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Research Article

AN ASSESSMENT OF GROUNDWATER QUALITY FOR THE SUITABILITY OF IRRIGATION IN RELIZANE PLAIN, ALGERIA

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ABSTRACT

Located in an area characterized by an arid climate, the plain of La Mina, records an annual rainfall of 300 mm and an evapotranspiration equal to 1500 mm, which generates a deficit of 1200 mm, this shortage of water allocated to agriculture, forced farmers to use groundwater. The soils of the plain of the Mina and in particular the soil of the irrigated perimeters, suffer from a problem of salinization. Irrigation methods and the quality of the water used are the decisive triggers. The results of the hydrochemical analyzes carried out, focused on the major elements of these waters. They mainly have a sodium chloride facies, an EC average of (5.16 dS / m) which indicates that the waters are heavily salted, an average value of (SAR) of 20.67, shows that there is a very high risk of sodicity, playing a role in the physical degradation of soils. The Riverside and Wilcox diagrams show that it is the C4S4 class which is the most dominant, corresponding to a water of very high salinity and strongly sodium of poor quality, not recommended for irrigation.

Key words: Mina Plain, Irrigation Water, Hydrogeology, Salinization.

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1. INTRODUCTION

Soil salinization is a major problem in the degradation of soil quality and consequent damage to crop production and soil fertility in in many regions especially in arid and semi-arid regions [1-3]. In addition, salinity problems reduce the soil productivity, eventually leading to loss of cultivable land and negatively affects food security. [4] According to [5]. Soil salinity is multi-factorial phenomenon, i.e., caused by various factors (an unfavorable chemical composition of irrigation water; land degradation and climate change, topography, geomorphology, bedrock geology). and is a major cause of desertification.

In Algeria, the extent of degradation of rainfed cropland is estimated (93 percent) [6] Dima note the causes of soil degradation are divided between deforestation (10.5 percent), overgrazing (68 percent), over-cultivation (21 percent), and overexploitation of natural vegetation for about 0.5 percent [7]

In Algeria, area equipped for irrigation is 569 418 ha [7] In addition, Algeria present salinized irrigated area: important primary salinity - 60 percent of large perimeters; secondary salinity - 400 000 ha [8]. The Mina plain (study area) is characterized by an arid climate, with strong evapotranspiration and soil salinization, which is starting to increase. Continuing drought has forced farmers to choose groundwater as their sole source of irrigation. However, the use of groundwater for irrigation will not be without consequences on soil degradation [9]. These irrigation practices increase the risk of salinization, to the point that more than 20% of irrigated land is affected by a salinity problem in Algeria [10].

Our main objective is to study groundwater quality parameters (PH, Ca2+, Mg2+, Na+, K+; Cl-, SO42-, CO32-, HCO3-, sodium adsorption ratio and electrical conductivity) in this area in order to assess the suitability of groundwater to establish an inventory strengthened by a cartography of suitability of groundwater for irrigation.

EXPERIMENTAL

2.1. Study Area, Sampling and Analysis

The plain of La Mina is located in the Relizane Wilaya in northwestern Algeria. Including the oldest irrigated perimeter of the country, it was created in 1943. It occupies an area of 17235ha of which 8250 ha are irrigable as well as an endorheic basin (the sebkha of beniziene). It is located between X1= 0° 13' 48’’; Y1= 35°26' 38" X2= 1° 25' 41" ;

Y2= 36°13' 40"

It is limited to the north, by the plateau of Mostaganem and the mountains of Dahra, to the south, by the mountains of Beni Chougrane, to the west, by the plain of El-Habra and the massif of Bel Hacel and to the East, by the massif of Ouarsenis figure1.

