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Assessment and Mapping of Groundwater Quality for Irrigation and Drinking in a Semi-Arid Area in Algeria

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ABSTRACT

Groundwater is the main resource used to meet the people's drinking water and irrigation needs of the Ain Oussera plain, because of the lack of surface-water resources. This paper intended to evaluate the suitability of groundwater for agriculture and drinking in the Ain Oussera plains. The data of the study were gathered and analyzed from twenty (20) groundwater samples collected to assess the plain groundwater quality, using the Water Quality Index (WQI) and GIS, carried out on physico-chemical parameters, including potential of hydrogen (pH), total dissolved solids (TDS) electrical conductivity (EC), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}) and major anions (Cl, HCO_3, NO_3, SO_4), as well as, the water suitability test for agricultural purposes, using the sodium adsorption ratio. These parameters were inserted into the GIS platform to create a spatial distribution map for each parameter using the inverse interpolation technique (IDW). The results indicated that the concentrations are within the Algerian permissible limits. The water quality index (WQI), which evaluates the suitability of water for consumption, varies from 31 to 173 with an average value of 81. 70% of the samples from the Ain Oussera plain fall within the excellent and good quality categories. Its water is suitable for consumption (WQI < 100), while 30% is in the poor water category. From the calculation of SAR values, it was found that 90% of the groundwater samples are considered excellent and suitable for irrigation. According to the classification of the United States Salinity Laboratory USSL, the Ain Oussera water quality is classified as poor for irrigation purposes.

Keywords: groundwater, drinking water. WQI, irrigation water, SAR, plain of Ain Oussera.

INTRODUCTION

Water resources are a major concern in dry or semi-dry countries. They are crucial to the development of human, economic and social activities [Ragab et al., 2002b; Williams., 1999; Misra., 2014; Wang et al. 2017]. Algeria has adopted a new policy to protect and safeguard water resources [Negm et al., 2020; Qadir et al., 2007], as population and urbanization increases, industrial units and farm land have resulted in the degradation of groundwater and surface water quality, combined with a very significant decline in the groundwater resources, the only water reserves for the supply of populations.

It is critical to understand the groundwater quality because it is a key mark of its suitability for human consumption, agriculture, and/or industry. In recent years, there has been a worldwide increasing concern for water quality. Several studies [Khan et al., 2020; Rao et al., 2012; Babiker et al., 2007] were conducted to assess the quality of groundwater.

Groundwater chemistry has been used as an instrument for evaluating the quality of water for human use and irrigation. [Srinivasamoorthy et al., 2014]. The weighted arithmetic method proposed by [Brown et al., 1972] is used to determine the appropriateness of drinking water quality for domestic, irrigation purposes in the QWI index of water quality.

This method has been frequently used to assess the groundwater quality for drinking purposes in various regions of the world [Tyagi et al., 2013; Chauhanet al., 2010; Chowdhury et al., 2012; Balan et al., 2012; Adimalla et al., 2019; Tiwari, et al., 2018; Kawo et al., 2018]. Similar studies have been conducted in Algeria using the water quality index [Bouteraa et al., 2019. Rachedi et al., 2015; Hamlat et al., 2018; Bouslah et al., 2017; Bouderbala., 2017a; Guettaf et al., 2017].

The primary goal of this study was to understand the status of groundwater quality in the Ain Oussera plain, the central steppe of northern Algeria, characterized by semi-arid climate. This is done by means of mapping the geographic distribution of groundwater quality for irrigation and drinking, in order to identify its suitability for these objectives, utilizing the Water Quality Index (WQI) and Geospatial System (GIS) methodologies, carried out on the basis of the physico-chemical parameters, namely potential of hydrogen (pH), total dissolved solids (TDS) electrical conductivity (EC), major cations (Mg, Ca, K, Na) and major anions (Cl, HCO_3, NO_3, SO_4). Moreover, the examination of the suitability of water for agricultural purposes was performed, using the sodium adsorption ratio (SAR). It was important to determine these factors in order to evaluate those impacts on human health and agricultural crops.

