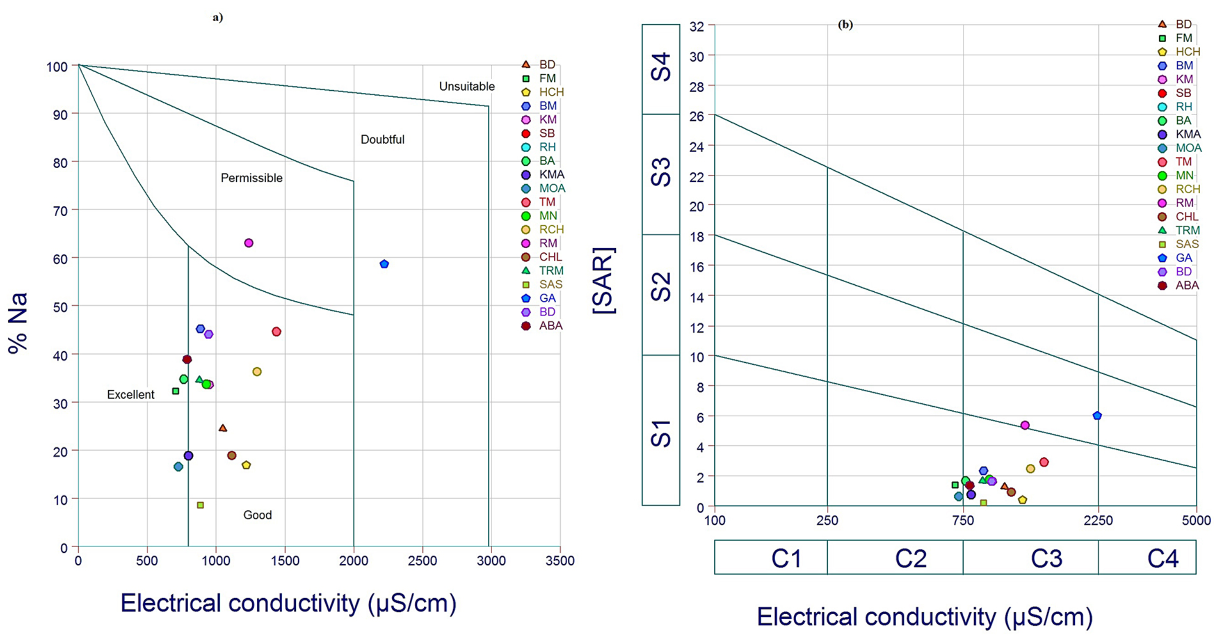

Figure 4. Wilcox diagram (a) and Richards's diagram (b) of groundwater samples

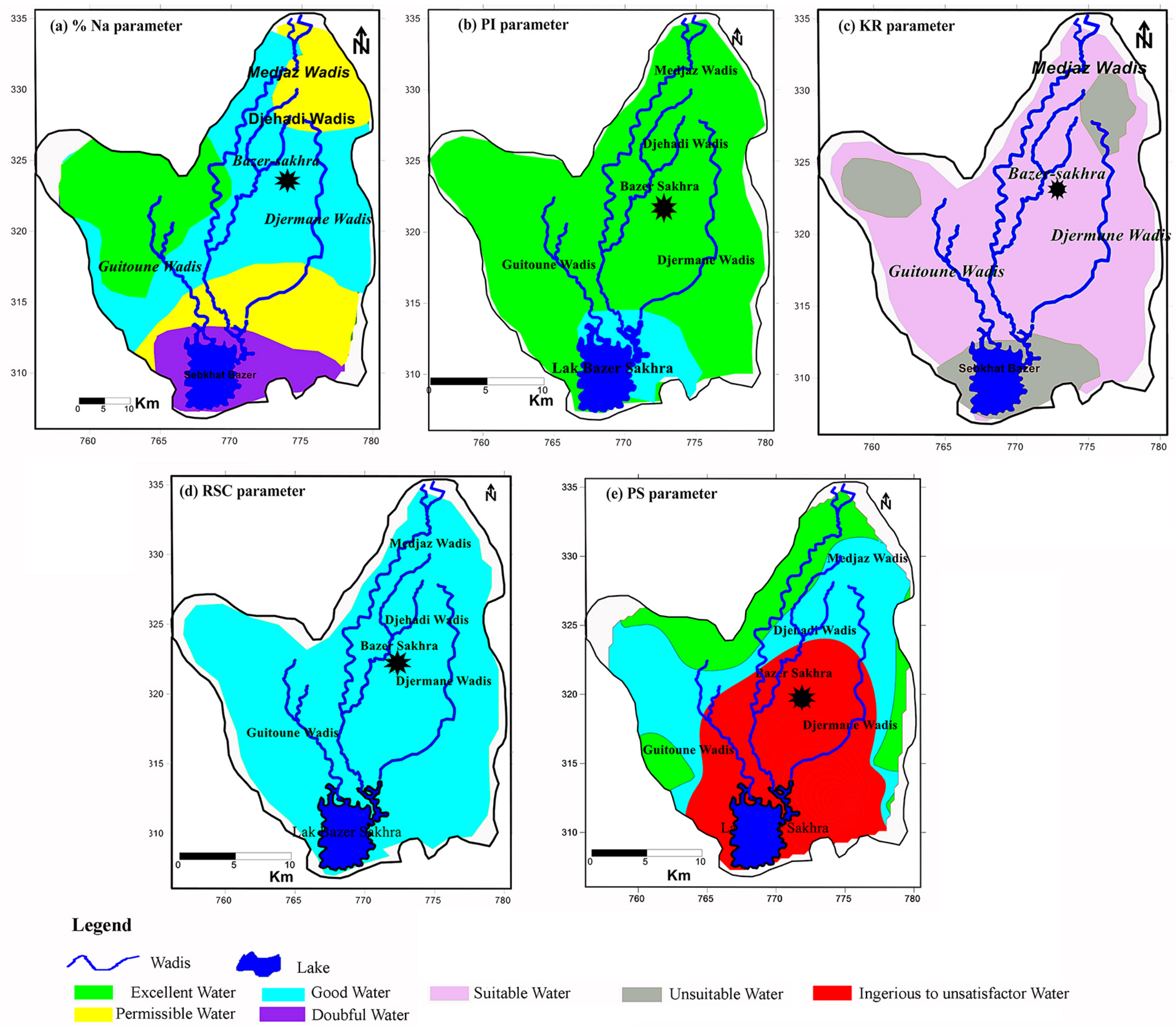

Figure 5. Spatial distribution of parameters a) $\%Na^{+}$, b) PI, c) KR, d) RSC, e) PS

water sample (GA) falling into the "doubtful" category for irrigation and therefore is unsuitable for irrigation use (Fig 4a).The spatial variation of $\%Na^{+}$ (Fig 5a) shows that the doubtful water type is observed near the lake.

Sodium adsorption ratio

SAR indicates the degree about which irrigation water tends to participate into cations-exchange reaction in soil (Bouderbala, 2015). The SAR values are crucial in irrigation water because of the concentration of sodium content in the soil after absorption (Kebili et al., 2021). Saleh et al. (1999) have shown that if the SAR value is around 6 to 9, the irrigation water can cause permeability issues when clayey soils shrink and swell. In this study, the values of the SAR in groundwater samples vary from 0.24 to 11.98 mg/l with a mean of 2.37 mg/l (Table 5). Richards (1954) categorized irrigation water according to the SAR into 4 classes (Table 6). According to this classification, the majority of samples fall into the excellent (95%) to good (5%) classes (Table 6) similar to the $\%Na^{+}$ classification. This implies that no danger of alkali hazard is intended for crops, according to Richards (1954). The electrical conductivity and SRA values plotted on the US salinity diagram Richards (1954) show that the most of the water samples belong into the C2S1 class (medium salinity low sodium) and C3S1 (high salinity low sodium), except two samples (GA and RM) which are in the field of C3S2 (high salinity medium sodium) (Fig. 4b). According to this figure (Fig. 4b), all of the groundwater samples could be utilized for irrigation on practically every soil. However, an expectable danger for exchangeable sodium was noticed (Table 6) (Richards, 1954).

Residual sodium carbonate

RSC is a concept used to classify the water quality for irrigation. Kshitindra et al. (2020) have shown that the high concentration of carbonate and bicarbonate ions in water relates to the alkaline earth metal ions (Ca^{2+} and Mg^{2+}), which have an effect on the use of water for irrigation. The RSC values greater than 5 in irrigation water have been considered harmful to the growth of plants (Guettaf et al., 2017). The computed RSC values are classified into three categories according to Eaton (1950) as follows:

- < 1.25 meq/l Suitable water,
- 1.25—2.50 meq/l marginally suitable water,
- >2.50 meq/l Unsuitable water.

In this study, the values of RSC of groundwater samples range from (-44.30 to -5.01), these values are less than 1.25 meq/l (Table 5). According to Eaton (1950) classification, all water samples fall in good water category, not hazard, so they are suitable for irrigation use (Table 6). Figure 5d shows that the whole studied area has good water quality for irrigation. In another area of El Eulma, the researchers have also reported similar results, with the RSC values range from -12.46 to -1.58 with a mean of -4.14 ± 2.58 indicating all samples have good water for irrigation (Belkhiri and Mouni, 2012).