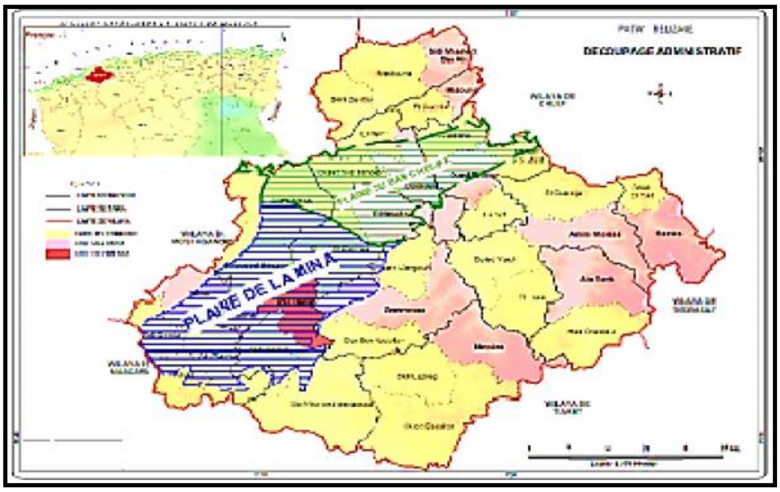

Fig.1. Geographic location of the plain of Mina – PATW, SOGREAH, 2013

A total number of, 30 samples were collected from boreholes and wells used for irrigation during 2018 (summer season) The sampling locations are shown in Fig. 2.

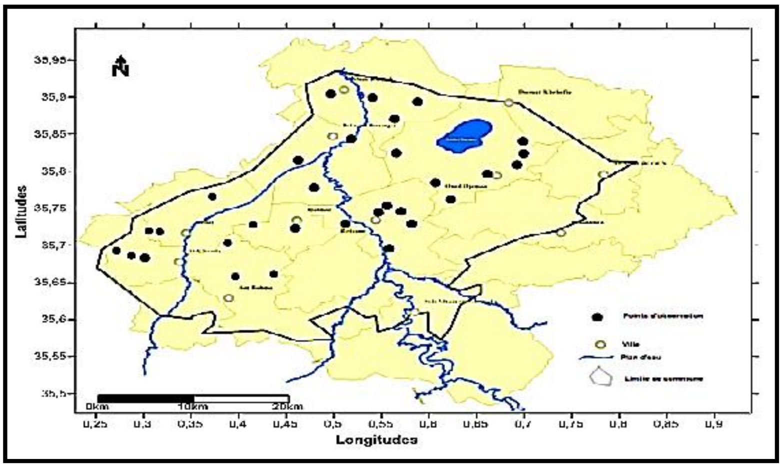

Fig.2. Spatial distribution of water points in the plain of Mina

The samples were analyzed in the laboratory for the physico-chemical attributes such as pH, electrical conductivity (EC) and major cations, such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na), potassium (K), and anions, such as bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), chloride (Cl-) and sulfate (SO42-).All concentrations are expressed in milligrams per liter (mg/l), except pH and EC. In addition to the above, the evaluation of irrigation groundwater-quality parameters such as sodium adsorption ratio (SAR). All samples had been stored in an ice chest and later transferred to the laboratory, the various analyses of the physico-chemical parameters of samples were conducted in the laboratory of the INSID (Institut National des Sols de irrigation et du Drainage).

For the identifcation of water types, the chemical analysis data of the groundwater samples weare plotted on the Piper diagram. Surfer (version 11.0) was used for preparation of regional variation in groundwater level.

3. RESULTS AND DISCUSSION

Many researchers have worked on the hydrochemical characteristics, and its qualitative status of land used for agricultural purposes.

In the current study, an effort has been made to calculate the groundwater quality indices for the aptness of groundwater resource for agricultural purpose.

The results of physico-chemical parameters and calculated irrigation water quality parameters are given in Table 1.

Table 1: Results of physico-chemical parameters.

