Chapter

Suitability and Assessment of Surface Water for Irrigation Purpose

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Abstract

Surface water is an important resource that can create tensions between different countries sharing the same water sources to know that the agriculture is considered as the last sector that exploits less water compared to the industry which uses very large water quantities. The future strategies of agricultural development in the most of these countries depend on the ability to maintain, improve and expand irrigated agriculture. In this light, this chapter is written in the way to show some steps of the evaluation of surface water for irrigation purpose. The results obtained from this research make it possible to evaluate the suitability of surface water for irrigation and to draw useful recommendations for dam managers and farmers.

Keywords: surface water, hydro chemical analysis, irrigation purpose, water quality index

1. Introduction

Surface water is an essential natural resource that plays a vital role in human life and has an important role in drinking, irrigation and economic sectors. According to FAO statistics, 20% of the land is irrigated but produces 40% of the crops [1]. Irrigation is an effective way to improve productivity significantly. However, there are environmental risks associated with irrigation, especially water stagnation and increased salinity. Agricultural irrigation is a factor of increase and diversification of crops. This is why its development must be encouraged in the world through agricultural, international, national and community policies [2]. For this reason, that successive governments have so far sought to harden the right to water while protecting the interests of irrigators. This strategy, if explained by the social contract that binds the state to farmers, is nonetheless debatable [3]. The priority is no longer today to increase yields among the highest in the world, but to ensure the continuity of drinking water supply services, the preservation of aquatic ecosystems and sufficient water levels to respond industrial needs. The salinity of water has increased in many watersheds around the world and the use of non-traditional resources, bet on the use of available resources, increases efficiency, waste reduction and water maintenance quality establishing surveillance networks, developing and setting standards, and enacting the necessary laws to protect them from pollution [4, 29]. The importance of developing a comprehensive strategy for water demand management appears to be a consequence of the exacerbation of the problem of scarcity of water resources due to drought, which has become more frequent with a longer duration [5]. Therefore, the main goal of this chapter is to evaluate suitability of surface water for irrigation purpose by appropriate parameters and indices in Koudiate Medouar dam in northeast of Algeria.

2. Descriptive of the study area

Koudiate Medouar dam built in 1994 on Oued Reboa is located 7 km north-east of Timgad and 35 km from Batna in Algeria (**Figure 1**). The dam is located at the east longitude 6°30′48″ and north latitude 35°30′57″. It is a reservoir dam that mobilizes the surface waters of Reboa river whose watershed covers 59,000 km^2.