APPROACH AND METHODOLOGY

Presentation of the study area

Ain Oussera is a part of the Algerian high plains. It is situated in the center of the North of Algeria, in Djelfa province, between 2°15' and 3°45' East longitude and 35° and 35°40' North latitude. About 200 km south of Algiers, the plain extends over 105 km along a NE- SW axis, and over 30 km along a perpendicular axis. Its surface area is approximately 3795 km². It is a flat or moderately undulated surface. It is bounded by the mountainous massif of Djebel Remila, Sbaa Rous and Oukat El Gharbi and Chergui in the South, by the rectilinear ridges of Koudiat Bou chakeur and Djebel Es Sersou in the North and by Oued Touil in the West (Figure 1). The area of the study has a semi-arid atmosphere with a dry and hot summer and a chilly winter. The average precipitation is 226.15 mm/year and the annual average temperature is 17.6 °C. The altitude of the Ain Oussera plain varies between 632 m and 900 m. The plain is covered by 08 municipalities with an estimated population of 449230 inhabitants [DPAT 2020]. The groundwater of the plain is the main resource of drinking and agriculture water supplies on which most of the population of the region depends. The region is pastorally structured, with livestock farming (sheep, goats, and cattle) being the most prevalent activity. On the agricultural level, the irrigated surfaces lay over a significant surface and are located in the plateau of Sersou and South-West of Birine.

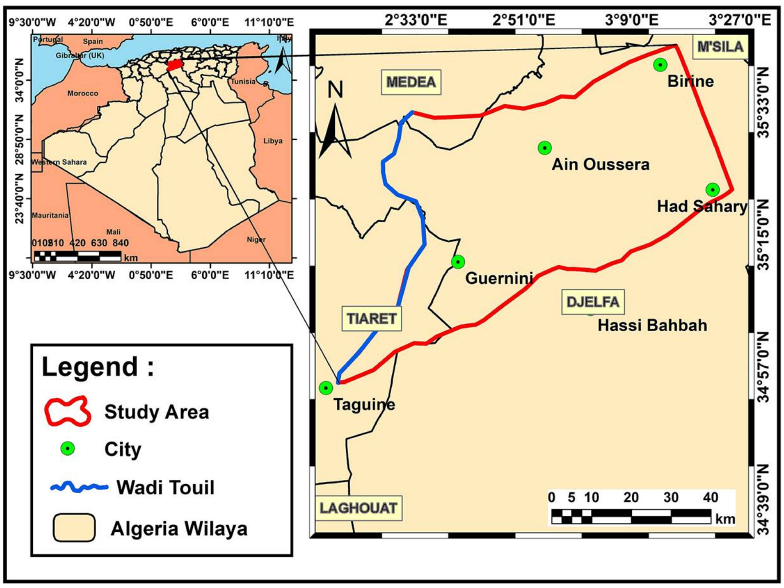


Figure 1. Study area

Geological settings of the area

The stratigraphic unit sections were obtained from various deep drillings conducted in the Bou Cedraa 1200 m and El Khrachem 1100 m areas. This lithostratigraphic description is based on the previous research on the region [Caratini., 1970; Mebrouk et al., 2007; Ayad., 1983]. This information allowed us to provide a comprehensive description of the area geology as well as identify the various existing aquifers (Figure 2).

Ain Oussera plain appears as a huge anticlinorium with a Cretaceous core area, complicated by a system of anticlinals, developed on the southern and northern slopes, and its axis passing through Bou Cedraïa [Azlaoui et al., 2017]. The plain is covered almost entirely by alluvial deposits (Quaternary formations). Cretaceous formations outcrop on the southern and northern flanks at Koudiat Es Seguia, El Fia, El Mouilah, Doghmane, and En Nesser [Azlaoui et al., 2017].

Hydrogeological framework

The Ain Oussera plain is home to a wide range of aquifer forms with varying hydraulic capacities. These formations are represented by the Quaternary filling, the Miocene sandstones, the limestones of the Lower Eocene, Turonian and Cenomanian and the Barremo-Albian sandstones [Azlaoui et al., 2017].