Parameters	pH	CE	SAR	Na+ (meq/l)	K+ (meq/l)	Ca ++ (meq/l)	Mg ++ (meq/l)	Cl - (meq/l)	SO4-- (meq/l)	CO3-- (meq/l)	HCO3- (meq/l)
Min.	6.65	1.800	6.21	14.2	0	1.87	4.32	7.70	1.98	0.10	0.10
Max.	8.42	13.910	60.76	160	2.01	9.05	37.66	111	48.2	1.5	8.74
Moy.	7.45	5.166	20.67	56.58	0.40	4.32	12.66	45.94	12.70	0.47	4.02

The pH values of groundwater samples in the study area ranges from 6.65 to 8.42 and averaged 7.45 (table 1).

According to the classification of irrigation water quality All the samples were found to be within the WHO and NDWQS guideline value [11]. According to the classification of irrigation water quality by Makoba and Muzuka [12] the pH values based on three categories of nearly neutral (6.4–7.5), slightly alkaline (7.5–8.5), and alkaline (8.5–11). In addition, the pH is mainly influenced by volume of water and soil type.

3.1. Electrical conductivity

The EC values of groundwater samples in the study area ranges from 1.800 to 13.910 and averaged 5166,17 (table 1). Excessively high EC values of 13.91dS / m have also been noted, which corresponds to excessive salinity due to very arid climatic conditions producing high evaporation which concentrates the soil solution [13]. Nevertheless, a certain number (13.33%) of water points are of better quality with an EC less than 2 dS / m.

The EC values of the groundwater of the study sites were within the permissible limit of WHO [11]. Romero-Aranda et al. [14] (2001) concluded that electrical conductivity of the soil solution increased significantly with increasing salinity of the irrigation water saline water.

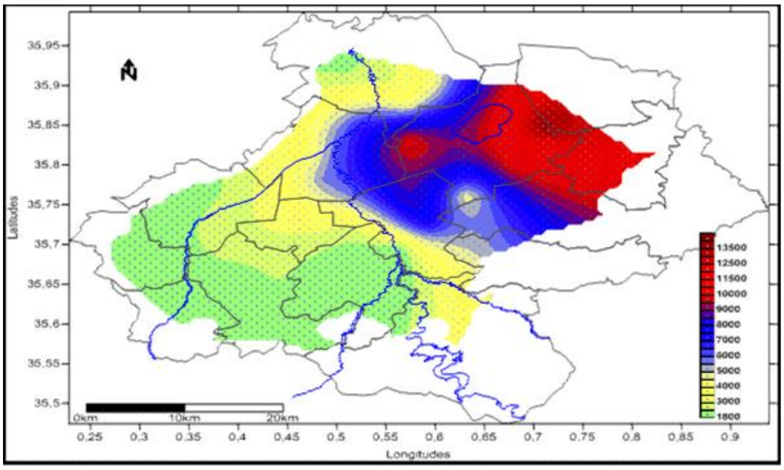

Fig.3. Variation of salinity

In the present study, SAR value ranges between 6.21–60.76 (mean 20.67). (Table 1). In terms of categorization of irrigation water, SAR hazard is conveyed, as low (SAR < 3), medium SAR: 2-9) and Increasing problem (SAR > 9). [15].

In our present study, SAR which indicates a very high potential for sodization. However, we note that 26.66% of the water points are characterized by a SAR less than 9 representing a slight risk of sodization Figure 4.