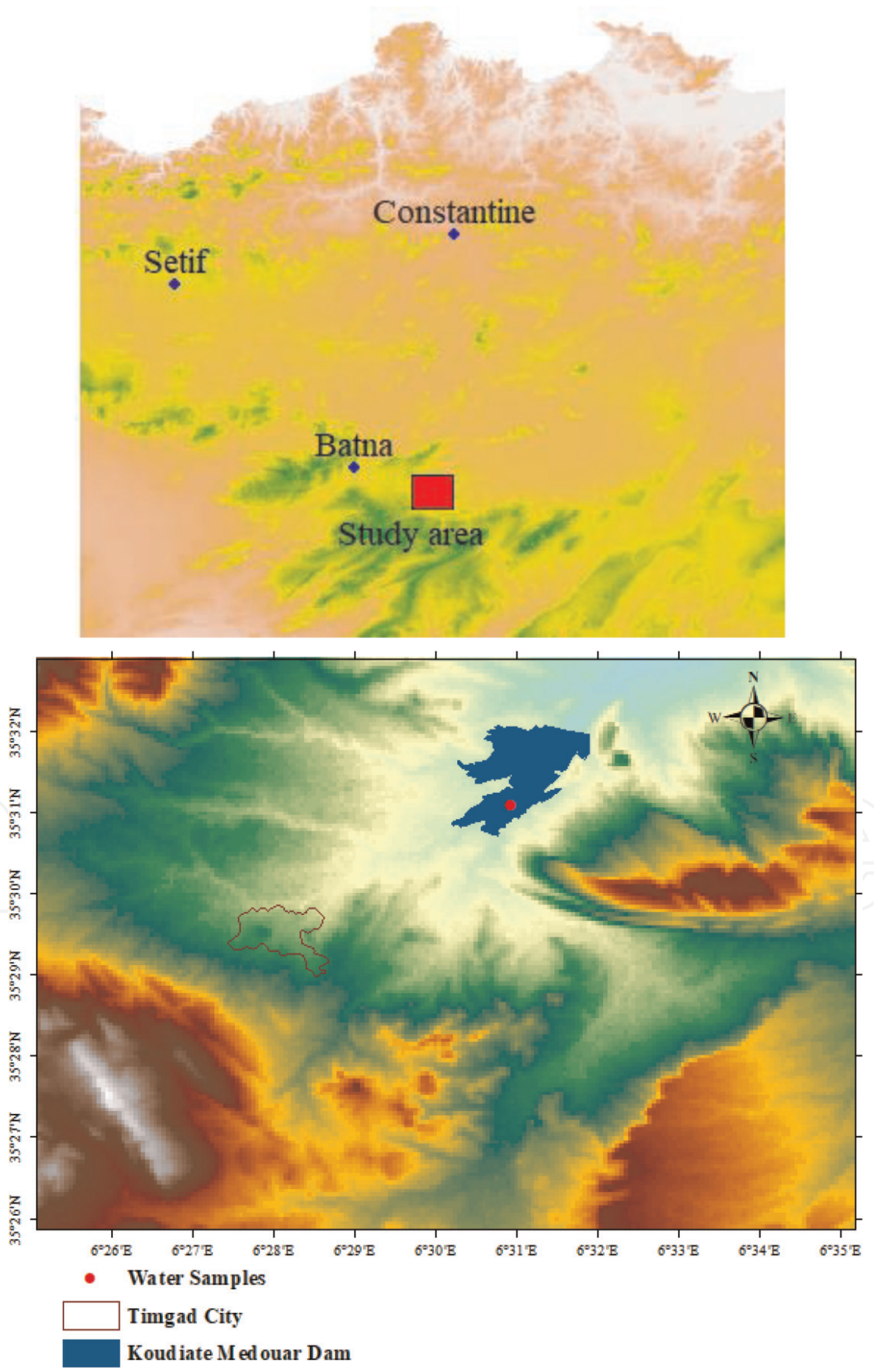

Figure 1.
Location of the study area.

About 48.72% of the population of Batna Wilaya, or 682,000 inhabitants, drink water from this dam that supplies the cities of Batna, Tazoult, Timgad, Ain Touta, Barika, Arris and Ouled Reach in the Wilaya of Khenchela. The climate of the study area is semi-arid, characterized by high temperatures and low rainfall. The average annual rainfall is about 370 mm, while the annual average temperature is around 15°C [6].

3. Methodology

3.1 Water sampling and analysis

Surface water samples collected from the dam basin during a year from February 2017 to January 2018. During water sampling, all samples were filtered on-site by 0.45-μm filter. The water samples were stored in 500-ml high-density polyethylene bottles (HDPE) for laboratory analyses. All water samples were kept at 4°C until they were analyzed with using standard methods APHA [7]. Measurements of pH and electrical conductance (EC) were carried out in field with the use of a portable multi-parameter analyzer Hem [8]. Major cations and anions including calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), sulfate (SO_4), bicarbonate (HCO_3), chloride (Cl) and nitrate (NO_3) were measured in laboratory. Total hardness (TH) and Ca were volumetrically analyzed using standard EDTA. Mg was calculated by taking the difference between TH and Ca. A flame photometer was used to estimate Na and K. HCO_3 and Cl were analyzed by titration with standard HCl and $AgNO_3$, respectively. SO_4 was determined using a turbidimetric procedure. NO_3 was analyzed using the colorimetric method. The reliability of the data set generated was verified through electrical neutrality by the following equation:

$$\text{Error of ion balance} = \frac{\sum\text{Cations} - \sum\text{Anions}}{\sum\text{Cations} + \sum\text{Anions}} \times 100 \qquad (1)$$

The analytical data were considered doubtful beyond an error of ±5% [9].

4. Results and discussion

4.1 Descriptive statistics

The statistical summary of the data used in this study is represented in **Table 1**. The results show that pH values varied from 7.4 to 7.8 with a mean of 7.5, indicating that the water is consider as a slightly alkaline water [10]. Electrical conductivity values express the amount of dissolved solids in the water sample. Water samples has EC values that ranged from 1040 to 1800 μS/cm with an average of 1349 μS/cm. EC of the surface water samples was above the fixed value of 1000 μS/cm by WHO [11]. The average values of Ca, Mg, Na and K are 94.04, 42.72, 93.92 and 1.01 mg/L, respectively. The order abundance of the major cations as follows Ca > Na > Mg > K, where the calcium and sodium are the dominate cations in surface water. The calcium values are generally upper than the limits set in WHO guides [11]. The high concentrations of Ca and Na are explained by the ion exchange process between sodium and calcium elements which leads to the precipitation of $CaCO_3$ in the soil profile. The order abundance of the major anion from the highest to the lowest is HCO_3 > Cl > SO_4 > NO_3, indicating that bicarbonate and chloride are the dominants anions in the surface water. The concentration of HCO_3 is varied from 134.2 to

Valid N	pH	EC (μS/cm)	TDS (mg/L)	Na	K	Ca	Mg	HCO_3	Cl	SO_4	NO_3
1	7.50	1080	691.20	103.30	1.26	88.18	45.48	195.22	106.50	90.00	0.6
2	7.40	1060	678.40	98.30	1.29	88.18	43.08	183.00	88.75	92.00	0.2
3	7.50	1040	665.60	95.70	1.01	88.18	45.49	183.00	88.75	91.00	0.3
4	7.40	1060	678.40	87.30	0.99	96.19	45.48	201.30	124.25	90.00	0.2
5	7.50	1100	704.00	99.50	1.00	96.19	43.08	183.00	88.75	90.00	0.3
6	7.80	1500	960.00	92.80	0.90	94.60	41.64	170.80	82.75	82.00	0.5
7	7.50	1500	960.00	92.20	0.81	93.20	42.48	170.80	80.75	78.00	0.3
8	7.40	1300	832.00	93.60	0.92	95.20	41.28	168.80	75.25	80.00	0.6
9	7.60	1800	1152.00	80.00	0.96	96.40	40.56	144.40	81.25	83.00	0.3
10	7.50	1600	1024.00	95.20	0.94	98.40	39.36	134.20	88.25	85.00	1.2
11	7.80	1800	1152.00	95.25	1.00	99.70	42.00	170.80	88.25	82.50	2.5
M	7.54	1300	832.00	95.20	0.99	95.20	42.48	170.80	88.50	85.00	0.3
SD	0.14	302	193.56	6.22	0.15	4.14	2.07	19.87	13.73	4.96	0.681
CV	1.90	22.48	22.41	6.62	14.40	4.40	4.85	11.47	15.21	5.79	107.1

