INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 13, No. 4, p. 211-224, 2018
http://www.innspub.net

RESEARCH PAPER
OPEN ACCESS

The suitability of géothermal waters for irrigation, Oued Righ area, South-easthern Algeria

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Article published on October 30, 2018

Key words: Continental intercalaire, Oued Righ, geothermal waters, irrigation.

Abstract

The Oued Righ area is characterized by a hot and arid climate, where an intense dryness with a very low humidity and a very strong evaporation. These various climatic characteristics are reflected on the hydrography of the study area, sight the scarcity of surface water, the ground water takes much importance. In the study area, groundwater samples were collected from twenty wells during two periods (January 2011 and May 2011). Different parameters such as water quality index , Electrical conductivity, total dissolved solids (TDS),Total hardness (TH), Chloride classification, Sodium adsorption ratio (SAR), Percent sodium (% Na), Potential Salinity (PS), Kelley's ratio, Permeability index (PI), Residual sodium carbonate and Magnesium hazard were used to evaluate groundwater suitability for irrigation purposes. Total hardness reveals that a majority of the groundwater samples falls in the very hard water category, total hardness values range from 59,40 to 106,40°F. The EC classification indicates that 80% of CI groundwater samples are doubtful for irrigation and 20% are unsuitable for irrigation.

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Introduction

In the arid areas, the groundwater constitutes the principal source of irrigation water. In recent years, agricultural development, the extension of irrigated surfaces and the intensity of agricultural practices are at the origin of the growing demands.

The Oued Righ region is part of the Lower Sahara characterized by a hot and arid climate, resulting in an intense drought with very low humidity, very high evaporation and low rainfall.

These different climatic characteristics have repercussions on the hydrography of the study area. Given the scarcity of surface water, groundwater is very important source of water for irrigation and drinking uses. The continental intercalaire is the most important aquifer in the area of Oued Righ, its lithology is primarily sand of thick layers of clay which give it the captive type. This reservoir is contained in the formations of the lower cretaceous (Albian and Barremien), they are sometimes argillaceous sands and sandstones.

Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Subramani *et al.*, 2005). However, the chemical composition of water is an important factor to be considered before it is used for domestic, irrigation or industrial purposes (Suresh *et al.*, 1991). The accumulation of water-soluble salts in the rooting soil negatively affects the growth of plants, two series of effects of salinity (Forges, 1972): some bear on vegetables, others on the soil. Moreover, (Person 1978) the salts cause changes in the structure of the soil (on its permeability and aeration), directly affecting the development of the plant.

Several studies have been conducted to determine the suitability of groundwater for irrigation for sustainable agriculture. Recently, Ziani *et al.*, (2017) used graphical to determine the groundwater quality, to identify the major hydrogeochemical processes and to delineate regions where groundwater is suitable or unsuitable for drinking and irrigation in the semiarid region: case of Djacer spring, Algeria. Bahroun *et al.*, (2017) studied the suitability surface waters for irrigation in Northeastern of Algeria.

In Tunisia Ben Alaya *et al.,* (2014) used different water quality parameters for the water suitability for drinking and irrigation purposes with World Health Organization (WHO) guideline values for drinking water. The study of Deshpande and Aher, (2014) revealed that 40% groundwater sample is unsuitable for irrigation purposes based on irrigation quality parameters in the region of Vaijapur taluka from India. The study of Nazzal *et al.* (2014) revealed that 21% samples are unsuitable for irrigation in Saq aquifer, northwest of Saudi Arabia.

As far as drinking water quality criteria are concerned, study showed that about 33% of samples are unfit for use. Hence, the aim of the present study assessment of water for irrigation purposes by comparing various parameters: Electrical conductivity, total dissolved solids (TDS),

Total hardness (TH), Chloride classification, Sodium adsorption ratio (SAR), Percent sodium (%Na), Potential Salinity (PS), Kelley's ratio, Permeability index (PI), Residual sodium carbonate and Magnesium hazard methods, the most frequently used, the two campaigns were the subject of this application.

Materials and methods

Description of the study area

The study area located in the Southeastern part of Algeria and lies approximately between the longitudes 5°30`-6°20`E and the latitudes 32°54`-34°9`N. More precisely northeast of the Sahara on the North boundary of the great oriental Erg.

Administratively is limited to the North by the province of Biskra, to the Southwest by the oasis of Ouargla and the East by the river of Oued Souf (Fig.1). The climate is arid; the mean annual temperature is 22°C. Potential evapotranspiration is approximately 1165 mm and precipitations are less than 100mm.

