Geochemical Study of Chemical Pollution and Quality of Groundwater of the Terminal Complex, in Ouargla, South-East of Algeria

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Abstract

Human health can be negatively impacted by low-quality or contaminated drinking water. Investigating groundwater quality and appropriateness for irrigation and drinking uses is therefore crucial. This study uses the entropy theory and geochemical characteristics to describe the groundwater quality in Algeria's Ouargla area. From the study region, a total of 28 samples have been gathered. The results show that the study area is characterized as being within an arid region where rainfall was lower; hence, the evaporation process becomes dominant in controlling the groundwater chemistry. and 75.72% of groundwater samples are active in ion exchange processes, with 14.28% having negative values, indicating reverse ion exchange of Na+ and K+ ions. The entropy-weighted water quality index (EWQI) calculation for groundwater samples revealed a range of water quality, from medium to extremely severe. Of the groundwater samples obtained, 46.7% were identified as medium, 40% as poor, and 13.3% as extremely poor. Based on Sodium hazard (SAR) 3.57% 46.42%, 17.85% and 35.71% of the samples were found to be in the Excellent, Good, Poor, Unsuitable respectively and according to Kelly's ratio (KR) 96.43% of the samples were found in suitable category. Permeability Index (PI) indicates that 92.86% of the groundwater samples were found suitable and 7.14% unsuitable category for irrigation purpose.

Keywords: Hydrochemistry; Groundwater quality; Entropy water quality index; Irrigation indices.

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1. Introduction

An important factor in the management of human activity is groundwater, especially in arid areas with limited surface water resources. North-West Sahara Aquifer System (NWSAS) groundwater, one of the world's largest groundwater basins, is the primary source of water supply, particularly in Algerian Sahara. (Altchenko & Villholth, 2013; Mazzoni & Zaccagni, 2019; Sekkoum *et al.*, 2012). Algeria's arid regions' groundwater supplies have been running low recently. (Ahmed, 2020; Benfetta & Ouadja, 2020; Khezzani & Bouchemal, 2018; Milewski *et al.*, 2020). However, an extensive contamination has posed more threats to the groundwater quality rather than the depletion of groundwater, with increasing economic development, growing human activities and expended agricultural areas, a number of problems have arisen and are becoming serious on human health, such as groundwater scarcity and contamination (Abdelkader *et al.*, 2012; Boufekane & Saighi, 2019; Zereg *et al.*, 2018). Understanding the state of groundwater quality for both consumption and irrigation is important for wise decisions on drinking water quality protection and management. Moreover, water resources assessments and sustainability considerations are important as well, since the water quality affects human health and economic development.

Since agriculture is one of the main economic pursuits for most people, contaminants from this industry appear to pose a major threat to the management of groundwater supplies. However, the use of groundwater in irrigation is on the rise, often leading to inappropriate use of groundwater (Foster *et al.*, 2018). Poor irrigation water quality has negative effects on crop productivity, crop product quality, and public health of consumers and farmers who come in direct contact with the irrigation water. The impact of water quality is measured by following the effect of the irrigation water on soil characteristics and crops (Asadi *et al.*, 2020; Houatmia *et al.*, 2016; Li *et al.*, 2018). Therefore, monitoring water quality is important to improve environmental conditions and human health.

To use a practical and efficient approach to provide dependable results for assessing the quality of drinking water is important and facilitating wise decision-making. In recent years, many approaches have been developed, and good results have been considered in groundwater quality assessment . Pei-Yue *et al.* (Pei-Yue *et al.*, 2011) proposed a novel approach for qualitative groundwater quality assessment known as Set Pair Analysis (SPA). Each index was delegated a weight dependent upon information entropy. Tian & Wu (Tian & Wu, 2019) evaluated the state of the groundwater with improved SPA weighting game theory. The results indicated that groundwater samples of Huanhe are suitable for drinking. Adimalla & Taloor (Adimalla & Taloor, 2020) conducted Geographic Information System (GIS) and groundwater quality index (GWQI) methods for the evaluation of groundwater quality in the Telangana State region of South India. Gao *et al.* (Gao *et al.*, 2020) assessed groundwater suitability for drinking purposes using the IWQI Integrated Weight Water Quality Index. Subba Rao and colaborators (Subba Rao *et al.* 2020) evaluated groundwater quality parameters in Wanaparthy, District of Telangana, India, by Ionic Spatial Distribution (ISD) and entropy water quality index EWQI. The result has indicated that some regions are inappropriate for drinking purposes. Wu and al (Wu *et al.,* 2017) assessed water quality of Shahu Lake of northwest China for drinking and irrigation using the Entropy Weighted method. The Entropy weighted method is an effective tools to assess the quality of groundwater. (Amiri *et al.*, 2014; Islam *et al.*, 2017; Jianhua *et al.*, 2011; Peiyue *et al.*, 2010; Ukah *et al.*, 2020).