M, mean; SD, standard deviation; CV, coefficient of variation (%).

Table 1.
Summary of the statistical analyses of the physicochemical parameters.

201.3 mg/L with an average of 173.21 mg/L, high concentration of this element related to the water-rock interaction process.

4.2 Determination of the origin of dissolved solids

In order to determine the origin of the highest values of some parameters in surface water the relationships between some parameters are studied.

Figure 2 shows the relationship between total cations and Ca + Mg, we see that all sample points are located below the equilibrium line 1/1 which confirms the alteration process and the exchange of alkaline ions [13].

Total cations versus Na + K is presented in **Figure 3**, we see that the samples are located below the equilibrium line 1/1, indicating that the excessive concentrations of Na and K are due to the accumulated salts in the soil during the evaporation process [13].

Na versus HCO_3 plot shows that there is a distribution of samples below and above the equilibrium line 1/1 indicating the presence of dissolution of the rocks during the infiltrations (**Figure 4**).

The chloride versus sodium plot (**Figure 5**) is employed to verify the relationship and sources of the ions in surface water. A Cl/Na ratio equal one is typically characteristic of halite dissolution, whereas values <1 implies the alkali metal is released from silicate weathering reactions [12, 13].

4.3 Suitability of surface water for irrigation

The evaluation of the water surface suitability of the study area for irrigation was carried out using total dissolved solids (TDS), total hardness (TH), electrical conductivity (EC), the sodium adsorption rate (SAR), the percentage of sodium (%Na), residual sodium carbonate (RSC), the permeability index (PI), the salinity

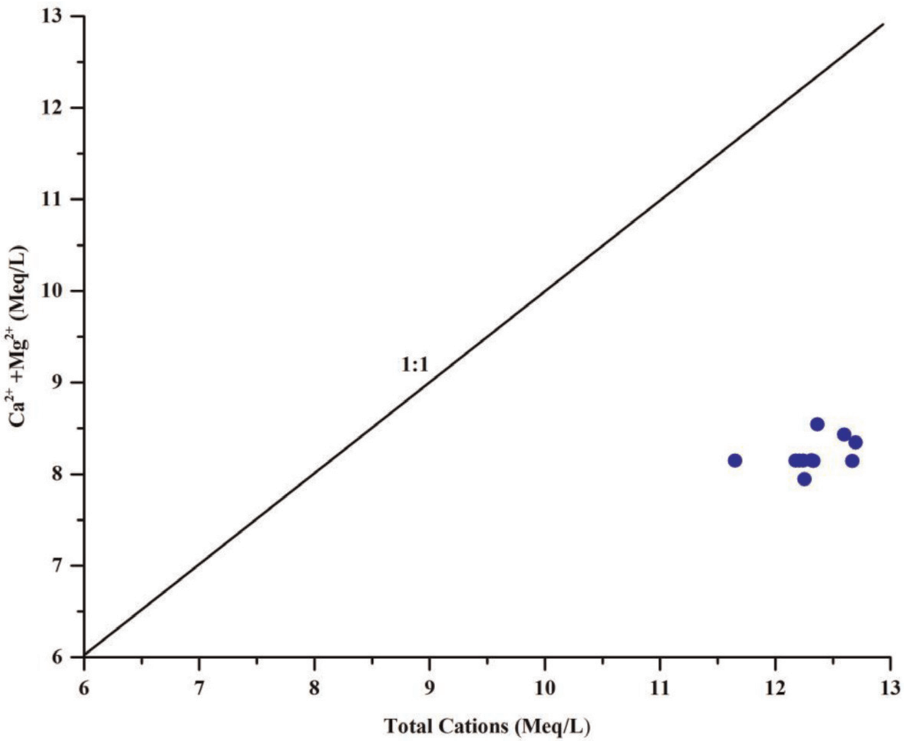

Figure 2.
Relations between the total cations and Ca^{2+} with Mg^{2+}.

