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Suitability of Cheffia dam surface waters for irrigation (El Tarf area)

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Abstract

El Tarf area has an agricultural vocation, an activity depending on much water to meet the needs of a variety of cultures. Water intended to irrigation must exhibit physicochemical features tolerable by crops. Even under humid climate, the recourse to irrigation is inevitable for most cultures. Superficial waters are then more and more required. Ahydrochemical study focusing on major elements of Cheffia dam waters has been carried out. 24 sampling have been performed during two months (2015/2016); the study findings show that surface waters are fresh and marginally miner alized; they are marked by medium salinity, so they are of good quality for agriculture.

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Introduction

The water is an indispensable element in the life and is of importance for several human activities. It may be scarce in some places, such as arid and semi-arid zones or relatively in abundance in the forest areas. Agriculture, in a general way is a large consumer of water and particularly when it is practiced in the dry season and often comes to miss. To palliate for this disadvantage, the best way that the men have found so far has been a technical mastery of water, with the help of various processes. It is this additional water that is called irrigation (Bouaroudj, 2012). The quality of the irrigation water varies as a function of anthropogenic activities of the soil and its use. It is certain that the increase in the demand for water for human activities will intensify the constraints on this resource (Gouaidia, 2008). These resources, following the regions from which they are derived, and their possible contact with sources of pollution have characteristics very diversified. Studies have been conducted in some countries and have treaty the quality of groundwater and surface water to use in agriculture. In Algeria (Douaoui and Hartani, 2007; Bouhlassa *et al.*, 2008; Rouabhia and Djabri, 2010) studied the quality of waters and have shown that the irrigation practices increase the risk of salinization, to the point that more than 20 per cent of irrigated soils are affected by a salinity problem. Ben Abbou *et al.*, (2014) have indicated that the quality physico-chemical and microbiological examination of water used for irrigation of crops in the city of Taza in Morocco does not always respond to the criteria for the use of these waters in the irrigation. In Côte d'Ivoire, the work of Oga *et al*, (2015) showed that 67% of groundwater sampled in the region of Katiolaare conducive to irrigation, with the exception of a few points located in the south-east.

Suitability of water for irrigation can be assessed not only from the total concentration of salt, but also from the type of salt and ions constituting it. It is then essential to study the parameters defining the characteristics of waters intended to irrigation (Rouabhia, 2006). This study aims to investigate the hazards of soils alkalinization and salinization of wadi Bounamoussa sub-basin in EL Tarf region (Algeria) from irrigation surface waters of Cheffia dam. The criteria as dry residue (DR), osmotic pressure (π), sodium adsorption rate (SAR), exchangeable sodium percentage (ESP), potential salinity (PS), magnesium hazard and Wilcox diagram have been used to describe waters alkalinization power.

Materials and methods

Study Area Presentation

Geographical location

Cheffia dam is situated on Bounamous sawadi, located about 50 Km southeast of Annaba city and covers a catchment of 579 Km² (Fig. 1); it is intended to the supply of water to the localities of Annaba region: El Bouni, Seraidi, El Hadjar, Sidi Amar and Ain Berda and to the localities of EL Tarf region: Hammam Beni Salah, Bouhadjar, Oued Zitoun, Ain Kermaand Zitouna to the industrial complexes (specifically El Hadjar industrial complex) and to the irrigation of wadi Bounamoussairri gated perimeter. Cheffia dam also helps prevent Bounamous sawadi floods (Bahroun, 2016b).

Sampling sites

In order to control the suitability of Cheffia dam surface water for irrigation purposes, we have performed a monthly monitoring during the years 2015 and 2016, at the rate of one sample for the dam raw waters. In total, 24 samples have been taken from Cheffia dam at a depth of 15 to 30 cm below water surface, avoiding air penetration. The sample is carried from the sampling point to the lab in a 4°C cooler (Bahroun, 2016a).

Samples analysis

Water samples have been collected according to Rodier techniques (2009) and AFNOR standards.

The studied water analysis and detectable compounds have been carried out by means of the following procedures:

Electrical conductivity (EC) has been measured in situ. Chemical parameters Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, and HCO3 and CO_3 have been analyzed at the central laboratory of Annaba.