Ouargla Districts is located in the south-eastern part of Algeria, which groundwater is very important for urban and rural water supply, ecological environment, and tourism. Therefore, the aims of the present study are (i) classification of the study area into the types of groundwater quality on the criteria of the EWQI for drinking purposes and (ii) assessing groundwater quality for irrigation by using various indicators of water quality. However, this study may be helpful in local groundwater management and may also be potentially relevant for the protection and governance of groundwater in many other areas of the world facing similar situations.

2. Material and methods Sample

2.1 Study area

The Ouargla region is situated in the south-east of Algeria and is one of the main oases in the Sahara Desert of Algeria (Figure 1). The study zone is between 31°90' to 32°17' N and 5°16' to 5°48' E, with a mean elevation of 134m. The overall population of the study area in 2010 is estimated 633,967 in 21 cities. The temperatures vary greatly daily (day and night) and annually (summer and winter). The average temperatures are 9.7 °C in January and 50 °C in July (*ANDI*, 2013).

Groundwater can be found from the most important aquifers in Algeria, the Northwest Sahara Aquifer System (NWSAS). Supports many socio-economic developments (agriculture, tourism, industry). The NWSAS has a surface area of about 1,279,963 square kilometers, covering Algeria (69 per cent), Tunisia (8 per cent) and Libya (23 per cent), with two main aquifer systems: the Continental Intercalaire (CI) overlaid by the Complex Terminal (CT) . (IGRAC; UNESCO-IHP, 2021; Maliva & Missimer, 2012; Nijsten *et al*., 2018; Sokono et al., 2008). The "Complex terminal (CT)" aquifer which circulates at a depth of 35 m to 200 m in Mio-Pliocene sands, Eocene deposits and carbonates of the upper Cretaceous (Senonian), and the deepest aquifer, found at a depth of 1,100 m–1,400 m, that of the "Continental intercalary (CI)" in which the aquifer is made up of lower Cretaceous clays, sandstones and sands (Barremian-Albian) (Maliva & Missimer, 2012).