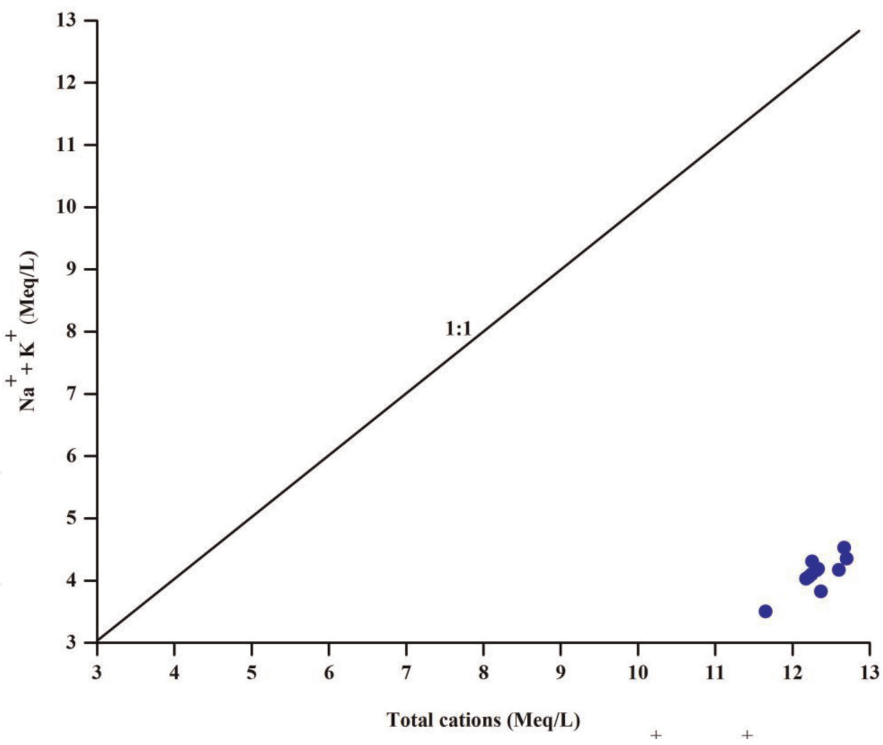

Figure 3.
Relations between the total cations and Na^+ with K^+.

index (PS), the soluble sodium percentage (SSP), the magnesium adsorption rate (MAR), and Kelly's ratio (KR). The results are presented in **Tables 2–4**.

4.3.1 Total dissolved solids (TDS)

Total dissolved solids (TDS) is calculated by the following equations:

$$TDS = 640 \times EC \quad (\text{for EC} < 5\ \text{dS/m}) \tag{2}$$

$$TDS = 640 \times EC \quad (\text{for EC} > 5\ \text{dS/m}) \tag{3}$$

The results showed that the values of TDS varied from 665 to 1152 mg/L with an average 863 mg/L (**Table 2**). This large variation of TDS values in surface water samples is classified in the high saline water zone and the water samples contain

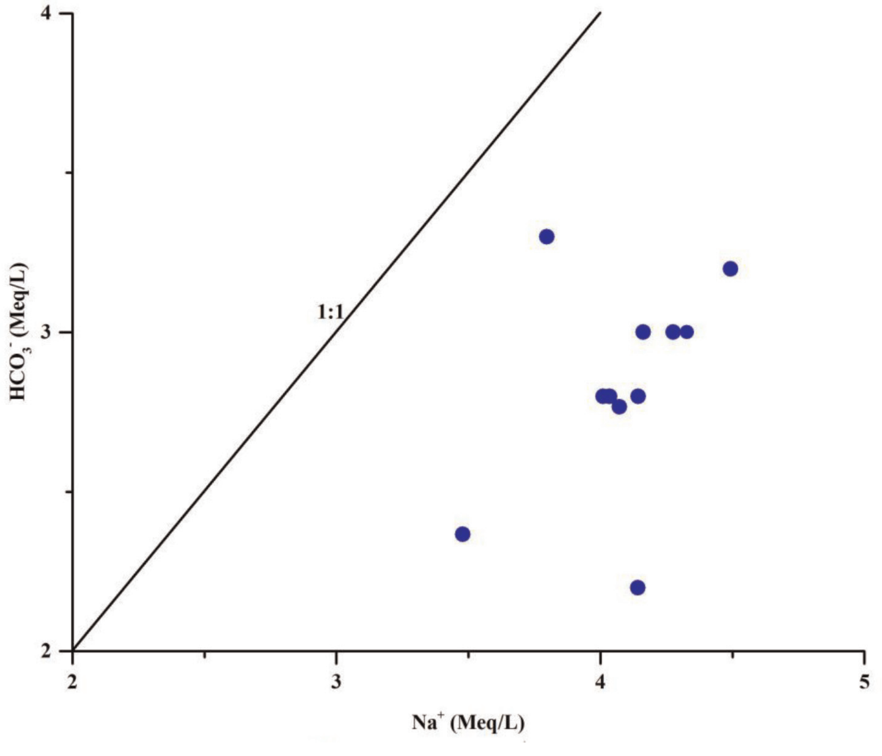

Figure 4.
Relation between: Na^+ versus HCO_3^-.