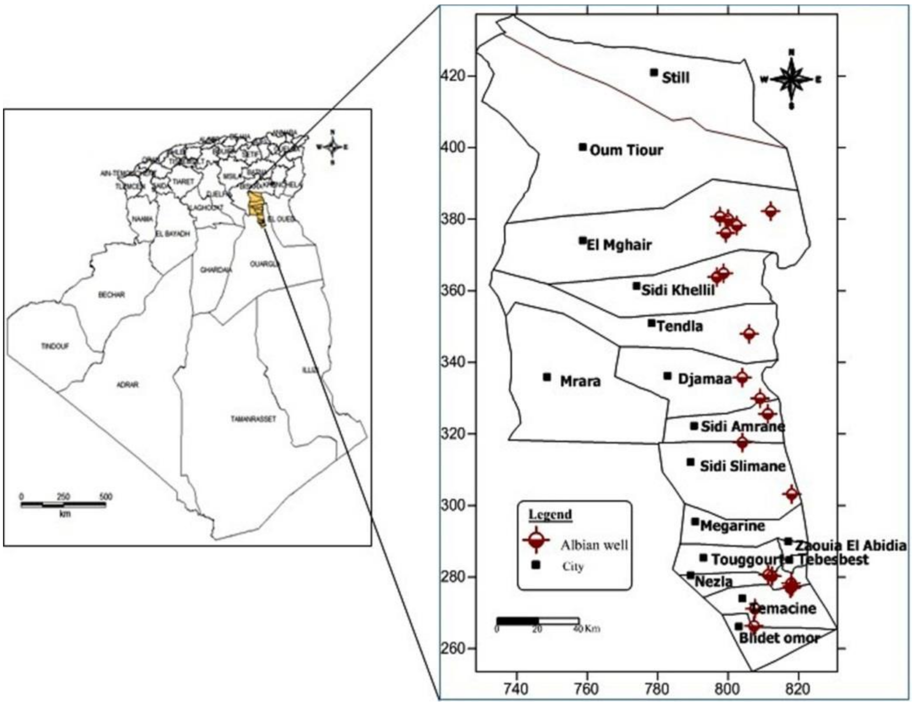

Fig. 1. Location map of Oued Righ region.

Geology and hydrogeology setting

The region of Oued righ forms part of lower Sahara and lies between the southern Atlas accident, and the first foothills of the Aures Mountains in the North. The southern limit is constituted by the southern cliff of the tinrhert. The Cretaceous outcrops of Dahar in the East and the M'zab dorsal in the west.

The lower sahara presents itself as a synclinal basin whose land, from the Cambrian to Tertiary are hidden in large part by the great oriental of Erg (oriental of basin). However, some outcrops are observed on the borders.

We distinguish from the bottom up, three sets:

1. The Paleozoic grounds appear in the South, between the Tademaït plateau and the Tinrhert plateau and Hoggar massif;
2. The Mesozoic and Cenozoic grounds constitute the main part of the outcrops of the borders of lower Sahara.
3. Continental deposits of the end the sector tertiary and the Quaternary, occupy the basin center.

Most of the studied sites are located in the deep confined Continental Intercalaire (CI) aquifer, which is contained in the lower Cretaceous formations.

The continental intercalaire aquifer of North Africa is one of the largest confined aquifers in the world, comparable in scale to the great artesian basin of Australia and covers some 600,000km² on only Algerian and Tunisian territories with a potential reservoir thickness between 120 and 1000m (Castany, 1982). The deep confined Continental Intercalaire (CI) aquifer is contained in the lower Cretaceous formations (Albian and Barremian). It is located within a complex sequence of clastic sediments of Mesozoic age. Their thickness and lithology show significant lateral variation (UNESCO, 1972).

The aquifer is continuous from north to south from the Saharan Atlas to the Tassilis of the Hoggar (Algeria) and west to east from western Algeria to the Libyan Desert through southern Tunisia (Edmunds *et al.*, 2003). The CI formation comprises permeable continental detrital deposits of sand-sandstone and argillaceous sands with intercalations of marine clays and arenaceous clays of Lower Cretaceous.

Albian age (Furon 1963). The principal areas of current or former CI recharge is in the South Atlas mountains of Algeria, the Tinrhert plateau of Algeria and the Dahar Mountains of Tunisia (Fig. 2).

The CI is mainly confined and discharges in the Chotts of Tunisia and in the Gulf of Gabes (Mediterranean Sea) (Cornet, 1964).

Analytical methods

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment (Vineesha Singh and U.C. Singh, 2008). Sodium then exerts a harmful action on the vegetation, indirectly, by degrading the physical properties of the soil (Rouabhia, 2010). The enrichment of the soil in Na^+ can involve harmful effects on water quality for irrigation of share this action, the soils become compact and asphyxiating for the plants (Tood 1980). The risk of sodicity is determined by the ratio between the sodium adsorption ration (SAR) of the irrigation water and its total mineralization. Twenty groundwater samples were collected during January 2011 and May 2011 from wells in Oued Righ.