In the Ain Oussera plain, the Albian is constituted by permeable continental sandstone. It is the most important and interesting aquifer in the region and is tapped by many boreholes which would supply the cities and farms with water for domestic consumption. Several 100 m to 300 m deep boreholes capture these sandstones. The flow rates vary from 20 l/s to 75 l/s. The main water flow table is from the South to the North.

The hydrodynamic parameters are measured using the data from pumping tests conducted in boreholes throughout the study. The high values of permeability are located in the North-East (Birine-Ain Oussera) and South-West of the plain, values vary between 2.10^{-5} m/s and 43.10^{-5} m/s. On the other hand, the low values are recorded in the South-East and North-West of the study area. The values are between $0.1.10^{-5}$ and 2.10^{-5} m/s.

Sampling and analysis

The samples were taken from 20 groundwater points. The sampling points were chosen to provide a consistent and uniform distribution across the entire Ain Oussera. plain (Figure 3). The bottles of samples were rinsed with distilled water. After 5–10 minutes of pumping, the standing water was removed and the water samples were collected. The physical parameters such as pH, total dissolved solids (TDS) and electrical conductivity (EC) were

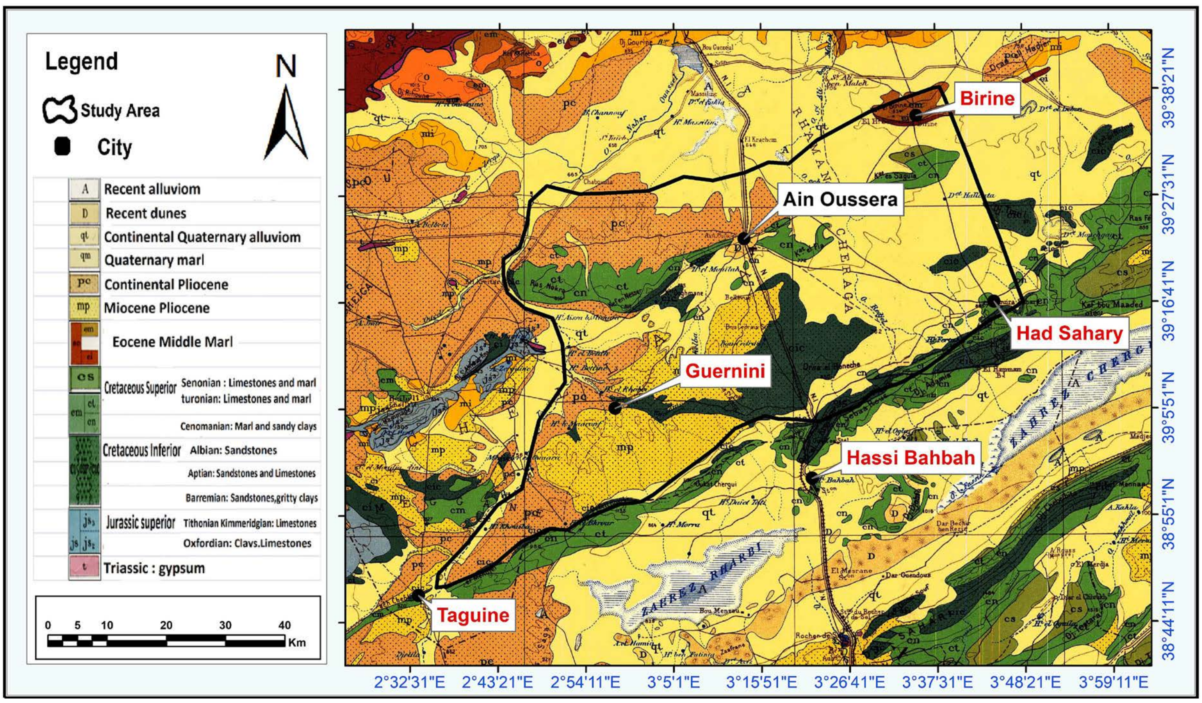


Figure 2. Geological map of the study area

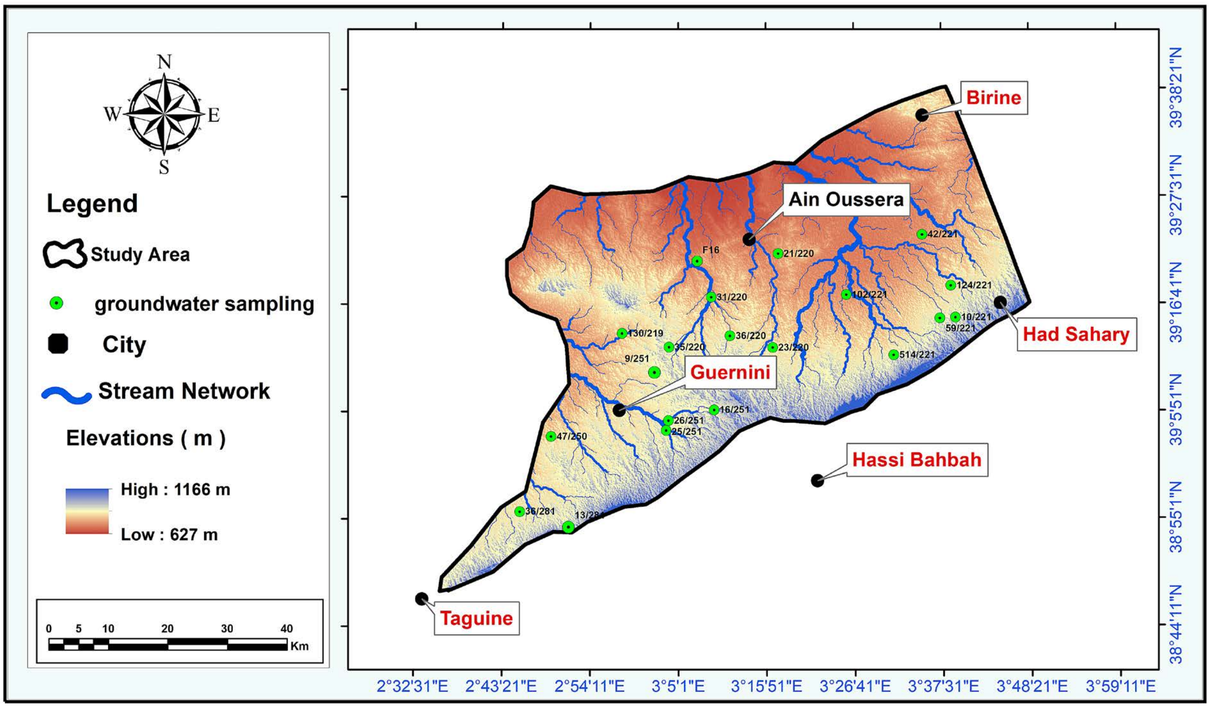


Figure 3. Groundwater sampling wells map in the area of the study

measured in the field (in situ) by a conductivity meter as per standard procedures. The samples were then analyzed in the laboratory of the National Agency for Hydraulic Resources (ANRH). The parameters analyzed included four cations (K^+, Ca^{2+}, Mg^{2+} and Na^+) and four anions (Cl^-, SO_4^{2-}, HCO_3^- and NO_3^-). For the chemical data interpretation, the analytical results were subject