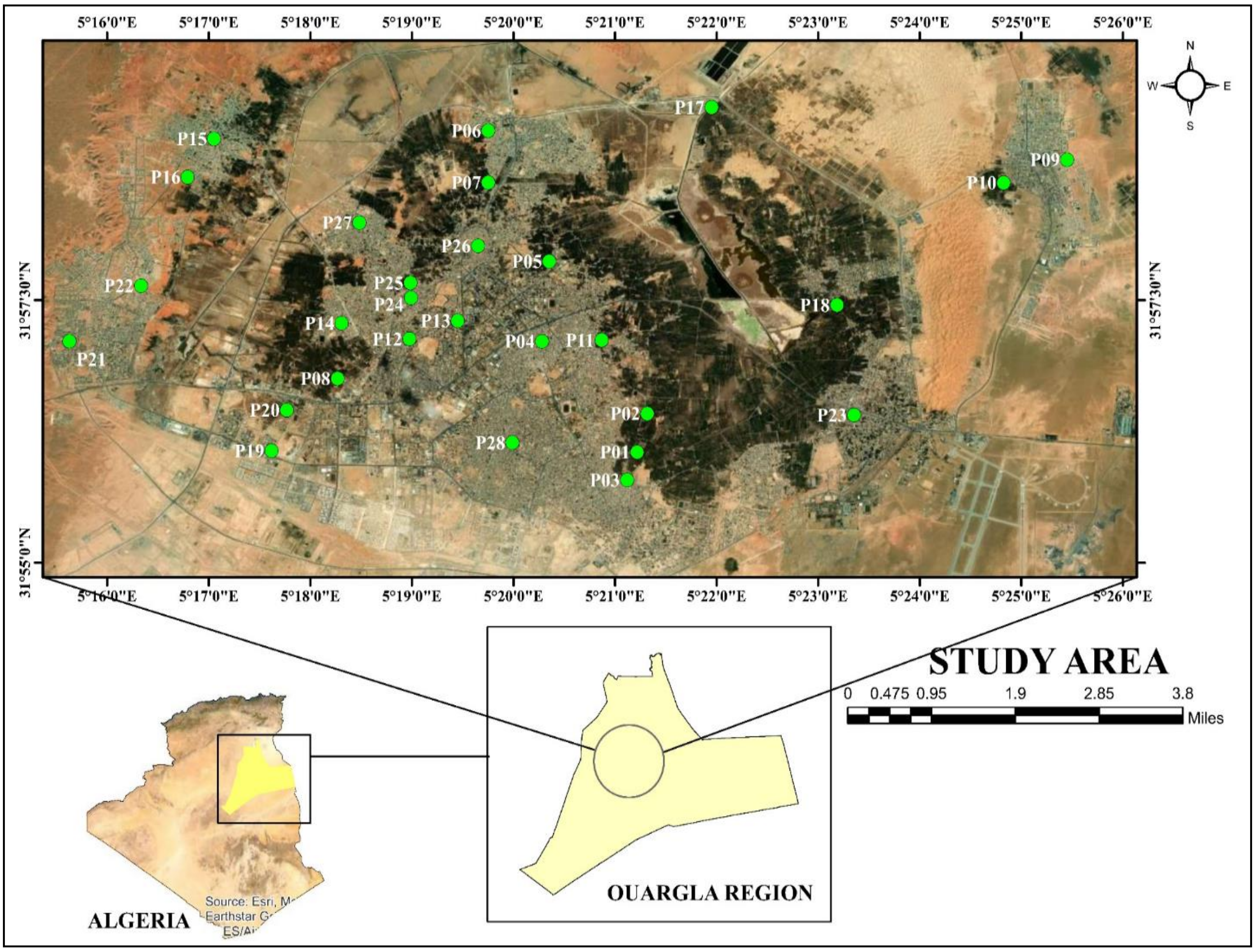

Figure 01. Study area.

Groundwater samples collection and analysis

In this investigation, thirty groundwater samples were taken in the month of April, 2021, from boreholes in the Ouargla complex terminal aquifer In this investigation, thirty groundwater samples were taken in the month of April, 2021, from boreholes in the Ouargla complex terminal aquifer. The sampling locations of these samples were recorded with a portable GPS device and are shown in **Error! Reference source not found.**.

Drinking water quality assessment

Entropy water quality index

The Entropy Water Quality Index (EWQI) is a mathematical tool that is widely used for evaluating water quality (Alizadeh *et al.*, 2018; Su *et al.*, 2018; J. Wu *et al.*, 2017; Zhou *et al.*, 2016).The explanation behind the use of entropy theory is that this tool can accurately classify groundwater quality data and effectively reduce problems resulting from other groundwater quality assessment techniques. The EWQIs were described and reviewed in the previous literature. (Jianhua *et al.*, 2011; Peiyue *et al.*, 2010).

The entropy, entropy weight and EWQI steps are listed below:

The eigenvalue matrix, X, Eq (1 can be constructed based on number of groundwater samples (m) and number of evaluated parameters (j) (Su *et al.*, 2018)

$$X_{ij} = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \quad \text{Eq (1)}$$

The eigenvalue matrix, X, is then converted into a standard-grade matrix, Y, to remove the effect of different units and quantity grades of groundwater quality parameters. The standard-grade matrix is defined in Eq (2).

$$Y = \begin{pmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{pmatrix} \quad \text{Eq (2)}$$

Then, the information entropy, ej, is computed by Eq (3)

$$\begin{cases} e_j = \dfrac{1}{\ln m} \sum_{i=1}^{m} P_{ij} \ln(P_{ij}) \\ P_{ij} = \dfrac{(1 + y_{ij})}{\sum_{i=1}^{m} (1 + y_{ij})} \end{cases} \quad \text{Eq (3)}$$

Eq (4) and Eq(5) are used to calculate the entropy weight (*wj*) and the quality rating scale (*qi*), respectively.

$$w_j = \frac{(1 + e_j)}{\sum_{i=1}^{m} (1 + e_j)} \quad \text{Eq (4)}$$

$$q_j = \frac{C_j}{S_j} \times 100 \quad \text{Eq(5)}$$

Where Cj represents the concentration of parameter j (mg/ L) and Sj represents the permissible limit of Chinese drinking water quality standards of parameter j (mg/L). At last, EWQI is calculated using Eq (6:

$$EWQI = \sum_{i=1}^{m} w_j q_j \quad \text{Eq (6)}$$

Irrigation water assessment

The SAR, %Na, PI, MH and KR are commonly used to evaluate the quality of irrigation water(Chandrasekar *et al.*, 2014; Kim *et al.*, 2019; Zhou *et al.*, 2016). SAR represents the relationship between Na^{+}, Ca^{2+} and Mg^{2+} as per Eq.(7):

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad \text{Eq. (7)}$$

Where, all cations are expressed in mEq/L.