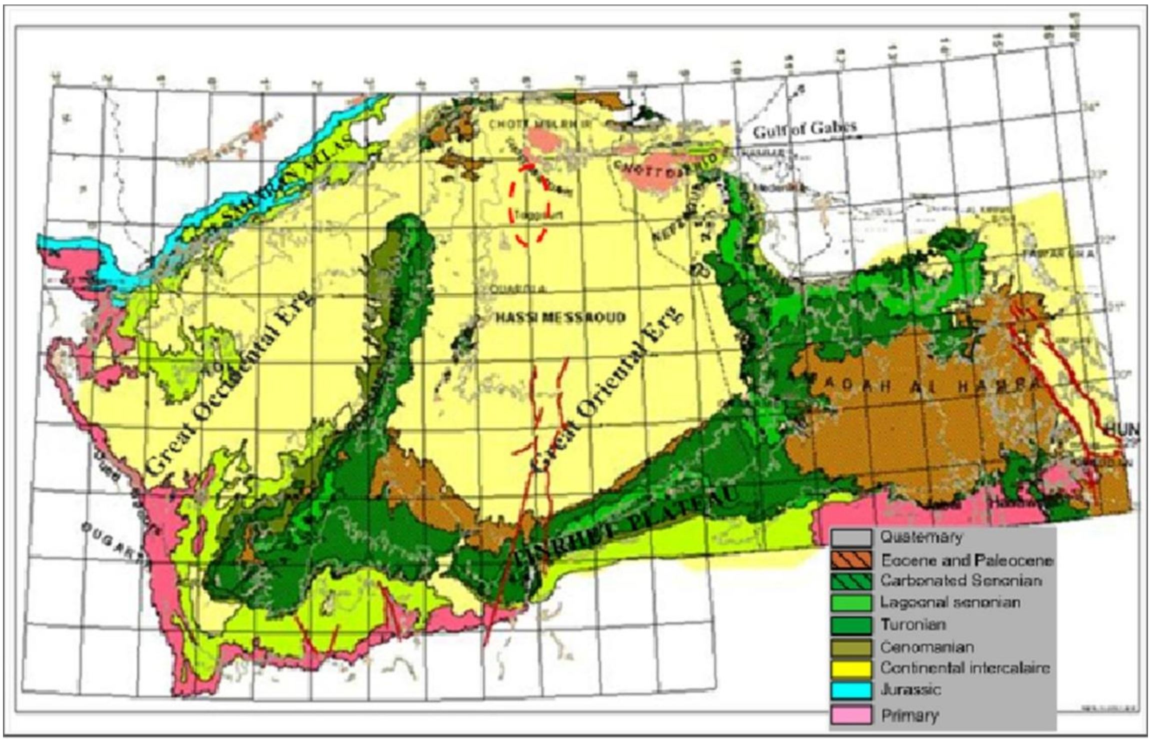

Fig. 2. Geological map of Septentrional Sahara (OSS. 2003).

The physicochemical parameters (temperature, pH and electrical conductivity) were measured in situ using a WTW multi-parameter. Water samples were analyzed for major and minor dissolved chemical constituents. Ca^{2+}, Mg^{2+}, Cl^- and HCO_3^- were determined by using the titration method. SO^{2-}_4 was determined using a spectrophotometric method. Na and K were analyzed using a flame photometer. Electrical conductivity, total dissolved solids (TDS),Total hardness (TH), Chloride classification, Sodium adsorption ratio (SAR), Percent sodium (% Na), Potential Salinity (PS), Kelley's ratio, Permeability index (PI), Residual sodium carbonate and Magnesium hazard.

Calculation parameters of water for agricultural use

The suitability of water for the irrigation can be judged not only from the total salt concentration, but also from the type of salts and the ions that constitute it (Rouabhia, 2010). The principal factors which can degrade the quality of water for irrigation, thus summarized with the dissolved salt concentration expressed by the dry residue or electrical conductivity, potential salinity, the relative sodium concentration and the quantity of the toxic elements (boron and chlore) present in water (Rouabhia, 2006). Salinity and indexes such as sodium absorption ratio (SAR), sodium percentage (% Na), residual sodium carbonate (RSC), and residual sodium bicarbonate (RSBC) and permeability index (PI) are important parameters for determining the suitability of groundwater for agricultural uses (Srinivasa Gowd 2005; Raju 2007).