to ion balance calculation to determine the error rate (reliability of the analysis) between the total cation and anion concentrations. The ionic balance error value is within the acceptable limit of ±5%. Finally, the analysis of the findings was evaluated and compared to the Algerian water quality standards [JORADP 2011] and the World Health Organization standards [WHO 2011].

Water quality index for drinking (WQI)

The term "WQI" refers to a scoring technique that gives the cumulative effect of various water quality parameters on the total quality of water suitable for human consumption [Mitra and ASABE member 1998]. The three steps required to calculate WQI are:

- For the first stage, the 11 parameters (PH, TDS, Cl, HCO_3, SO_4, NO_3, Mg, Ca, K, and Na), with TDS being one of the primary quality parameters, usually refer to the various minerals that can be found in water. The water that contains a lot of solids might have induce constipation or have laxative impacts [Hajji et al., 2018]. Due to the critical nature of parameters such as total dissolved solids, chlorides, sulfates, and nitrates in quality water assessment, the highest weighting rate of 5 has been assigned to them [Vasanthavigar et al., 2010; Srinivasamoorthy et al., 2014]. Bicarbonate is assigned a lowest weighting rate of 1 because it plays a minor role in determining the water quality. Other parameters such as potassium, sodium, magnesium, and calcium were given a value of between 2 and 4 based on their significance in determining the quality of water. See Table 1.
- For the second stage, the determination of the relative weight (W_i) must be calculated according to the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where: W_i represents is the relative weight, w_i is the weight and the number of parameters corresponds to n. The values calculated for each parameter relative weight (W_i) are listed in Table 1.