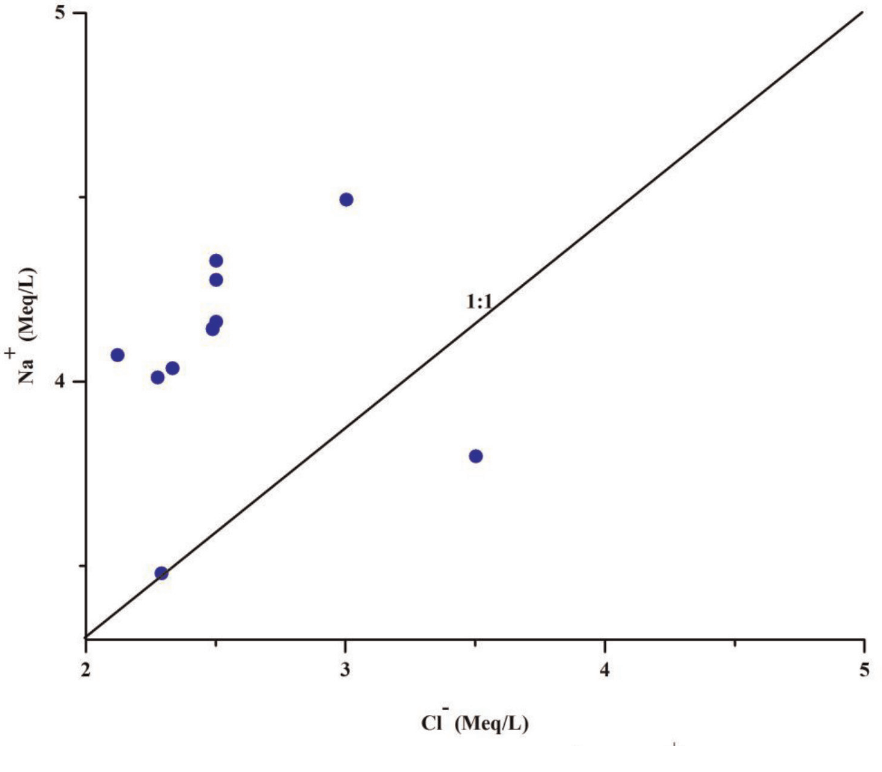

Figure 5.
Relation between: Cl^- versus Na^+.

Parameters	Mean	Median	Minimum	Maximum	Std. dev.	Coef. var.
TDS	863.418	832.0100	665.600	1152.000	193.561	22.418
TH	413.098	410.000	399.950	429.975	8.348	2.021
%Na	40.942	40.917	37.152	43.893	1.918	4.685
RSC	37.889	36.220	−1.560	62.960	20.109	53.075
SAR	4.017	4.006	3.418	4.468	0.286	7.128
KR	0.687	0.686	0.584	0.773	0.054	7.795
MH	31.260	30.933	28.571	34.033	1.807	5.782
PI	46.382	46.223	42.412	49.490	1.958	4.222
PS	99.576	97.470	84.194	133.737	13.901	13.961
MAR	31.260	30.933	28.571	34.033	1.807	5.782
SSP	68.241	68.123	58.003	76.563	5.265	7.715

Table 2.
Summary of the statistical analyses of the irrigation parameters.

Parameters	Desirable permissible [15]	Irrigation [16]
EC	–	1000
TDS	500–2000	–
TH	300–600	712
All major ions and TDS are expressed in mg/l while pH on scale and EC in μS/cm.		

Table 3.
Standards used for drinking and irrigation suitability and relative weight for each parameter.

different amounts of major ions [14] (**Table 4**). The large variation of TDS values can be attributed to the variation in the hydrological processes and geological formations in the study area. 36.36% of the total water samples are classified in the good water class while 63.63% of the total samples are represented a permissible water quality with an estimated SD value of 193.53 (**Table 4**). No prescribed value limits the threshold for TDS in irrigation waters (**Table 3**).

4.3.2 Total hardness (TH)

Total hardness is defined as the sum of calcium and magnesium using the following equation:

$$TH = \left[\left(2 \times \frac{Ca^{2+}}{40}\right) + \left(2 \times \frac{Mg^{2+}}{24}\right)\right] \times 50 \tag{4}$$

where Ca and Mg concentrations are in meq/L.

The values of TH varied from 399 to 429.97 mg/L with an average of 413 mg/L (**Table 2**) where the maximum value is below the prescribed limit for irrigation water of 712 mg/L (**Table 3**). The majority of water samples showed TH values are below the standard values used for drinking and irrigation suitability BIS [15] and FAO [16]. The low values of TH are probably due to the presence of alkaline earth ions (Ca and Mg) of weak acids (HCO_3 and CO_3) and strong acids (Cl, SO_4 and NO_3) [30, 31]. Therefore, low alkalinity values reflect immature hydrochemistry of