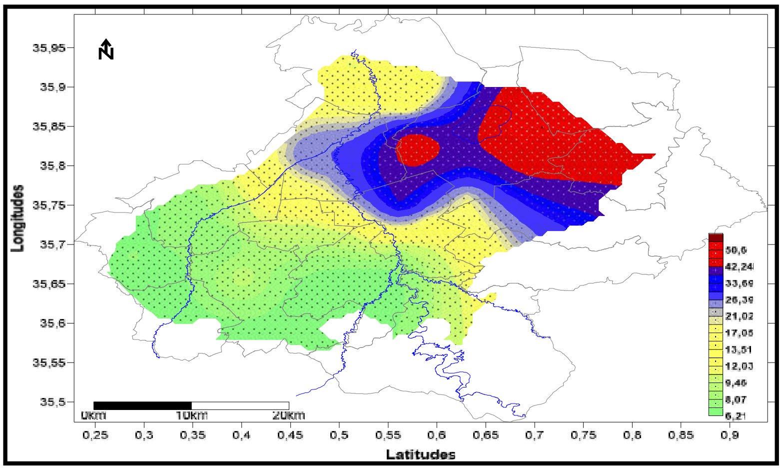

Fig.4. Variation of sodicity

The concentration of Na and K ions ranged from 14.2 to 160 and 0 to 2.01 mg/L, respectively. Cl-was dominant among all the cations, suggesting that 45,94 % of the samples were calcium-rich water (Table 1) The order of abundance of major cations was Na > Cl > SO4-- > Mg ++ > Ca ++ > HCO3-> CO3--> K+.

3.2. Determination of hydrochemical facies (HF) of waters

Accorted by Ravikumar and Somashekar [16]. the general chemical nature of ground water and variation in hydrochemical facies can be understood by plotting major cation and anion concentrations on different graphical representations. In addition, the graphical representation of groundwater major cations and major anions helps in understanding its hydrochemical evolution, grouping and areal distribution. In our study, Piper trilinear diagram were constructed to evaluate variation in hydrochemical facies.

The Piper diagram links sodium adsorption ratio (SAR), which conveys the sodium or alkali hazard, to EC (salinity hazard) Fig. 4.

The representation of our 30 samples on the Piper diagram (Fig 4) showed the presence of different chemical facies namely**:**

- A predominant facies: chlorides-sodium facies.
- The other facies: sulphated-sodium, chlorinated-calcium.

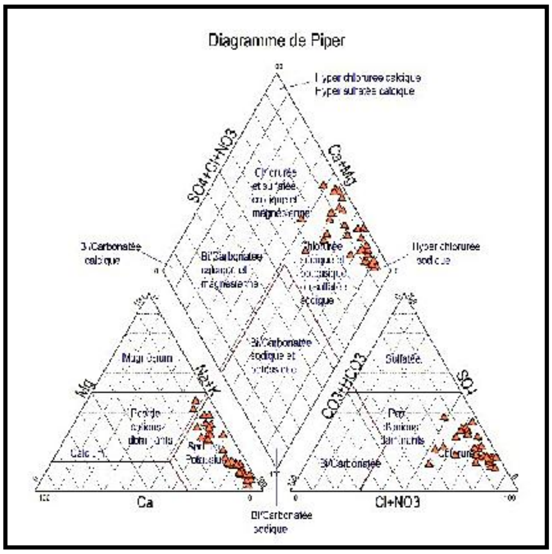

Fig.5. Piper Trilinear diagram classifying major hydrochemical facies

3.3. Irrigation water quality

3.3.1. Riverside Method

On the basis of Riverside diagram that classifies water samples in terms of degree of EC-SAR (Fig. 8 and table 4).

According to Etteieb et al [17] two parameters were adopted as indicators of the suitability of the sampled waters for agricultural uses: salinity and SAR. [17].

All water samples have an average EC value of 5.92 dS / m v, indicating the presence of salinity hazards for irrigation. Additionally, the salinity problem is outlined when salt concentrations in soil solution exceed crop threshold levels for salt tolerance which vary from a crop to another.

SAR is an important parameter for determining the suitability of water for irrigation because it is a measure of alkali/sodium hazard to crops [17]. Additionally, SAR also indicates irrigation water tendency to cation-exchange reactions in soil [17].