Magnesium hazard

Szaboles and Darab (1964) have proposed a MH index for assessing the suitability of water quality for irrigation. High level of this is due to the exchangeable Na^{+} in irrigated soils. This can damage the soil structure and affect crop yields (Szaboles and Darab, 1964). More Mg^{2+} can affect the soil quality by rendering it alkaline and affects crop yields (Zaki et al., 2018). In general, Ca^{2+} and Mg^{2+} retain a state of equilibrium in most waters. Excess Mg^{2+} in waters unfavorably affects the crop yield (Subbarao and Reddi Bhaskara Reddy, 2018). According to magnesium ratio, water can be classified as "suitable" for irrigation purpose, if the MH ratio is greater than 50% (Palliwal,1972). In this study, the MH values range from 11.85 and 48.34 with a mean of 31.19 (Table 3). These values obtained are less than 50 and show that all groundwater samples are good and suitable for irrigation according to Szaboles and Darab (1964) classification.

Kelly's ratio

Kelly (1940; 1963) has introduced an important parameter ration to evaluate the quality of irrigation water in terms of the Na^{+} concentration relative to Ca^{2+} and Mg^{2}. The water with KR < 1 is suitable for irrigation, while the water with KR >1 is unsuitable for irrigation (Kelly 1940; 1963). In the present study, the KR values are more than 1 in 85% of the groundwater samples (Table 6). According to these results, the vast majority of samples from the studied area are suitable for irrigation use. Figure 5c, shows that the unsuitable water quality for irrigation is located near the lake and in the North and North - Western parts of the studied area.

Permeability index

Doneen (1964) has proposed the PI to determining the soil permeability for assessing the suitability of water for irrigation purposes. Long-term irrigation water use has an impact on the soil permeability. It is influenced by sodium, calcium, magnesium, and bicarbonate contents of soil (Bouderbala, 2015). According to Doneen (1964) the PI values are classified into three categories as follows:

- > 75 Excellent water,
- 25–75 Good water,
- < 25 Unsuitable water.

As shown in Table 5, the PI values of the samples range from 26.94 to 75.4 with a mean of 52.31. It revealed that 100% of water samples fall into good water category, which indicates that the water is suitable for irrigation purposes (Table 6) and (Fig. 5b).

Potential salinity

The concentration of highly soluble salts increases the soil salinity because the low solubility salts precipitate in the soil and accumulate with each successive irrigation (Gad et al., 2020; Nagaraju et al., 2014; Panpan et al., 2019). In this study, the PS values of groundwater samples range from 1.26 to 80.6 with a mean of 7.64 (Table 5). According to the PS classification, 65% and 15% of the samples were classified as excellent to good, and were good to harmful category of water quality, respectively. These water types are located in the north, north-eastern and north western parts of the studied area (Fig. 5e). Thus, this

Table 7. WQI and water quality for drinking purpose

Sample N°	Location name	WQI	Water quality	Sample N°	Location name	WQI	Water quality
01	BD	104.494	Poor	11	TM	121.278	Poor
02	FM	80.864	Good	12	MN	102.628	Poor
03	HCH	108.248	Poor	13	RCH	122.211	Poor
04	BM	91.916	Good	14	RM	130.203	Poor
05	KM	96.409	Good	15	CHL	128.190	Poor
06	SB	506.430	Unsuitable	16	TRM	86.294	Good
07	RH	113.527	Poor	17	SAS	81.360	Good
08	BA	87.341	Good	18	GA	127.543	Poor
09	KMA	74.591	Good	19	BD	128.389	Poor
10	MOA	72.460	Good	20	ABA	117.589	Poor

Table 8. Scores of WQI index and water types

Range of WQI	Water quality	Number of samples	% of samples
< 50	Excellent	0	0
50–100	Good	8	40
100–200	Poor	11	55
200–300	Very poor	0	0
> 300	Unsuitable	1	5

makes the water suitable for irrigation usage. In turn, 20% of samples were classified as injurious to unsatisfactory class (Table 6), this water type is situated in the central zone of the studied area. According to the classification of PS parameter (Table 6), high value of potential salinity in the area (80.6 mg /l) were noticed, it can be ascribed to high Cl^- concentration (2750.4 mg/l).