Potential salinity (PS)

(Doneen, 1954) explained that the suitability of water for irrigation is not dependent on soluble salts. (Doneen, 1962) is of the opinion that the low solubility salts precipitate in the soil and accumulate with each successive irrigation, whereas the concentration of highly soluble salts increase the soil salinity.

Potential salinity (Sp) could (may) be estimated by (Doneen, 1961):

$PS = Cl + {}^{1}/_{2}\ SO4$ (1)

All ionic concentration is in meq/l.

- For sodium, the presence of high content of this element causes a structural modification of the soil, decreased permeability and its aeration. This risk is determined by the SAR value, which is defined by the following formula:

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

All ionic concentration is in meq/l.

Sodium percentage (% Na)

It is based on the total concentration of dissolved salts and sodium percentage with respect to other salts in water (Wilcox, 1955).

The sodium percentage (Na %) is calculated using the formula:

$\%\ Na = \frac{(Na+K)}{(Ca+Mg+Na+K)} \times 100$ (3)

Where concentrations are measured in meq/L.

The permeability index (PI)

As defined by Doneen (1964) and Ragunath (1987), is calculated by the following equation:

$IP(\%) = \frac{Na^{+}+\sqrt{HCO_3}}{Ca^{2+}+Mg^{2+}+Na^{+}} \times 100$ (5)

Where all the ions are expressed in meq/l.

Kelly's Ratio (KR)

The Kelly's ratio calculated employing the following equation (Kelly, 1963):

Where all the ionic constituents are expressed in meq/l.

$RK = \frac{Na}{Ca+Mg}$ (6)

Residual sodium carbonate (RSC)

In addition to the SAR and Na %, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability of groundwater for irrigation. This is termed as residual sodium carbonate (RSC) (Richard, 1955).

The RSC index is calculated by the following equation (Ragunath, 1987):

$RSC = (CO3 + HCO3) - (Ca + Mg)$ (7)

Where the concentrations are reported in meq/l.

Irrigation water having RSC values greater than 5 meq/L have been considered harmful to the growth of plants, while waters with RSC values above 2.5 meq/l are unsuitable for irrigation.

Magnesium hazard

Generally, Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most waters, although in soil system, Ca^{2+} and Mg^{2+} do not behave equally and Mg^{2+} deteriorates soil structure particularly when waters are sodium dominated and highly saline (Ravikumar *et al.*, 2011). The magnesium hazard was calculated using the formula given below (Szaboles and Darab, 1964):

$MH = \frac{Mg}{Ca+Mg} \times 100$ (8)

Where all ionic concentrations are expressed in meq/l.

Results and discussion

Hydrochemical facies

The classification of groundwater facies was done using Piper's diagram. This diagram reveals similarities and differences among groundwater samples because those with similar qualities will tend to plot together as groups (Todd and Mays, 2005).

In the Albian aquifer of Oued Righ three types seem to exist for the period January 2011 and four types for the period May 2011 (Fig. 3 and table 1).

The sodium sulfate type represents 65% (period January 2011) and 70% (period May 2011), some samples are rich in chloride and sodium showing sodium chlorinated type which represents 10% (period January 2011) and 5% (period May 2011).

The calcium sulfated type is present in 25% (period January 2011). Finally, the magnesium sulfated type is present in 20% and the magnesium chloride type represent 5% of the samples for the period May 2011. Hydrochemical facies of all waters is summarized in Table 1.

Table 1. Hydrochemical facies of geothermal waters (wells).

Periods	Chemical facies (%)				
	Sulfated sodium	Chloride sodium	Sulfated calcium	Sulfated magnesium	Chloride magnesium
January 2011	65	10	25	0	0
May 2011	70	5	0	20	5

Table 2. Results of different parameters groundwater quality for agricultural purposes.

	CE (µs/cm)	TDS (mg/l)	Na%	SAR (meq/l)	IP %	PS (meq/l)	RSC (meq/l)	RK (meq/l)	TH (°F)	Cl (meq/l)	MH%
January 2011											
Max	3280	2667	49.06	5.27	53.80	28.95	-11.04	0.87	106.4	18.20	60.00
Min	2110	1734	33.14	2.47	37.14	15.95	-18.00	0.42	76	8.40	30.49
Mean	2552	2063.45	42.27	3.91	46.12	20.83	-13.72	0.67	86.62	12.65	43.81
May 2011											
Max	3070	2522	53.29	6.23	57.20	29.46	-8.60	1.08	100	20.20	89.14
Min	2140	1695	34.06	2.68	38.05	16.41	-17.00	0.46	59.4	8.60	42.40
Mean	2507	2127.25	44.11	4.09	48.72	23.10	-12.41	0.74	78.06	13.49	67.44