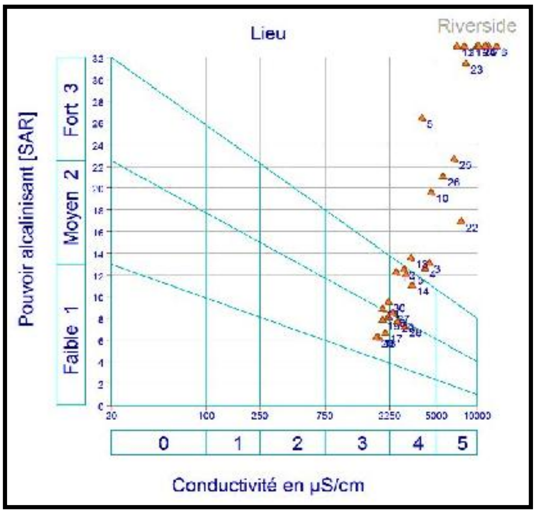

Fig.5. Evaluation of irrigation water quality according to the Riverside method (EC -SAR)

Table 2. Classification of groundwater of degree of suitability for irrigation using Riverside diagram: (EC- SAR)

Riverside Classification	Number of water points	Percentage%
C3S2	17-18-19-20	13.33
C3S3	21-30	6.66
C4S2	16-27-28-29	13.33
C4S3	1-2-14-15	13.33
C4S4	3-4-5-10-13	16.66
C5S4	6-7-8-9-11-12-22-23-24-25-26	36.66

- **C3S2:** the best class of these waters, with only 4 samples (13.33%), it is of generally good quality for irrigation for salt-tolerant crops on well-drained soils, excluding heavy soils, however evolution of salinity must be well controlled.
- **C3S3:** the class less present with 2 samples (6.66%), C4S2 represented with 4 water points (13.33%). Highly mineralized water, suitable for irrigation with great care, only in light and well-drained soils and for salt-resistant plants. With a high risk leaching and gypsum additives are essential.
- **C4S3 and C4S4:** show a percentage of presence of 13.33%, with 4 samples each, but the C5S4 class is the most representative with its 11 water points, dominating with a presence rate of (36.66). These waters are not generally suitable for irrigation, they are not recommended. To be used only in exceptional circumstances and under certain conditions, (very permeable soils, good leaching, plants tolerant of salt very well).

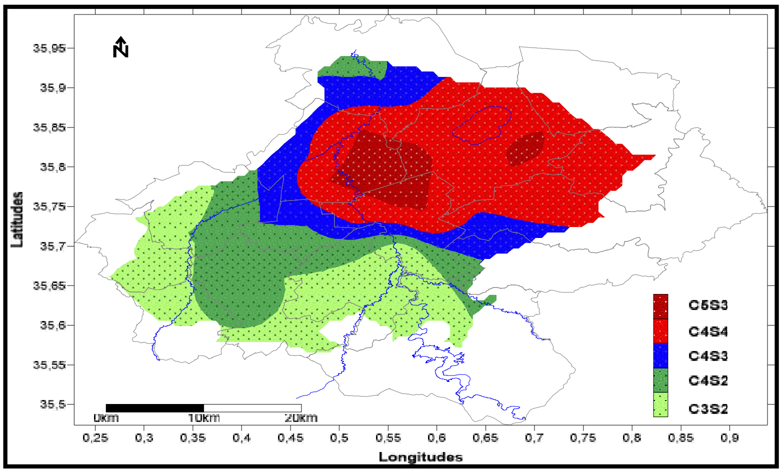

Fig.6. Water point mapping Riverside (CE - SAR)

3.3.2. Wilcox Method

On the basis of Wilcox diagram that classifies water samples in terms of degree of suitability for irrigation Fig. 8 and table 4.