Na % represents the relationship between K^{+}, Ca^{2+}, Na^{+} and Mg^{2+} as per Eq. (8):

$$Na\% = \frac{Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \qquad \text{Eq. (8)}$$

Where, all cations are expressed in mEq/L.

The PI is mainly determined by Na^{+}, Ca^{2+}, Mg^{2+}, K^{+} and HCO_3^{-} concentrations in the water as per Eq. (9):

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \qquad \text{Eq. (9)}$$

The calculations for MH are as follows：

$$MH = \frac{Mg^{2+}}{(Ca^{2+} + Mg^{2+})} \times 100 \qquad \text{Eq. (10)}$$

Where, all cations and anions are expressed in mEq/L. The results obtained by above irrigation water quality parameters may result in different outcomes, which will affect the decision making.

Results and discussions

Physico-chemical parameters of groundwater

Table 1 showed the statistical results of the hydrochemical parameters in the groundwater of the study area. The studied groundwater is alkaline in nature with the hydrogen ion concentration ranging from 6.41 to 8.18 (Table 1). The means of EC, TDS, and TH are 1962 µS/cm, 1625.36 mg/L, and 1001.576 mg/L (Table 1). The concentrations of Ca2+, Mg^{2+}, Na^{+}, K^{+}, NO_2^{-}, NO_3^{-}, SO_4^{2-}, and Cl^{-}, vary from 180.36 to 384.76 mg/L, 46.17 to 631.24 mg/L, 154.5 to 560 mg/L, 3.1 to 37 mg/L, 0.01 to 10 mg/L, 3.3 to 38.02 mg/L, 640 to 1075.0 mg/L, 150.6 mg/L to 2030.792 mg/L respectively. The mean dominance of cations is Na^{+}> Ca^{2+}> Mg^{2+} > K^{+}, whereas that of anions is Cl^{-} > SO_4^{2-} > HCO_3^{-} > NO_3^{-} > NO_2^{-}> F^{-}.

Table 1 Statistical analysis of major physicochemical indices.

Index	Unit	Minimum	Maximum	mean	SD	WHO (2017)
pH	/	6.41	8.18	7.425	0.36867	7.0
EC	µS/cm	1962	5910	3098.77	1242.45	
TH	mg/l	750	1530	1001.576	177.448	
TDS	mg/l	985	3200	610.877	1625.36	1000
K^+	mg/l	3.1	37	13.02	8.050	12
Na^+	mg/l	154.5	560	279.019	112.20	200
Mg^{2+}	mg/l	46.17	631.24	128.479	105.59	50
Ca^{2+}	mg/l	180.36	384.76	237.503	47.469	75
F^-	mg/l	0.92	1.65	1.24643	0.2395	1.5
HCO_3^-	mg/l	101	306.19	157.833	66.18	
Cl^-	mg/l	150.6	2030.792	809.78	570.965	250
SO_4^{2-}	mg/l	640	1075.0	851.88	116.614	250
NO_2^-	mg/l	0.01	10	2.2239	3.653	3
NO_3^-	mg/l	3.3	38.02	12.03	8.505	50
NH_4	Mg/l	0.002	0.138	0.02956	0.04056	

Hydrogeochemical type of groundwater

Piper diagram

Arthur Piper (Piper, 1944) developed the Piper diagram which uses two triangles and one diamond shaped field to graphically represent water chemistry. First lower left side triangle is related to cation, on right side is for anion and third triangle placed above these two is used to plot an overall chemical composition of groundwater. Through the use of specialized charts and diagrams for visualizing groundwater chemistry trends and interpretation for determining flow pattern and source identification as well as the chemical history of groundwater samples, the concept of hydro-geochemical facies is used to understand and classify water composition. Based on Piper diagram, Figure 1 shows that SO. Cl-Ca. Mg; and SO_4.Cl-Na+K are the main hydrochemical facies. The Piper diagram (Figure 1) can demonstrate anomalies in chemical composition of groundwater samples. Plotting for the research area reveals that in most groundwater samples, the concentrations of alkaline earth elements (Ca + Mg) are higher than those of alkali elements (Na + K) while a few simples the alkali elements exceeded the alkaline earth concentrations. In all the groundwater samples, strong acids (SO_4 + Cl) dominate over weak acids (CO_3 +HCO_3). These water facies are primarily affected by the processes of cation-exchange, dedolomitization, and evaporation; anthropogenic processes in connection with irrigation water return flow also have an impact.