Data treatment method

There are many criteria of quality control of waters intended to agricultural activity. In the case of our study, we have used the seven quality parameters such as dry residue (DR), osmotic pressure (π), sodium adsorption rate (SAR), exchangeable sodium percentage (ESP), potential salinity (PS), magnesium hazard (MH) and Wilcox diagram. These methods describe alkalinizing power of waters; they are used in combination to assess the potential hazard of soil desalination in order to control the negative effects of irrigation waters on soils and crops.

Dry residue (DR) and osmotic pressure (π)

The primordial effect of total salinity consists in reducing the cultures growth and their yields (N'diaye *et al*, 2010; Rouabhia *et al*, 2010); it is generally expressed by the overall mineralization or electrical conductivity (EC); this latter is linked to dry residue (DR) and osmotic pressure by the equations 1 and 2used by Rouabhia and Djabri (2010).

$$\mathrm{DR}\ (\mathrm{mg/l}) = 0{,}7 \times \mathrm{CE}\ (\mu\mathrm{S/cm})\ (1)$$

$$\pi(\mathrm{atm}) = 0{,}00036 \times \mathrm{CE} \quad (2)$$

Sodium adsorption rate (SAR)

Alkalinity hazard is generally expressed by sodium adsorption rate (SAR). This parameter quantifies sodium ions proportion (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) in a water sample. It should be noted that Na^+ plays a negative role in the soil since it reacts with the soil by decreasing its permeability and so by stopping waters circulation; its presence in the soil increases the clay particles volume, thereby leading to an obstruction of the pores between the particles. When a soil is rich in Na^+ and SO_4^{2-} and its dominant anion is CO_3^{2-}, this is an alkaline soil. If soil is rich in Na^+ and SO_4^{2-}, orin Cl-, this is a salt. However, in both cases, the crops bear less such a soil. SAR calculation allows assessing the probable degradation of the soil structure and the alteration of its physical qualities. Sodium adsorption rate SAR has been calculated from the equation 3 proposed by Richard (1954):

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\mathrm{Ca}+\frac{\mathrm{Mg}}{2}}}(3).$$

In this SAR formula, sodium adsorption rate (SAR), Na^+, Ca^{2+} and Mg^{2+} concentrations are expressed in méq l^{-1}.

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). Wilcox recommends also considering conductivity, i.e. water salinity, hazard of soil alkalinization and harmful elements concentrations for crops, notably boron. In fact, high salt contents, sodium and boron are harmful for crops. For this reason, Wilcox proposes five classes of water for agriculture, in function of the three elements, namely, conductivity, Na% and boron. Sodium percentage is calculated as (equation 4):

$$\mathrm{Na}\ \% = \left[\frac{(\mathrm{Na}+\mathrm{K})}{(\mathrm{Ca}+\mathrm{Mg}+\mathrm{Na}+\mathrm{K})}\right] \times 100\ (4)$$

In this formula, Ca^{2+}, Mg^{2+}, Na^+ and K^+ concentrations are expressed in méq.l^{-1}.

Exchangeable sodium percentage (ESP)

Sodium concentration in irrigation waters impacts soil permeability and infiltration. The presence of Na^+ has harmful effects on the soil structure by clay dispersion. Exchangeable sodium percentage (ESP) is calculated from the following equation 5 (Rouabhia *et al*, 2010).

$$\mathrm{ESP} = 100 \times \frac{[b(\mathrm{SAR})-a]}{1+[b(\mathrm{SAR})-a]}\ (5)$$

Wherea = 0, 0126et b = 0, 01475.

Potential salinity (PS)

Doneen potential salinity is given by the formula of equation 6:

$$\mathrm{PS} = \mathrm{Cl}^- + \frac{1}{2}\mathrm{SO}_4^{2-}(6)$$

In these formulas, contents of different ions are expressed inméq. l^{-1}.

Kelly ratio or Kelly coefficient (KR)

Kelly coefficient is provided by the following expression (equation 7):

$$\mathrm{KR} = \frac{\mathrm{Na}}{\mathrm{Ca}+\mathrm{Mg}}\ (7)$$

Na^+, Ca^{2+}, Mg^{2+} are expressed in méq.l^{-1} (Kelly, 1957 and 1963).

Water quality is good for irrigation when Kelly ratio is lower than one.