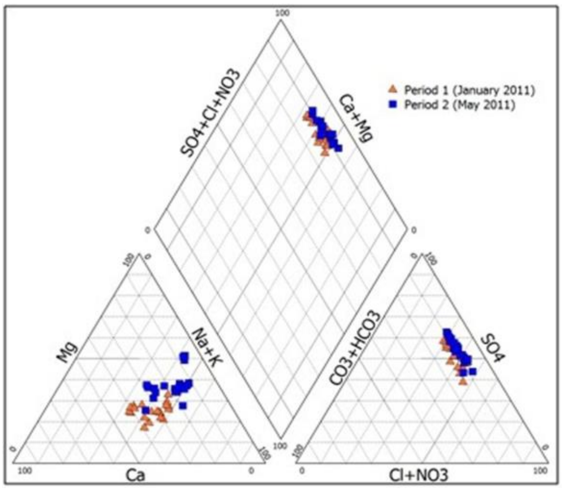

Fig. 3. Chemical facies of groundwater in Piper diagram.

Suitability of water for irrigation purpose

Moreover suitability of water for irrigation is depended on the effect of some mineral constituents in the water on both the soil and the plant (Wilcox, 1948 & 1955). The suitability of groundwater for irrigation can be evaluated by several parameters:

Electrical conductivity

Electrical conductivity is a good measure of salinity hazard to crops as it reflects the TDS in groundwater (Ben Alaya and *et al.,* 2014).

The higher EC, the less water is available to plants (Tank and Chandel, 2009). The US Salinity Laboratory (1954) classified ground waters on the basis of electrical conductivity (Table 3).

The overall fluctuations of water mineralization can be translated by the determination of the electrical conductivity of water, which is a linear function of the dissolved ions.

The electrical conductivities measured range from 2110 to 3280µs/cm in January 2011, with an average of 2552µs/cm. In May 2011, the conductivity is between 2140 and 3070µs/cm with a mean value of 2507µs/cm. The EC classification indicates that the majority of CI groundwater is doubtful for irrigation.

Table 3. Suitability of groundwater for irrigation based on Electrical conductivity.

Electrical conductivity	Range	Classification	Number of samples		Percentage of samples	
			January 2011	May 2011	January 2011	May 2011
Based on EC (lS/cm) after Wilcox (1955)	< 250	Excellent	-	-	-	-
	250-750	Good	-	-	-	-
	750–2250	Permissible	4	4	20%	20%
	2250–5000	Doubtful	16	16	80%	80%
	>5000	Unsuitable	-	-	-	-

The EC classification indicates that 80% of CI groundwater samples are doubtful for irrigation and 20% are unsuitable for irrigation. On the whole, the groundwater in this area is highly mineralized. It is due to the dissolution of the evaporites that constitute the aquifer (Chaib, 2016).

The total dissolved solids (TDS)

To ascertain the suitability of groundwater for any purposes, the TDS should be below 500mg/l (Catroll 1962; Freeze and Cherry 1979). According to Freeze and Cherry (1979), all groundwater samples from the CI are brackish water type, based on Davis and DeWiest (1966) classification (Table 4), all groundwater samples collected from the CI are useful for irrigation.

Table 4. Groundwater classification based on TDS (Davis and DeWiest 1966 and Freeze and Cherry 1979).

TDS (mg/l)	Classification	Number of samples		Percentage of samples	
		Janury 2011	May 2011	Janury 2011	May 2011
Davis and DeWiest (1966)					
500	Desirable for drinking	-	-	-	-
500-1000	Permissible for drinking	-	-	-	-
1000-3000	Useful for irrigation	20	20	100	100
> 3000	Unfit for drinking and irrigation	-	-	-	-
Freeze and Cherry (1979)					
< 1000	Fresh water type	-	-	-	-
1000 - 10000	Brackish water type	20	20	100	100
10000 -100000	Saline water type	-	-	-	-
>100000	Brine water type	-	-	-	-

Total hardness (TH)

The principal natural sources of hardness in groundwater are dissolved polyvalent metallic ions from sedimentary rocks, seepage, and run-off from soils (M. Irfan and M. Said, 2008). Calcium and magnesium ions present in groundwater are particularly derived from leaching of limestone, dolomites, gypsum and anhydrites, whereas the calcium ions are also derived from cation exchange process (Garrels 1976; Haritash *et al.*, 2008).

Hard water is a potential problem since the calcium and magnesium can combine with bicarbonate to form insoluble calcium and magnesium carbonate salts (Ben Alaya and *et al.,* 2014). These salts can affect media pH and reduce the amount of sodium available to a plant (Robbins, 2010). Based on United States Department of Agriculture method (USDA) specification of TH, up to 200mg/l is the upper limit for water irrigation.