Classification scheme	Categories	Range (mg/L)	Percentage	Number of samples
Total dissolved solid (TDS)	Excellent	<450	0	0
	Good	450–750	4	36.36
	Permissible	750–2000	7	63.63
	Unsuitable	>2000	0	0
Total handers (TH)	Soft	<75	0	0
	Moderately hard	75–150	0	0
	Hard	150–300	0	0
	Very hard	>300	11	100
Electrical conductivity (EC) in μS/cm	Excellent	<250	0	0
	Good	250–750	0	0
	Permissible	750–2250	11	100
	Unsuitable	>2250	0	0
Permeability index (PI)	Excellent	>75	0	0
	Good	25–75	11	100
	Unsuitable	<25	0	0
Salinity potential (SP)	Excellent to good	<5	0	100
	Good to injurious	5 10	0	0
	Injurious to unsatisfactory	>10	11	0
Magnesium absorption ratio (MAR)	Acceptable	<50	11	100
	Non-acceptable	>50	0	0
Kelly's ratio (KR)	Suitable	<1	11	100
	Unsuitable	>1	0	0
Sodium absorption (SAR)	Excellent	<10	11	100
	Good	10–18	0	0
	Fair	>18–26	0	0
	Poor	>26	0	0
	Hard	>200–300	0	0
	Very hard	>300	0	0
Sodium percentage (%Na)	Excellent	Up to 20	0	0
	Good	>20–40	1	9.09
	Permissible	>40–60	10	90.9
	Doubtful	>60–80	0	0
	Unsuitable	>80	0	0
Residual sodium carbonate (RSC) in meq/L	Good	<1.25	1	100
	Medium	1.25–2.5	0	0
	Bad	>2.5	10	0
Soluble sodium percentage (SSP)	Excellent	0–20	0	0
	Good	20–40	0	0
	Permissible	40–60	0	100
	Doubtful	60–80	11	0
	Unsuitable	>80	0	0

Classification scheme	Categories	Range (mg/L)	Percentage	Number of samples
Irrigation water quality index (IWQI)	Excellent	85–100	0	0
	Good	70–85	11	100
	Poor	55–70	0	0
	Very poor	40–55	0	0
	Unsuitable for irrigation use	0–40	0	0

Table 4.
Classification schemes for surface water quality indicators.

surface water during seepage and hypodermic flow [17]. The water of the Dam is classified as a very hard water (**Table 4**).

4.3.3 Electrical conductivity (EC)

Wilcox [18] proposed a diagram with respect to a combination of EC and %Na for judging suitability of water quality for irrigation. The diagram is divided into five zones, which are excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable, with increasing salinity hazard and sodium hazard for irrigation.

The results show that EC values of the most water samples represented high saline water for irrigation use which are due to the high concentrations of ions in surface water (**Tables 3** and **4**). Moreover, the EC value which 100% of the surface water in the study area represents permissible water and greater than the value fixed by FOA for irrigation water (EC > 1000 μS/cm).

4.3.4 Sodium adsorption ratio (SAR)

The United States Soil Laboratory Staff (USSLS)'s diagram in Richards [19] illustrates the combined effect of EC, SAR and percent sodium (%Na), residual sodium carbonate (RSC) in the classification of irrigation water quality which, divided into four shared areas between EC and SAR: C1S1 to C1S4, C2S1 to C2S4, C3S1 to C3S4 and C4S1 to C4S4. The salinity hazard classes that have been classified into four classes: low salinity hazard class (C1) with an EC value less than 250 μS/cm; medium salinity risk class (C2) with EC value between 250 and 750 μS/cm; high salinity risk class (C3) with EC value between 750 and 2250 μS/cm; and a very high salinity risk class (C4) with an EC value greater than 2250 μS/cm.

The SAR values varied from 3.41 to 4.46 mg/L with an average of 4.01 mg/L where the water samples are classified in the excellent class of water suitable for irrigation according to the Richard and Wilcox irrigation water quality classification (**Tables 2** and **4**).

The result of the effect of ion exchange processes on soil quality and its capacity in terms of sodium uptake is expressed by the SAR which is calculated by the following equation:

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

where all ions concentration is in meq/L.

The calculated SAR value expresses that all water samples are classified in the best water range. **Figure 6** shows that all surface water samples are located in the C3S1 zone.

Figure 7 illustrates the Wilcox diagram [18] which highlights the combination of EC and %Na for judging suitability of water quality for irrigation. The diagram is divided into five zones, which are excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable, with increasing salinity hazard and sodium hazard for irrigation. From **Figure 7**, we see that all water samples are classified in the good to permissible water categories, which is reflected by the EC value which shows more than 100%. Water from the study area is permissible distributed between 750 and 2250 μS/cm (**Table 4**).

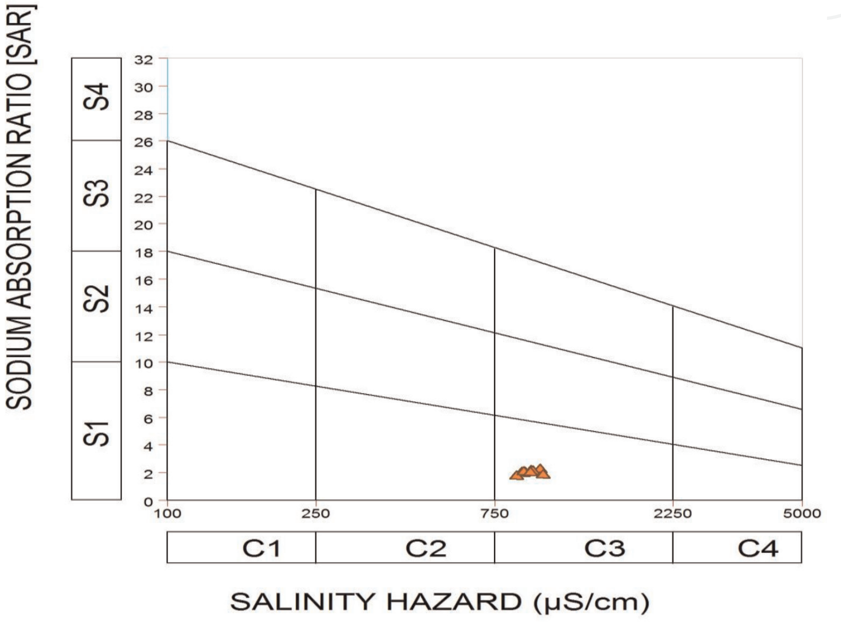

Figure 6.
Classification of Richards [19]. EC versus SAR.