Magnesium hazard (MH)

Magnesium hazard (MH) is calculated as follows (equation 8):

$$MH = \frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}} \times 100 \quad (8)$$

MH > 50 is considered as harmful and unfit for irrigation.

Permeability index (PI)

Recent studies have indicated that soil permeability depends on many other factors such as water total concentration, sodium amount, bicarbonate concentration and the nature of soil itself (Tampo, 2015); the first three terms are combined in one single formula giving what we call permeability index (PI) defined by (Doneen, 1962):

$$PI = \frac{Na^{+}+\sqrt{HCO_3}}{Ca^{2+}+Mg^{2+}+Na^{+}} \times 100 \quad (9)$$

Where all terms are expressed inméq.l^{-1}.

Residual sodium carbonate (RSC)

Residual sodium carbonate is calculated as follows (Baricket *et al*, 2014):

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)(10)$$

Results and discussion

Study of water quality for irrigation

The measured conductivities range from 389 to 265µs.cm^{-1}, with a mean of 334.83µs.cm^{-1}in 2015 and from 453 to 349µs.cm^{-1}, with a mean of 394.33µs.cm^{-1}in 2016. In the whole, waters of Cheffia dam display a mean salinity comprised between 250 and 750µs.cm^{1}, sothe estimated soluble salts in corresponding Na Clare comprised between 160 and 500 mg.l^{-1}. The findings of different water quality parameters for agricultural purposes in the study area are reported in table 1.

Dry residue (DR) and osmotic pressure (π)

Osmotic pressure and dry residue vary in function of electrical conductivity. The categories are similar to those of electrical conductivity of waters for agricultural purposes (Table 2). DR of raw water ranges from 272.3 to 185.5mg.l^{-1}, with a mean of 234.4 mg.l^{-1} in 2015 and from 317.1 to 244.3mg.l^{-1}, with a mean of 276mg.l^{-1} in 2016. As regards osmotic pressure, it is comprised between 0.140 and 0.095 at m, with a mean of 0.121 at min 2015 and from 0.163 to 0.216 at m, with a mean of 0.142 at min 2016, 100% of sampled waters are marked by low salinity.

Sodium adsorption rate (SAR)

SAR of waters varies from 1.24 to 0.76méq.l^{-1}, with a mean of 0.97méq.l^{-1} in 2015 and from 0.87 to 0.55méq.l^{-1}, with a mean of 0.69méq.l^{-1} in 2016. SAR values calculated allow to isolate only one category: excellent quality water with low-alkalinizationh azard (Table 3).

Table 1. Results of different water quality parameters for agricultural purposes in 2015/2016.

Sampling station	DR (mg.l^{-1})	π (atm)	SAR (méq.l^{-1})	Na (%)	ESP	PS (méq.l^{-1})	KR (méq.l^{-1})	MH	PI (%)	RSC (méq.l^{-1})
Year 2015										
January	242.9	0.125	0.85	26.51	- 0.01	1.45	0.34	7.6	41.75	- 2.60
February	224.0	0.115	1.06	34.76	0.31	1.42	0.50	7.6	55.50	- 1.70
March	185.5	0.095	1.09	35.27	0.34	0.90	0.52	7.6	57.30	- 1.59
April	224.0	0.115	1.02	32.30	0.24	1.37	0.46	7.6	51.50	- 1.95
May	236.6	0.122	1.07	37.00	0.32	1.55	0.55	7.6	61.74	- 1.30
June	238.0	0.122	0.96	33.57	0.15	1.78	0.48	7.6	57.55	- 1.44
July	214.9	0.111	1.00	34.52	0.22	1.57	0.50	7.6	58.52	- 1.43
August	221.2	0.114	1.01	33.13	0.24	1.32	0.47	7.6	53.88	- 1.76
September	227.5	0.117	0.79	29.00	- 0.10	1.38	0.37	7.6	49.90	- 1.74
October	262.5	0.135	1.24	37.56	0.57	1.96	0.59	7.6	59.42	- 1.60
November	263.2	0.135	0.80	27.86	- 0.08	1.60	0.36	7.6	47.49	- 1.93
December	272.3	0.140	0.76	26.15	- 0.14	1.52	0.33	7.6	43.92	- 2.17
Year 2016										
January	280.0	0.144	0.73	24.47	- 0.18	1.46	0.31	19.66	40.49	- 2.44
February	286.3	0.147	0.63	21.40	- 0.33	1.44	0.26	21.52	35.76	- 2.71
March	244.3	0.126	0.73	24.73	- 0.18	1.26	0.31	21.38	41.02	- 2.40
April	278.6	0.143	0.64	22.40	- 0.31	1.59	0.28	09.30	39.68	- 2.28
May	280.0	0.144	0.67	21.98	- 0.27	1.46	0.27	24.46	37.06	- 2.66
June	254.1	0.131	0.64	23.37	- 0.32	1.27	0.29	03.47	42.94	- 1.98
July	266.0	0.137	0.55	20.31	- 0.46	1.44	0.24	09.90	38.27	- 2.16
August	252.0	0.130	0.87	28.04	0.02	1.34	0.36	08.57	43.92	- 2.42
September	269.5	0.139	0.71	25.12	- 0.21	1.54	0.31	12.21	41.72	- 2.28
October	272.3	0.140	0.72	24.12	- 0.19	1.62	0.30	17.02	39.78	- 2.50
November	312.2	0.161	0.67	22.03	- 0.27	1.48	0.27	13.63	37.15	- 2.65
December	317.1	0.163	0.66	24.13	- 0.28	1.43	0.30	03.31	42.42	- 2.09