The total hardness values of the groundwater samples range from 59,40 to 106,40°F, the high TH values reveal that a majority of the groundwater samples is a very hard water category (Fig.4 and 5).

Fig. 4. Total hardness for geothermal waters (January 2011).

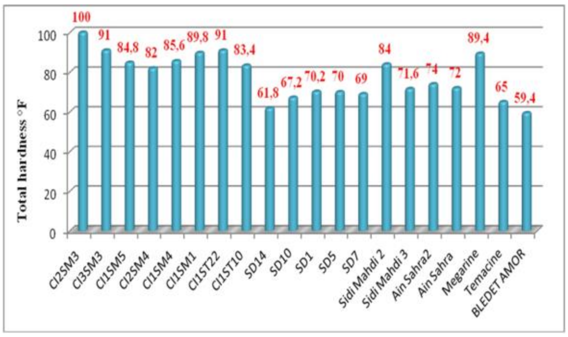

Fig. 5. Total hardness for geothermal waters (May 2011).

Chloride classification

Stuyfzand (1989) classified water on the basis of Cl^- ion concentration (table 5). According to this classification, the all groundwater samples from the CI of the study area are of the brackish water type for the two periods.

Sodium adsorption ratio (SAR)

High concentration of sodium in water produces harmful effects changing soil properties and reducing soil permeability (Kelley 1951; Domenico and Schwartz 1990; Todd and Mays 2005). SAR is an important parameter for determining the suitability of groundwater for irrigation because it is a measure of alkali / sodium hazard to crops (Subramani *et al.*, 2005). Sodium replacing adsorbed calcium and magnesium is a hazard causing damage to the soil structure, making it compact and impervious (Raju 2007). The sodium adsorption ratio (SAR) indicates the effect of relative cation concentration on sodium accumulation in the soil; thus, sodium adsorption ration (SAR) is a more reliable method for determining this effect than sodium percentage (Richards, 1954).

Table 5. Groundwater classification based on chloride (Stuyfzand 1989).

Cl^- (méq/l)	Classification	Number of samples		Percentage of samples	
		January 2011	May 2011	January 2011	May 2011
Stuyfzand (1989)					
> 0,14	Extremely fresh	-	-	-	-
0.14–0.85	Very fresh	-	-	-	-
0.85–4.23	Fresh	-	-	-	-
4.23–8.46	Fresh brackish	-	-	-	-
8.46–28.21	Brackish	20	20	100	100
28.21–282.06	Brackish –salt	-	-	-	-
282.06–564.13	Salt	-	-	-	-

According to the SAR classification (Richards, 1954), all groundwater samples in both the periods fall within excellent category for irrigation purposes in almost all soils. The USDA classification for salinity (C) and sodicity hazards (S) in the continental intercalaire aquifer is shown in table 6 and Fig. 6.

All of the wells fall within in the two salinity classes C3 and C4 (High salinity hazard class (C3) is satisfactory for plants having moderate salt tolerance, on soils of moderate permeability with leaching, High salinity hazard class (C4)), including all two sodicity classes (S1 and S2).

Low sodium water (S1) can be used for irrigation on almost all soils with little danger of developing harmful levels of exchangeable Na+ (Ketata *et al.*, 2011).

Medium sodium water (S2) presents an appreciable sodium hazard in certain fine-textured soils, especially poorly leached soils (Subba Rao 2006). Waters belonging to this class are classified as excellent for irrigation and can be used safely on coarse-textured or organic soils having good permeability and may be used to irrigate salt-tolerant and semitolerant crops under favorable drainage conditions (Ben Alaya, 2014).

The analytical data plotted on the US salinity Laboratory (USSL) diagram 1954; Wilcox 1955) (Fig. 6) illustrates that the 20% of the well waters fall in the field of C3-S1 for the two periods, indicating water of high salinity and low sodium, which can be used for irrigation in almost all types of soil with little danger of exchangeable sodium.

25% for the period January 2011 and 35% for the period May 2011 of the well waters fall in the field of C4-S1, indicating very high salinity and low alkalinity hazard.

This can be suitable for plants having good salt tolerance, and it also restricts suitability for irrigation, especially in soils with restricted drainage, 55% for the period January 2011 and 45% for the period May 2011 of the well waters fall in the field of C4-S2, indicating a very high salinity hazard and medium alkalinity hazard. All sampling points on the US salinity diagram are shown in Fig. 6 and summarized in Table 6.

Table 6. Groundwater classification based on SAR (Richards 1954).