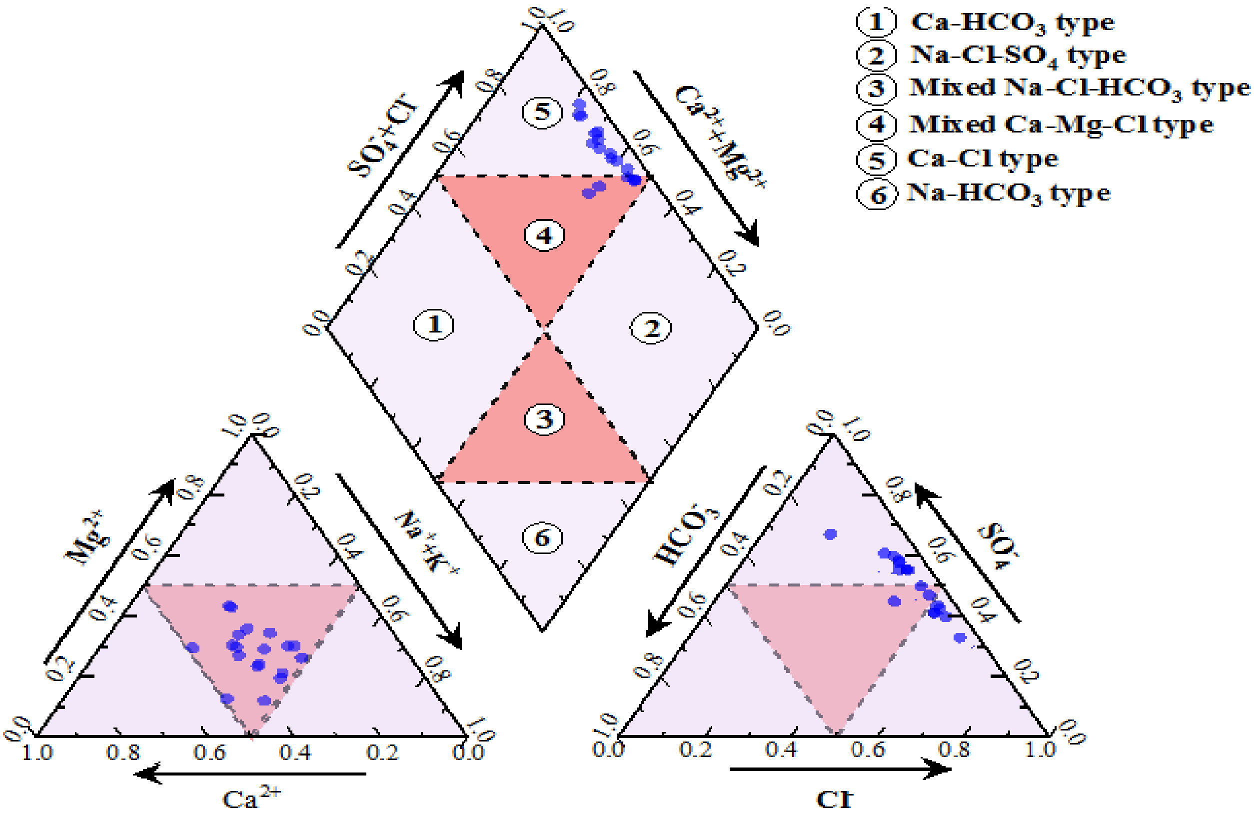

Figure 1. Piper diagram of collected groundwater samples.

Gibbs diagram

Ronald T. Gibbs developed the Gibbs diagram (Figure 2) which is mainly used to represent the source of chemical constituents in groundwater related to the dominance of precipitation, rock, and evaporation (Gibbs, 1970). The ratios for cations and an- ions, i.e., Na/ (Na + Ca) and Cl-/ (Cl + HCO_3) and of the groundwater samples when plotted against relative values of total dissolved solids (TDS). As shown in Figure 2, the groundwater samples fall into the evaporation dominance zone, suggesting that the evaporation is a main factor regulating the evolution of groundwater water chemistry. which are affecting the groundwater quality in the study area. This pattern confirms that evaporation increases salinity in the majority of groundwater samples from the vicinity of agricultural areas by raising Na and Cl in correlation with an increase in TDS. Additionally, man-made inputs such as fertilizers for agriculture and irrigation return flows affect evaporation by raising Na+ and Cl-, which raises TDS. This proves unequivocally that man-made variables, specifically anthropogenic activity, determine and dominate changes in the chemical composition of groundwater in addition to natural sources. (Hem, 1991). The study area is characterized as being within an arid region where rainfall was lower; hence, the evaporation process becomes dominant in controlling the groundwater chemistry.