Table 2. Water quality in agriculture in function of DR and π.

	Class	DR (mg/l)	π (atm)	Water quality	Waters percentage
2015 and 2016	C2	175 <DR< 525	0.09 <π< 0.27	Low-salinity water	100 %

Table 3. Water quality in agriculture in function of SAR.

	Class	SAR value	Water quality	Waters percentage
2015 and 2016	S1	< 10	Excellent quality water with low alkalinization hazard	100 %

Conductivity values lead to one single category C2: medium-salinity water (Table 4). In 2015 and 2016, 100% of sampled surface waters are marked by medium salinity. Considering conductivity evolution with respect to SAR, sampled waters belong to only one category: C2S1 (Table 4).

Suitable water for irrigation of most of cultures, but attention should be paid to leaching, difficult in marginally permeable soils and to drainage.

Sodium percentage: (Na %)

In our investigation, given that boron has not been dosed, we deal only with conductivity and Na % (Table 5). In 2015, sodium percentage of sampled waters ranges from37.56 to 26.15 %, with a mean of 32.20 %and from 28.04 to 20.31 %, with a mean of 23.51 % in 2016. Wilcox diagram relating to sodium percentage and conductivity shows that 100% of sampled surface waters fall into excellent quality water class

Table 4. Water quality for irrigation from conductivity evolution with respect to SAR.

	Class	Conductivity (µs/cm)	Water quality	Waters percentage
2015 and 2016	C2	250 < C < 750	Low-salinity water	100 %
		Characteristics		
2015 and 2016		C2S1		100 %
C2S1	Suitable water for irrigation of most cultures, but attention should be paid to leaching, difficult in marginally permeable soils, and to drainage..			

Table 5. Water quality for irrigation from Na% evolution.

	Class	Na%	Water quality	Waters percentage
2015 and 2016	C2	20 < Na < 40	Excellent quality water for agriculture	100 %

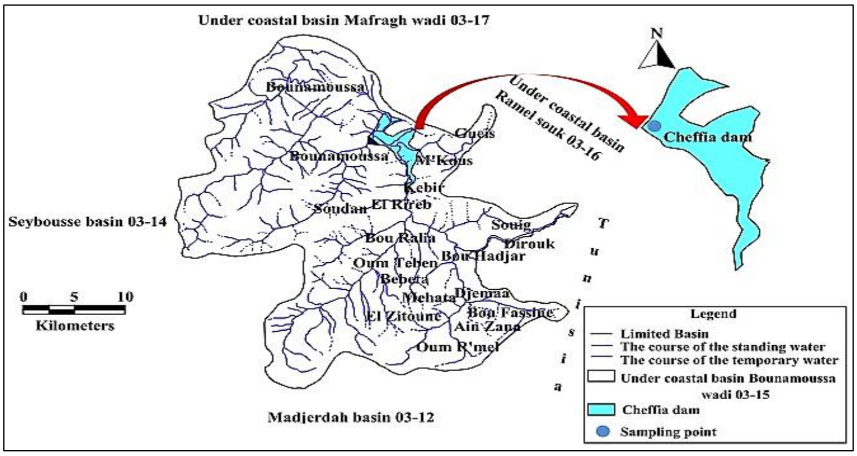

Fig. 1. Location of the dam Cheffia.