Based on alkalinity hazard (SAR) after Richards (1954)	classification	Number of samples		Percentage of samples	
		January 2011	May 2011	January 2011	May 2011
<10	Low (Excellent)	20	20	100	100
10 –18	Medium (good)	-	-	-	-
18–26	High (doubtful/fair poor)	-	-	-	-
>26	Very high	-	-	-	-

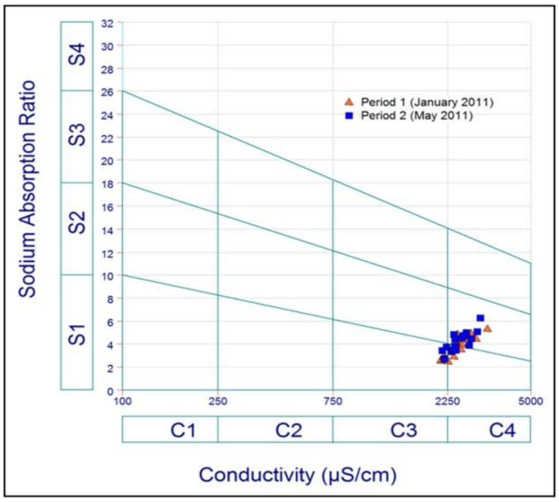

Fig. 6. Classification of irrigation waters by USSL (after Richards 1954) (January. 2011 and May 2011).

Percent sodium (%Na)

Na^+ is an important cation which in excess deteriorates the soil structure and reduces crop yield (Narsimha and al 2013).

The estimates of sodium percentage (Na %) range from 33.14 to 49.06% with an average value of 42, 27% (in January 2011).

The sodium percentage (Na %) content in study area (in May 2011) has shown variation from 34.06 to 53.29% with an average value of 44.11%. The majority of samples (70%) have Na% values between 40 and 60 corresponding with good to permissible class (Table 7).

Table 7. Groundwater classification based on percent sodium (Wilcox, 1955).

Based on percent sodium (%Na) after Wilcox (1955)	Classification	Number of samples		Percentage of samples	
		January 2011	May 2011	January 2011	May 2011
0 –20	Excellent	-	-	-	-
20 – 40	Good	6	6	30%	30%
40–60	Permissible	14	14	70%	70%
60 - 80	Doubtful	-	-	-	-

Potential Salinity (ps)

(Doneen, 1954) explained that the suitability of water for irrigation is not dependent on soluble salts. (Doneen, 1962) is of the opinion that the low solubility salts precipitate in the soil and accumulate with each successive irrigation, whereas the concentration of highly soluble salts increase the soil salinity. The potential salinity of the water samples ranged from 15.95 to 28.95 meq/l with an average value of 20.83meq/l (in January 2011).

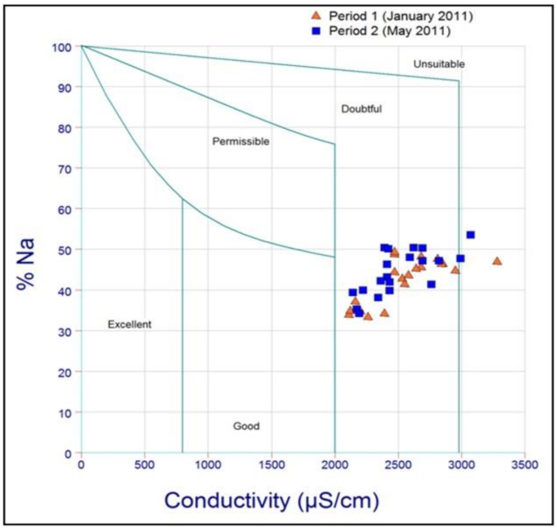

Fig. 7. Classification of irrigation waters using Wilcox diagram (January 2011and May 2011).

It varied from 16, 41 to 29, 46 meq/ l in May 2011 with an average value of 23, 10meq/ l (table 2). For both periods, the all samples of the study area are Injurious to Unsatisfactory.

Kelley's ratio

A Kelley's index of more than one indicates an excess level of sodium in waters. Hence, waters with a Kelley's ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation (Deshpande S.M. and Aher K.R., 2012). Kelley's index in the present study varied from 0.42 to 0.87 with an average value of 0,67meq/ l in January 2011, in May 2011, it varied from 0,46 to 1,08 meq/ l with an average value of 0,74 meq/ l (table 2), all the samples of study area having values less than 1 and indicate good quality water for irrigation purpose while remaining one sample is more than 1 indicates the unsuitable water quality for irrigation according to Kelley's index.

Permeability index (PI)

The permeability index also indicates whether groundwater is suitable for irrigation. The soil permeability is affected by the long-term use of irrigation water as influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contents of the soil (Ben alaya, 2014).