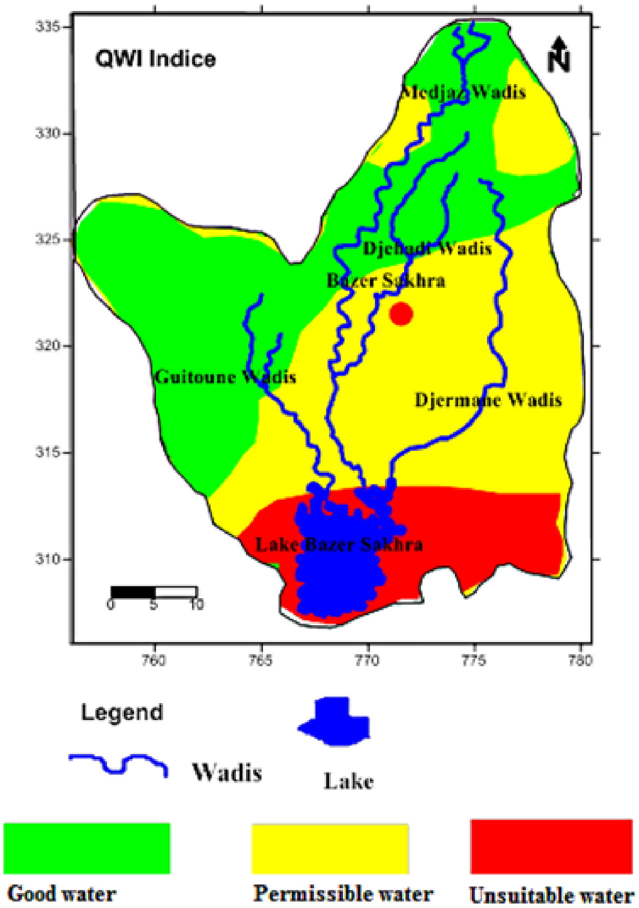

Figure 6. Spatial variation of WQI Index of the samples

Suitability for drinking purposes

The WQI was calculated using 11 physico-chemical parameters (n=11) (Table 1). According to the results shown in Table 7, the WQI values ranged from 72.46 to 506.426. The results obtaining are compared with the WQI scores illustrated in Table 3. On the basis of this categorization of WQI (Sahu & Sikdar, 2008), it has been found that 40% of the samples belonged to the "good" water class, while the remaining water samples belonged to the unsuitable and poor water categories with percentages of 5 and 55, respectively (Table 8). It was found that the highest values of WQI (indicating very poor waters) were found to be closely associated to high values of dissolved solids (Azlaoui et al., 2021). The WQI spatial variation map (Fig. 6) shows that the southern part of the studied area is characterized by unsuitable water quality with a QWI value of 506.43 (Table 7).

This quality of water is observed in the BS sample, which may be due to the highest concentration of Cl^- and Na^+ at 2750.4 and 1300 mg/l, respectively. Larger parts of the central and south-western zones of the studied area have poor water quality, with the WQI values ranging from 102.62 to 130.20 mg/l this type of water is found in 11 samples according to the Table 7. In turn, the north-eastern zone had good water quality for drinking purposes with the WQI values less than 100, belonging to the samples (FM, BM, KM, BA, KMA, MOA, TRM, and SAS), (Table 7).

CONCLUSIONS

This work concerned characterizing and monitoring quality of groundwater for different use. To achieve this aim, twenty groundwater samples and eleven parameters (pH, EC, TDS, Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-) were included to assess the suitability of the water for irrigation and drinking purposes. The physico-chemical analyses showed that the groundwater is alkaline and the order of abundance of the major ions is as follows: Ca^{2+}>Na^+>Mg^{2+}>K^+ and HCO_3^- >SO_4^{--}>Cl^-. Stabler diagram showed that 45% of the samples were of the HCO_3^->SO_4^{--}>Cl^- / Ca^{2+}>Na^+>Mg^{2+} water type. Therefore, the dominance of HCO_3^- Ca^{2+} water types was determined (80%). This study used indicators to assess the suitability of groundwater for irrigation purposes, the results calculated from chemical data illustrated that the entire reservoir is suitable for irrigation. It was found that 95% of the samples had excellent to permissible water quality based on %Na^+ classification. Thus, the RSC values revealed that all groundwater samples had good water quality do not pose a hazard and are suitable for irrigation purposes. The values of MH are below 50 into all groundwater samples, which indicate good and suitable water quality for irrigation. According to the potential salinity and Kelly's ratio classification, 80% to 85% of the groundwater samples represented suitable water for irrigation purposes respectively. In addition, all the samples show suitable water for irrigation purposes based on the PI classification. According to the SAR classification, 95% of the groundwater samples belonging to the suitable water for all types of plants and all types of soils category. On the other hand, this research attempted to assess the potability of groundwater using the WQI index. The results showed that 40% of the groundwater samples have suitable water quality for drinking, while the remaining water samples exhibited between poor to unsuitable water quality for drinking purposes class with a percentage of 55 and 5, respectively.

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