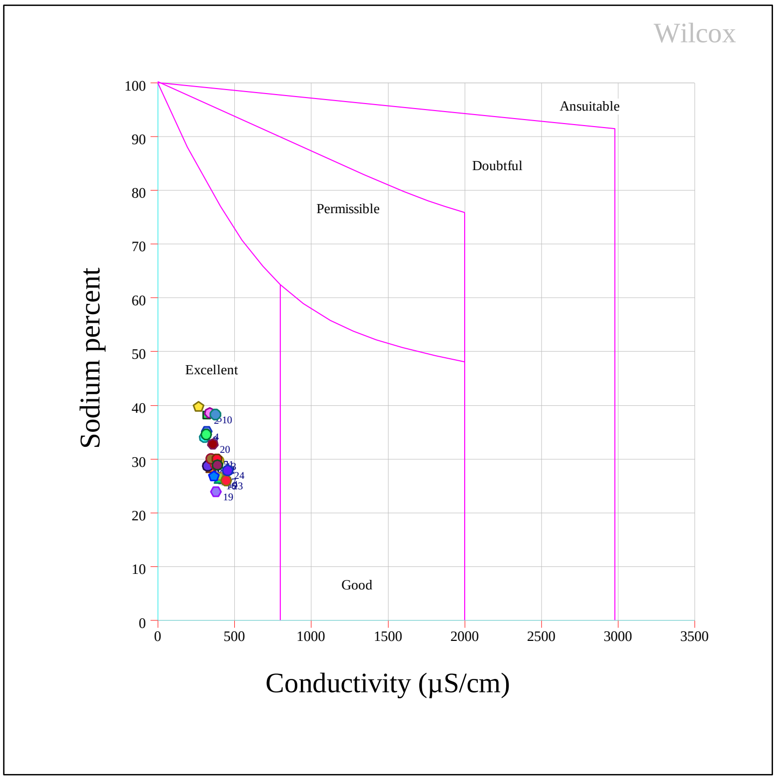

Fig. 2. Wilcox diagram of the water samples.

Exchangeable sodium percentage (ESP)

ESP values of sampled waters in raw waters of Cheffia dam vary from 1.97 to 0.9méq/l (Table 1) in 2015 and from 0.02 to – 0.46 in 2016. All ESP values are negative and show very low sodium content in studied waters in 2016. Consequently, all waters samples are excellent for crops irrigation, without alkalinizationh azard (pH < 8, 5) and soils sodicity.

Potential salinity

PS values of the study area range from 1.97 to 0.9méq.l^{-1}, with a mean of 1.49 méq.l^{-1} in 2015 and from 1.62 to 1.26méq.l^{-1}, with a mean of 1.44méq.l^{-1} in 2016, 100% of surface waters PS values are lower than 5; these waters are of good to excellent quality for agriculture (Table 6).

Kelly ratio (KR)

KR values of waters range from 0.59 to 0.33méq.l^{-1}, with a mean of 0.46méq.l^{-1} in 2015 and from 0.36 to 0.25méq.l^{-1}, with a mean of 0.29 méq.l^{-1} in 2016 (Table 1). KR obtained values are lower than one. Therefore, all surface waters of the study area belong to good-quality waters for irrigation (Table 7).

Table 6. Surface waters classification based on potential or effective salinity.

	Class	PS	Waters percentage
2015 and 2016	Good to excellent	PS< 5	100 %

Table 7. Surface waters classification based on KR.

	KR	Water quality	Waters percentage
2015 and 2016	< 1	Water is good for irrigation	100 %

Magnesium hazard (MH)

MH values of waters oscillate between 24.46 and 3.31, with a mean of 13.70 in 2016 and 7.6 in 2015. The values obtained are lower than 50 and show that Cheffia dam waters are good and suitable for irrigation (Table 8).