Doneen (1964) and Ragunath (1987) used a criterion for assessing the suitability of water for irrigation based on permeability index and accordingly, water can be classified as class I, II and III. Class I and II water are categorized as good for irrigation with 75% or more of maximum permeability. Class III water is unsuitable with 25% of maximum permeability. PI values ranges from 37.14 to 53.80% in January 2011, with an average of 46.12% and the corresponding values in May 2011 ranged from 38.05 to 57.20%, with an average of 48.72%.

These values fall into the water class II which is categorized as suitable for irrigation (Table 8).

Table 8. Groundwater classification based on permeability index (Ragunath, 1987).

Based on permeability index Ragunath (1987)	Classification	Number of samples		Percentage of samples	
		January 2011	May 2011	January 2011	May 2011
>75	Safe	-	-	-	-
25 – 75	Moderate	20	20	100%	100%
<25	Unsafe	-	-	-	-

Residual sodium carbonate

The RSC was calculated to determine the hazard effects of carbonate and bicarbonate on the quality of groundwater for agricultural and irrigation purposes (Eaton 1950). According to the US Department of Agriculture, the waters having >2.5 (meq/ l) RSC are unsuitable for irrigation, 1.25-2.5 are marginal and <1.25 are safe waters. The RSC of CI groundwater ranged from -11.04 to -18.00meq/ l with an average value of -13.72meq/ l in January 2011 and the corresponding values in May 2011 ranged from -8.60 to -17.00 meq/ l with an average -12.41meq/ l (table 9). The RSC values are <1.25meq/ l and are therefore considered safe for irrigation purposes.

Table 9. Groundwater classification based on Residual sodium carbonate. (Richards, 1954).

Based on RSC after Richards (1954)	Classification	Number of samples		Percentage of samples	
		January 2011	May 2011	January 2011	May 2011
<1.25	Good	20	20	100%	100%
1.25 – 2.5	Doubtful	-	-	-	-
>2.5	Unsuitable	-	-	-	-

Table 10. Groundwater classification based on magnesium hazard.

Based on MH	Classification	Number of samples		Percentage of samples	
		January 2011	May 2011	January 2011	May 2011
< 50	Suitable	15	1	75%	5%
> 50	Unsuitable	5	19	25%	95%

Magnesium hazard

The magnesium hazard proposed for irrigation depends on alkaline earths ions Ca^{2+} and Mg^{2+} which maintain a state of equilibrium in most groundwater (Hem, 1985). Excess Mg^{2+} in groundwater during equilibrium will adversely affect the soil quality rendering it alkaline resulting in decrease of crop yield (Kumar *et al.*, 2007). MH values range from 30,49 to 60 and from 42,40 to 89,14 for to January 2011 and May 2011, respectively. The MH of CI groundwater indicates that 25% >50 and 75% <50 in January 2011; and in May 2011, 95% of the wells have MH values >50 are considered harmful and unsuitable for irrigation purposes (table 10). About 5% of the groundwater samples of the study area are safe for irrigation, as the value of the magnesium hazard in them less than 50.

Conclusion

The analytical results of groundwater samples reveal that the EC classification indicates that 80% of CI groundwater samples are doubtful for irrigation and 20% are unsuitable for irrigation. Using the Piper's approach, groundwater has been classified into three hydrochemical types seem to exist for the period January 2011 and four types for the period May 2011.

The total dissolved solids based on Davis and DeWiest (1966) classification, all groundwater samples collected from the CI are useful for irrigation. The total hardness values of the groundwater samples range from 59,40 to 106,40°F, the high TH values reveal that a majority of the groundwater samples is a very hard water category.

Irrigation waters classified Chloride has indicated that both periods have a brackish water type. According to the SAR classification, all groundwater samples in both the periods fall within excellent category for irrigation purposes in almost all soils. The Wilcox classification illustrates that the 20% of the well waters fall in the field of C3-S1 for the two periods, 25% for the period January 2011 and 35% for the period May 2011 of the well waters fall in the field of C4-S1, indicating very high salinity and low alkalinity hazard. 55% for the period January 2011 and 45% for the period May 2011 of the well waters fall in the field of C4-S2. Na%, Kelley's index, PI and RSC values suggest suitability of most water samples for irrigation purposes.

The potential salinity; the all samples of the study area are Injurious to Unsatisfactory. The MH of CI groundwater indicates that 25% >50 and 75% <50 in January 2011; and in May 2011, 95% of the wells have MH values >50 are considered harmful and unsuitable for irrigation purposes (table 10). About 5% of the groundwater samples of the study area are safe for irrigation, as the value of the magnesium hazard in them less than 50.

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