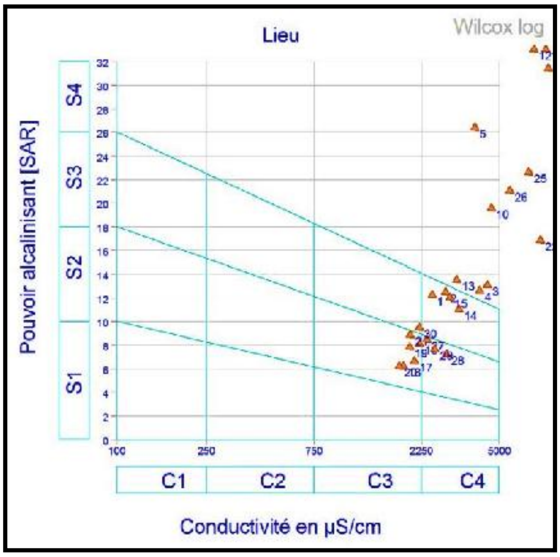

Fig.7. Classification of groundwater of degree of suitability for irrigation using Wilcox diagram: (EC- SAR) (Wilcox 1955).

Table 3. Classification of groundwater of degree of suitability for irrigation using Wilcox diagram: (EC- SAR) **(Wilcox 1955).**

Classification Wilcox	**Number of water points**	**Percentage %**
C_3S_2	17-18-19-20-21	16.66
C3S3	30	3.33
C_4S_2	16-27-28-29	13.33
C_4S_3	1-2-14-15	13.33
C_4S_4	3-4-5-6-7-8-9-10-11-12-13-22-23-24-25-26	53.33

According to the Wilcox diagram, groundwaters have 5 classes: C3S2, C3S3, C4S2, C4S3, and C4S4.

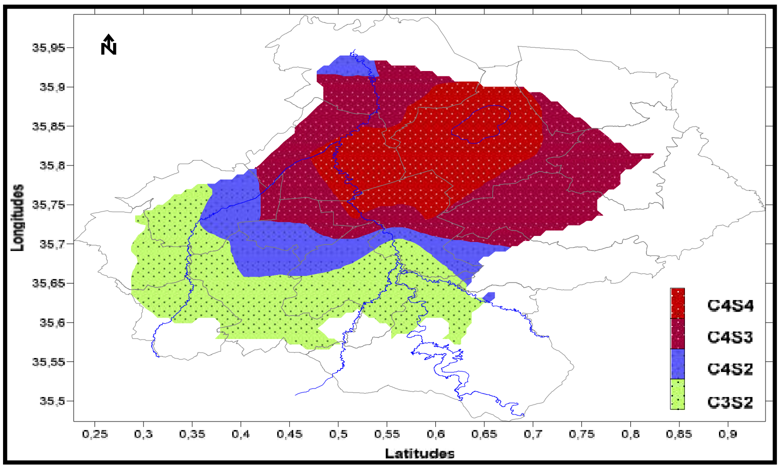

Fig.8. Water point mapping Wilcox (CE - SAR).

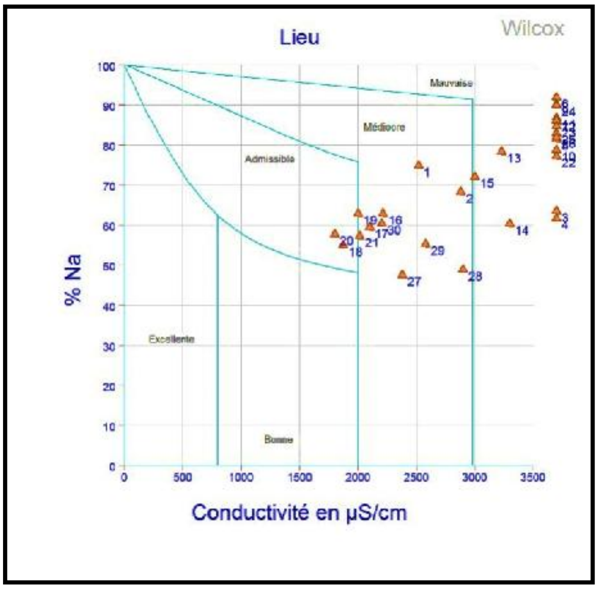

Fig.9. Evaluation of irrigation water quality according to the Wilcox method (EC -Na%).