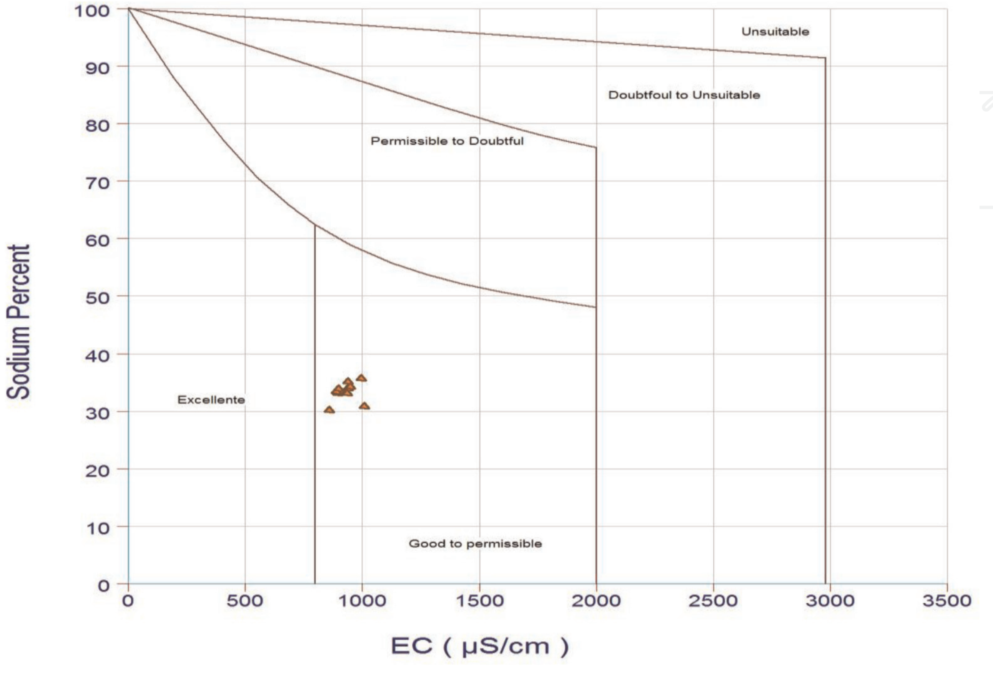

Figure 7.
Classification of Wilcox [18]. EC versus %Na^+.

4.3.5 Parentage sodium (%Na)

The values of %Na varied from 37.15 to 43.89 mg/L with an average of 40.94 mg/L (**Table 2**). The water samples are classified in the class good to permissible for irrigation water (**Figure 6**). This variation could be due to the size of the samples, the geological factor, the type of soil, the anthropic activities and the addition of chemical fertilizers, the climatic factor, and the dissolution of the minerals of the lithological composition [20].

Therefore, Eq. (6) shows another way to determine the sodium risk ratio when calculating the sodium ratio (%Na) in order to determine the water quality for irrigation uses.

$$\%Na = \frac{(Na^+ + K^+) \times 100}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \quad (6)$$

The values of %Na express that 9.09% of the total water samples are classified in the good water category and 90.9% in the permissible water category (**Table 4**).

4.3.6 Residual sodium carbonate

RSC is a very important parameter in the study of suitability water for irrigation. The RSC is calculated using the equation given below in Eston [21]:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \quad (7)$$

where the concentrations are reported in meq/L.

The values of RSC varied from −2.33 to −4.68 meq/L with an average of −3.50 meq/L (**Table 2**). The water samples are classified in the category of good water irrigation according to the recommendations of Eaton [21] and Arslan [22]. In addition, the values of RSC calculated by Eq. (7) for all samples are classified in the good zone (**Table 4**).

4.3.7 Permeability index (PI) and salinity index (PS)

The permeability index (PI) of surface water for irrigation, which in turn is influenced by Na, Ca, Mg and HCO_3 concentration. PI is defined by the following equation:

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100 \quad (8)$$

The salinity index (PS) is defined as the chloride concentration plus half of the sulfate concentration [33]. PS is computed using the equation bellow:

$$PS = Cl^- + \sqrt{SO_4^{2-}} \quad (9)$$

where the concentrations are reported in meq/L.

The values of PI and PS ranged from 42.41 to 49.49 and 84.19 to 133.73 mg/L with an average of 46.38 and 99.57 mg/L, respectively (**Table 2**). The PI and PS for all water samples are classified in the type of water good to excellent and good, respectively (**Table 4**).