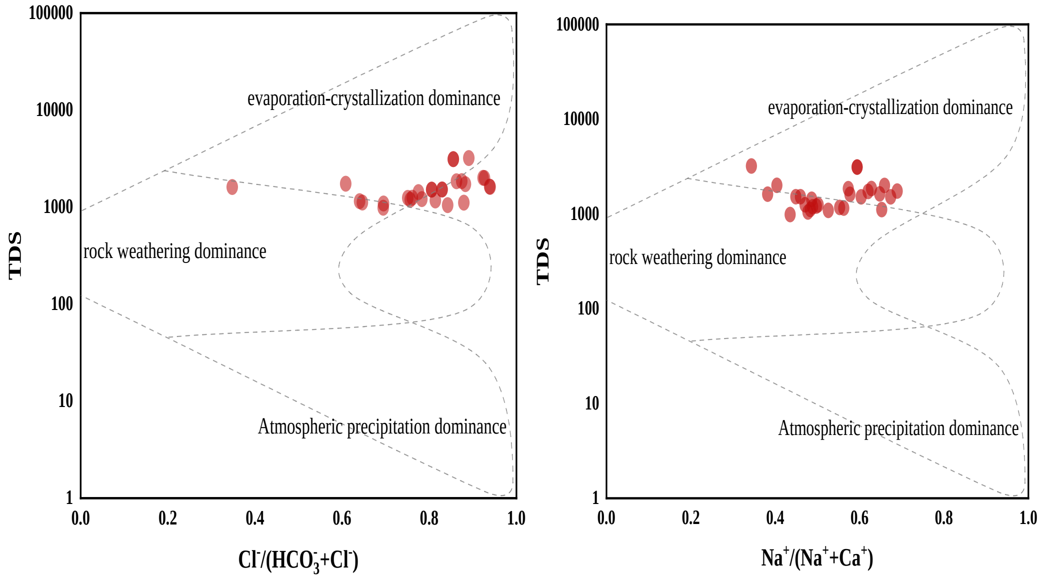

Figure 2. Gibbs diagrams: (a) TDS versus Na/(Na+Ca) and (b) TDS versus Cl/(Cl+HCO3).

Chloroalkaline (CA) index and its hydrochemical process

The chloroalkaline (CA) index is a frequently used measure that was developed by Schoeller (Schoeller, 1977) to understand the ion exchange interaction between groundwater and its host rocks. CA is calculated by Eq 12 and 14, where the concentrations of ions are expressed in meq/L.

$$CA-1=\frac{Cl^{-}-(Na^{+}+K^{+})}{Cl^{-}} \qquad \text{Eq (12)}$$

$$CA-1=\frac{Cl^{-}-(Na^{+}+K^{+})}{(SO_4^{2-}+HCO_3^{-}+NO_3^{-})} \qquad \text{Eq (13)}$$

The CA-1 and CA-2 index values, if positive, indicate major ion exchange between Na^{+} and K^{+} from the groundwater and Mg^{2+} and Ca^{2+} from the host rocks, while index value, if negative, indicates the ion exchange of Mg^{2+} and Ca^{2+} from the groundwater and Na^{+} and K^{+} from the host rocks; this is called reverse ion exchange. The results indicated that above 75.72 % of groundwater samples are active in ion exchange process or direct exchange through host rocks, while 14.28% of groundwater samples have negative values where Na^{+} and K^{+} ions in the aquifer materials are exchanged with Mg^{2+} And Ca^{2+} called as a reverse ion exchange of CA-1 and CA-2, respectively.

Table 2 Classification of Chloro-alkaline (CA) Index

Index	CA-1 and CA-2, + Value	CA-1 and CA-2, -Value

$CA-1=\frac{Cl^- - (Na^+ + K^+)}{Cl^-}$ $CA-1=\frac{Cl^- - (Na^+ + K^+)}{(SO_4^{2-} + HCO_3^- + NO_3^-)}$	Ion exchange between Na^+ and K^+ from the groundwater and Mg^{2+} and Ca^{2+} from the host rocks or Direct exchange.	the ion exchange of Mg^{2+} and Ca^{2+} from the groundwater and Na^+ and K^+ from the host rocks or reverse ion exchange