Table 4. Evaluation of irrigation water quality according to the Wilcox method (EC – Na %)

Water quality	Number of water points	Percentage%
Acceptable	18-19-20-21	13,33
Poor	1-2-16-17-27-28-29-30	26,66
Inappropriate	3-4-5-6-7-8-9-10-11-12-13-14-15-22-23-24-25-26-	60,00

According to the Table 4, the water quality was divided into three categories as, acceptable, poor and inappropriate.

- Water of acceptable quality, the least represented with 4 samples and a presence rate equal to (13.33%).
- Poor quality water with 8 water points and an attendance rate of (26.66%).
- Water of poor quality, the dominant category with its 18 samples, with an attendance rate of (60%).

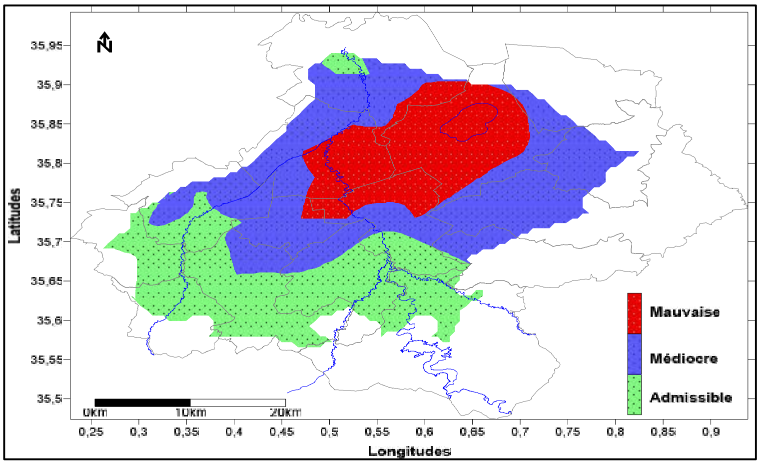

Fig.10. water quality of the plain of Mina according to the Wilcox diagram (EC -Na +).

4. CONCLUSION

The Mina Plain with a arid and semi-arid climate, strong evapotranspiration and persistent drought has forced farmers to choose groundwater as a single source of irrigation.Following the observation of salinization of soils that is starting to grow, the groundwater of the region area the first suspected to be the source of the problem. In this research, a total of 30 groundwater samples were investigated to assess the physic-chemicals characteristics of the study regions. Taking into account the results of the groundwater analyzes obtained, the evaluation of their qualities by conventional methods has shown that the majority of these waters are of a very high salinity with a mean equal to 5.92, and represents a danger of sodization very high with an SAR average of 20.67, especially in the center and east of the plain near the beniziene sebkha. The use of RICHARDS and WILCOX methods revealed three types of water quality. Water of acceptable quality, poor, and of poor quality which is the dominant category.The classifications of Richards and Wilcox made it possible to classify the waters of the region and show that the salinity and the risk of sodicite increases from the north towards the east of the plain while approaching the sebkha of Beniziene, and the establishment groundwater suitability maps confirm the results obtained by the two methods.These waters are generally discouraged for irrigation, nevertheless the use of some points is tolerated under certain conditions and with great care.The influence of the endorheic basin (beniziene sebkha, located east of the study area) results in high levels of chlorides and sodium.Several factors, natural (Geological and Climatic) and anthropogenic contributed to the acquisition of this mineralization and can be held responsible for the salinity of the groundwater of the plain of Mina:

- Primarily by lithological contamination, the elements encountered are of geological origin. Generally, this type of salinization develops in depressions subject to an evaporating climate.
- The evaporites rich in Cl, Na, SO4, and Ca, resulting from the increase in salt concentrations until their precipitation, especially in the arid zones, these evaporites are a considerable source of groundwater contamination.
- The solid salts formed in the irrigated agricultural perimeters of the plain of Mina and the endorheic basin (the sebkha of beniziene), under the effect of the evapotranspirations very important and successive.
- Irrigation practices that require more and more the exploitation of groundwater by pumping, favors vertical exchanges going back up deep saline waters.

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