Chloride is also a hazard when it is present in irrigation waters because it can be directly adsorbed in sheets during sprinkling irrigation (Morris *et al*, 1991). Crops toxicity for chloride is defined as follows:

Cl< 150mg/l	Non-toxic
150 mg/l <Cl< 350mg/l	Moderate toxicity
Cl> 350mg/l	severe toxicity

However, 100%of Cheffia dam waters don't exhibit high chloride concentrations (< 150 mg.l^{-1}), so they are considered as non-toxic; it is the case of all samples for the years 2015 and 2016.

Permeability index (PI)

Waters PI values vary from 61.74 to 41.75%, with a mean of 53.21% in 2015 and from 43.93 to 35.76%, with a mean of 40.02% in 2016 (Table 1). PI values obtained are lower than 75% and higher than 25%. Therefore, all surface waters of the study area belong to the category of good-permeability waters (Table 9).

Residual sodium carbonate (RSC)

RSC values of waters vary from - 1.30 to – 2.60méq.l^{-1}, with a mean of – 1.77méq.l^{-1} in 2015 and from – 1.98 to – 2.71méq.l^{-1}, with a mean of – 2.38 méq.l^{-1} in 2016 (Table 1). RSC values obtained are lower than 1.25méq.l^{-1}. Therefore, all surface waters of the study area belong to the category of good- quality waters (Table 10).

Table 8. Surface waters classification based on MH.

	MH	Water quality	Waters percentage
2015 and 2016	< 50	Good and suitable for irrigation	100 %

Table 9. Surface waters classification based on PI.

	PI	Water quality	Waters percentage
2015 and 2016	25 <PI< 75	Good	100 %

Table 10. Surface waters classification based on RSC.

	RSC	Water quality	Waters percentage
2015 and 2016	RSC<1.25	Good	100 %

In the sub-basin of wadi Bounamoussa, sampled surface waters of Cheffia dam have medium salinity; this latter increases in 2016 with respect to 2015. In fact, during the drought periods, high temperatures favour surface waters evaporation, temperature elevation favours a gradual increase in solutions salinity of unsaturated area.

In our study, this medium salinity is reflected by low values of osmotic pressure and dry residue.

Calcium and magnesium can be tolerated, even in relatively great amounts in irrigation waters. High values of these parameters indicate that sodium is not in excess in the dam waters and that the hazard of defoliating sensitive crops by a sprinkling system is very low (Couture, 2004).

Water with sodium adsorption ratio comprised between zero and six can generally be used on all types of soil, with little problems of sodium accumulation (Couture, 2004). In our work, all studied waters have a SAR lower than six and represent excellent-quality waters, with low hazard of soil alkalinization in the study area.

Considering conductivity values with respect to SAR, waters are mainly represented in C2S1 class corresponding to medium-salinity and low-alkalinization water. C2S1 class waters are suitable for most cultures, but attention should be paid to leaching, very difficult in marginally permeable soils, and to drainage. Good quality of these waters for irrigation is highlighted by KR values obtained that are all lower than oneméq/l., so these waters are fit for irrigation.

The studied surface waters are of good quality for agriculture in relation to Na%. Considering conductivity and Na%, 100% of surface waters are classified as excellent quality waters for agriculture (Fig. 2), according to Wilcox (1948).

Conclusion

In this study, we have assessed surface waters quality of Cheffia dam, used for irrigation in the sub-basin of Bounamoussa, by means of seven quality parameters of waters intended to agricultural activity, such as dry residue (DR), osmotic pressure (π), sodium adsorption rate (SAR), exchangeable sodium percentage (ESP), potential salinity (PS), magnesium hazard (MH) and Wilcox diagram.

The study findings reveal that surface waters are fresh and marginally mineralized. The sampled surface waters are characterized by medium salinity (100%).

According to the mean value of potential salinity (PS < 5) of Kelly Ratio (KR< 1) and SAR (<10 méq.l^{-1}), all sampled surface waters are of good quality for agriculture. We observe 100% of excellent quality water for agriculture from Wilcox diagram. Osmotic pressure (π), dry residue (DR) and conductivity values demonstrate that these waters are fit for irrigation of most cultures, but attention should be paid to leaching, difficult in marginally permeable soils, and to drainage.

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