Drinking water quality assessment

EWQI and its distribution

The computed data of EWQI and its classification are presented in Table 2. The values of EWQI range from 51.13 to 354.58 with an average of 114.99. Groundwater quality can be divided into five categories (Table 2) based on the EWQI classification: excellent (rank 1), good (rank 2), medium (rank 3), bad (rank 4), and severely poor (rank 5). When the EWQI readings exceed 100, the groundwater is unfit for human consumption. (Amiri *et al.*, 2014, 2021; Su *et al.*, 2018; Subba Rao, 2021; C. Wu *et al.*, 2021). As seen in Table EWQI values vary from medium to very poor. The results are generally in consistency with those obtained using the entropy-weighted approach (Li *et al.*, 2019). Of all collected groundwater samples, 46.7% (14 samples), 40 % (12 samples) and 13.3 % (4 samples) are categorized as medium, poor and extremely poor-quality water, respectively. 46.7% (14 samples) are suitable for drinking and other purposes such as agricultural irrigation; 40 % (12 samples) are grouped into the poor-quality classification, which can be readily used for irrigation after some preliminary treatment. The remains are extremely poor (4 samples, accounting for 13.3 %), which is not fit for consumption. If they are used for irrigation, some treatments may be required. demonstrates the spatial distribution of the overall groundwater quality.

Table 3. Classification of entropy weighted water quality index (EWQI).

EWQI	<25	25-50	50-100	100-150	>150
Rank	I	II	III	IV	V
Water quality	Excellent quality	Good quality	Medium quality	Poor quality	Extremely poor quality

Table 4. Assessment results of the EWQI values for the study region Sample.

Sample	EWQI	Rank	Water Quality	Sample	EWQI	Rank	Water Quality
P01	103.72	IV	Poor	P15	129.33	III	Poor

P02	112.28	IV	Poor	P16	98.04	III	Medium
P03	237.97	V	Extremely poor	P17	74.29	III	Medium
P04	151.32	V	Extremely poor	P18	354.85	V	Extremely poor
P05	108.19	IV	Poor	P19	123.88	IV	Poor
P06	126.81	IV	Poor	P20	87.43	III	Medium
P07	98.70	III	Medium	P21	102.19	IV	Poor
P08	79.34	III	Medium	P22	150.23	V	Extremely poor
P09	121.31	IV	Poor	P23	75.36	III	Medium
P10	80.42	III	Medium	P24	91.70	III	Medium
P11	81.65	III	Medium	P25	127.71	IV	Poor
P12	67.86	III	Medium	P26	137.19	IV	Poor
P13	51.13	III	Medium	P27	129.73	IV	Poor
P14	78.97	III	Medium	P28	82.18	III	Medium

The total hardness values

The major constituents that result in hardness in groundwater are Ca and Mg ions, generally produced by the dissolution minerals with carbonate such as dolomite and calcite. According to the WHO, Total Hardness (TH) levels greater than 200 mg/L could result in scaling in water pipes, whereas levels lower than 100 mg/L may cause lower pH values and therefore increase the corrosion hazard in water distribution systems. In terms of drinking water hardness, the WHO advises against setting any health-based limitations. It was established that the sampling wells were hard and very hard since their TH values ranged from 750 to 1530 mg/L, with a mean value of 177.448 mg/L. (Sawyer *et al.*, 2003), see Table 1. Greater hardness ratings in the majority of the sample wells. Based on the combination of TDS and TH levels, all samples were categorized as hard brackish, as illustrated in Fig. 4.