4.3.8 Soluble sodium percentage (SSP)

Soluble sodium percentage (SSP) is an important parameter to assess the hazard towards irrigation. SSP is defined by Todd [23] as shown below:

$$SSP = \frac{Na^{+}}{\left(Ca^{2+} + Mg^{2+} + K^{+}\right)} \times 100 \tag{10}$$

where the concentrations are reported in meq/L.

The values of soluble sodium percentage (SSP) varied between 58 and 76.56 mg/L with an average 68.24 mg/L. The calculation of SSP using Eq. (10) reflects that all water samples are classified in the permissible waters area (**Table 4**).

4.3.9 Magnesium adsorption rate

The magnesium adsorption rate (MAR) is expressed in terms of magnesium hazard (MH), which is computed by Eq. (11) in Raghunath [24], using the values of ions in meq/L.

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \tag{11}$$

The computed values of magnesium hazard from the surface water of the study area are in between 28.57 and 34.03 mg/L (**Table 2**). The majority of the water samples of the study area are less than 5 and hence they are safe for irrigation purpose (**Table 4**).

4.3.10 Kelly ratio

The Kelly's ratio (KR) indicates the degree and the potential effect of sodium on water quality for irrigation.

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \tag{12}$$

where the concentrations are reported in meq/L.

The results show that the values of Kelly ratio varied from 0.58 to 0.77 mg/L with an average of 0.68 mg/L (**Table 2**).

Kelly ratio of more than 1 indicates an excess level of Na in water. Kelley [25] suggested that the ratio for irrigation water should not exceed 1. All water samples in the study area fall in suitable water type, indicating that there is no significant excess of sodium in the surface water [29] (**Table 4**).

4.4 Irrigation water quality index (IWQI)

The surface water quality index method for irrigation is a very important tool in determining the overall impact of the various parameters that are used as a single variable. In addition, the method of the surface water quality index for irrigation is considered a very satisfactory way to measure and classify the adequacy of surface water quality for irrigation as unique parameters. Taking into account various water quality variables. In this study, the IWQI model was developed by combining the eight water quality parameters (SAR, RSC, %Na, EC, pH, TDS, Na and Cl), which is based on the recommendations of Amanuel Gidey [26], Meireles et al. [27] and

Parametres	W_{cv}	Q_{rv}	$W_{cv} \times Q_{rv}$
EC	0.000444444	59.95555556	0.026646914
pH	0.117647059	88.58823529	10.42214533
TDS	0.0005	43.1705	0.02158525
%Na	0.011111111	45.48888889	0.505432099
SAR	0.038461538	15.38461538	0.591715976
RSC (meq/L)	0.005882353	21.76470588	0.128027682
Cl	0.01	90.31	0.9031
Na	0.014285714	134.1714286	1.916734694
HCO_3 (meq/L)	0.001639344	28.39508197	0.046549315
Total	0.199971564		14.56193726
IWQI	72.82003972		

Table 5.
The relative weight of hydrochemical parameters in the study area.

Hussain et al. [28]. The irrigation water quality index is calculated by the following equations:

$$Q_{rv} = \frac{C_v}{RS_v} \times 100 \tag{13}$$

Q_{rv} represents the quality rating values, C_v stand for the observed concentration values.

$$W_{cv} = \frac{1}{RS_v} \tag{14}$$

W_{cv} represents the stands for the relative weight coefficient of the parameters, RS_v stands for the recommended standards values of the water quality variable.

$$IWQI = \frac{\sum_{i=1}^{n} W_{cv} \times Q_{rv}}{\sum_{i=1}^{n} W_{cv}} \tag{15}$$

where IWQI represent for water quality index, is a dimensionless parameter ranging from 0 to 100, and *n* stands for the number of water quality variables.

The Irrigation Surface Water Quality Index was calculated by Eqs. (13)–(15) and these values are shown in **Tables 4** and **5** and are compared to the irrigation water quality parameters proposed by University of California Committee of Consultants, Meireles et al. [27], and Mohamed et al. [32]. The values of IWQI ranged between 85 and 100 have no restriction for irrigation water, so values between 70 and 85 have low water, and 55–70 reflects the moderate water area, 40–55 high tolerance crops can grow, and 0–40 this unsuitable for all for all crops.

The IWQI values ranged between 70 and 85 with an average of 78.11 indicating the good waters area.

5. Conclusion

In this chapter, surface water quality and its suitability for irrigation in Koudiate Medouar dam as an example were examined. All samples are suitable for irrigation, and appropriate management measures are suggested to safeguard this resource and improve its quality.

6. Recommendation

Surface water represents a very important source for all consumptions, however it must be preserved, for the moments of crisis especially during the dry years, so it should not be used by farmers and industries, a better management by rational and optimal use must be taken into account by future generations.

In this perspective, the following suggestions have been made:

- Uncontrolled use of agricultural chemicals by farmers where stricter controls are needed to prevent contamination of surface water which in turn affects groundwater during of infiltrations.
- Improved soil texture, soil and water salinity are key factors that need to be controlled and monitored accordingly improvements require deep soil drainage, leaching and drip irrigation.
- Periodic sampling allows taking adequate, appropriate, and consistent measures at the appropriate time to deal with any possible contamination.
- Dam managers must make the public and all farmers aware of water quality forget to implement the appropriate management measures to improve the quality of groundwater.

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