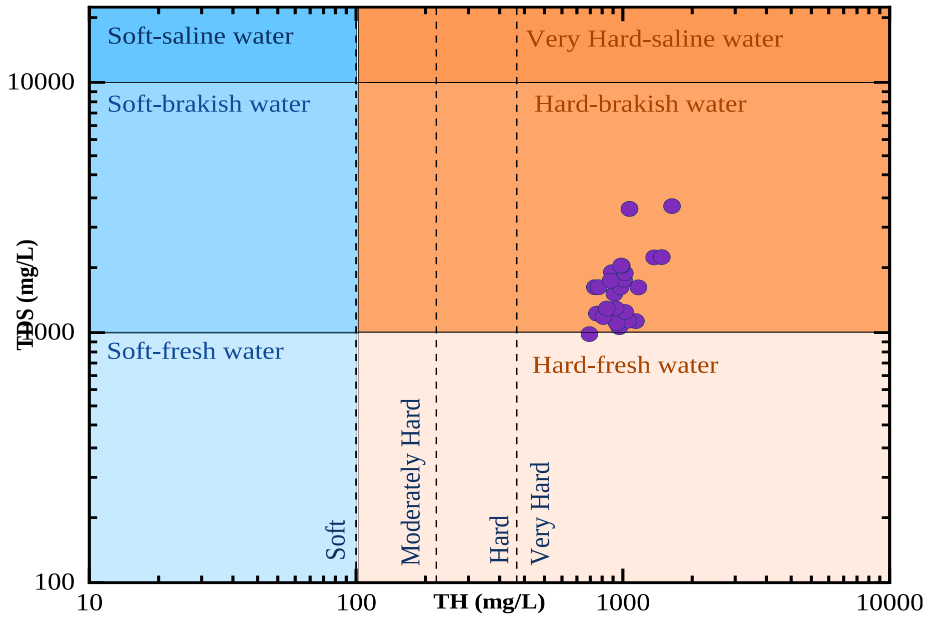

Figure 4. the combination of TDS and TH contents

Irrigation Quality Assessment

The higher proportion of exchangeable sodium in irrigation water cause sodium hazards to the soil which eventually causes loss of crops production and limits the choice of crops. Sodium hazard is determined by SAR, KR and Na%. On the other handan increased concentration of Mg^{2+} in irrigation water also degrades the structure and quality of the soil, making it alkaline, especially when the irrigation water is dominated by sodium. Higher Mg^{2+} contents in irrigated soil cause MH which eventually reduces the crop yield productivity. When contaminated irrigation water is used, the concentration of salts in the soils of agricultural fields rises and eventually accumulates, endangering the crops. Using EC, the SH of irrigation water is calculated (Richards, 1954). Increased dissolved salt irrigation water over an extended period can impact soil permeability. PI is a useful indication for figuring out the soil permeability issue brought on by using contaminated groundwater for irrigation. The indices mentioned above are calculated using Eqs. 7 –10 and water quality classifications based on these indices are illustrated in Table 5 (Doneen, 1975; Eaton, 1950; Paliwal, 1972).

Table 5 Groundwater quality classification for irrigation use.

Parameter	Unit	Classification	Range	Sample (%)
EC	µS/cm	Excellent	<250	-
		Good	250-750	-
		Fair/medium	750-2250	21.42
		Poor	>2250	78.57

SAR	-	Excellent	<10	3.57
		Good	10-18	46.42
		Poor	19-26	17.85
		Unsuitable	>26	35.71
Na %	%	Excellent	<20	3.571429
		Good	20-40	67.85714
		Permissible	40-60	28.57143
		Doubtful	60-80	-
		Unsuitable	>80	-
MH	%	Suitable	≤50	32.14
		Unsuitable	>50	67.86
KR	-	Acceptable	≤1	96.43
		Unacceptable	>1	3.57
PI	%	Highly suitable	>75	-
		Suitable	25-75	92.86
		Unsuitable	<20	7.14

EC: salinity hazard (electric conductivity); Na%: sodium percentage; SAR: sodium adsorption ratio; MH: magnesium hazard; PI: permeability index; KR: Kelley's ratio; PS: potential salinity; K: synthetic harmful coefficient; Ka: the irrigation coefficient

4. Conclusion

The Algerian region of Ouargla uses groundwater for irrigation and consumption. The main observations based on geochemical characteristics of the samples collected from this region are:

- The Pipers trilinear diagram area shows that SO. Cl-Ca. Mg; and SO_4.Cl-Na+K are the main hydrochemical facies. The principal factor affecting these water facies is the dissolution of evaporation.

- According to the Gibbs diagram, the evaporation process becomes dominant in controlling the groundwater chemistry.
- The bulk of sampling wells with greater hardness values, which take into account the mixture of TDS and TH contents, were categorized as having hard brackish samples.
- With an average value of 91.5, the EWQI indicates that the groundwater quality in the area of study region ranges from 57.6 to 134.8, with about 70.5% of the groundwater samples being moderately appropriate for human consumption. Among the total number of groundwater samples gathered, the following percentages are assigned to the water quality: medium (46.7%), poor (12 samples), and severely poor (4 samples).
- Based on Sodium hazard (SAR) 3.57% 46.42%,17.85%and 35.71% of the samples were shown to be in the Excellent, Good, Poor, Unsuitable respectively and according to Kelly's ratio (KR) 96.43% of the samples were found in suitable category. It was determined by the permeability Index (PI) that 92.86% of the groundwater samples were appropriate. and 7.14% unsuitable category for irrigation purpose.

The current study will help policymakers and competent authorities to take preventive measures on a long-term basis.

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Compliance with ethical standards

There is no conflict of interest, according to the authors.

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