- In stage three, based on its concentration in each water sample, the scale of quality assessment (q_i) is determined taking into account the respective standards, in accordance with the WHO recommendations, and then multiplied by 100, which is calculated according to this formula:

Table 1. The weight (w_i) and relative weight (W_i) of each chemical parameter

Parameter	Algerian Standards (JORADP 2011)	Weight (w_i)	Relative weight (W_i)
PH	6.9 < pH < 9.0	4	0.105
EC (μS/cm)	2800	4	0.105
TDS (mg/L)	No-Limit	5	0.132
Calcium (mg/L)	200	2	0.05
Magnesium (mg/L)	150	2	0.05
Sodium (mg/L)	200	3	0.08
Potassium (mg/L)	12	2	0.05
Chloride (mg/L)	500	5	0.132
Sulphate (mg/L)	400	5	0.132
Nitrates (mg/L)	50	5	0.132
Bicarbonate (mg/L)	No-Limit	1	0.03
		Σwi = 38	Σwi = 1.00

$$q_i = \frac{C_i}{S_i} \cdot 100 \quad (2)$$

where: q_i is the quality rating; C_i is the concentration of chemical parameter of each water sample (mg/L). S_i is the drinking water standard for each chemical parameter (mg/L) according to the guidelines of the World Health Organization [WHO 2011] and Algerian Standards [JORADP 2011].

In this stage, the values of the sub-indices *SI* values for all chemical parameters are computed by multiplying the proportional weight and the rating of quality.

$$SI_i = W_i \cdot q_i \quad (3)$$

In the last stage, the Water Quality Index (*WQI*) was calculated by adding up all of the subsets of all groundwater samples, following Equation 4:

$$WQI = \sum_{i=1}^{n} SI_i \quad (4)$$

The sub-index of each parameter is SI_i, and the number of parameters is *n*.

The calculated water quality index *WQI* was divided into five categories given in Table 2.

Table 2. Water quality classification based on WQI values [Tiwari et al., 2018; Ibrahim., 2019]

WQI range	Type of water
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Unfit for drinking

Quality water for irrigation purposes

The impacts of mineral components in water on plants and soil determine the appropriateness of groundwater for irrigation. Excessive dissolved ion levels influence the agricultural soils and plants in irrigation water, which lowers productivity [Ravikumar et al., 2010].

The high sodium concentration in water produces adverse impacts by altering the soil properties and reducing permeability [Kelley., 1951; Schwartz., 1990; Mays et al., 2005; Ben Alaya et al., 2014]. Thus, the sodium concentration is critical in classifying water for irrigation. *SAR* (sodium absorption ratio) is used to classify sodium risk in irrigation water because it is a measure of alkali/sodium risk to crops. Indeed, it indicates to what extent irrigation water manages to enter soil cation exchange reactions; the *SAR* is defined by the following formula.

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

The groundwater concentrations utilized in these calculations were all measured in meq/l.

Geographic information system (GIS)

On a local-to-regional scale, GIS may be a strong instrument to deal with water sources issues, zone mapping, determining availability of water, and risk evaluation on environmental problems, generating solutions, and making swift policy decisions [Tiwari et al., 2018; Singh et al., 2013]. Systems of geographic information GIS enable the spatial distribution of quality groundwater parameters such as, pH, total dissolved solids (TDS), electrical conductivity (EC), anions, cations, SAR, and WQI. Hence, all physicochemical characteristics were mapped using inverse distance weighted (IDW) interpolation techniques in ARC GIS. IDW is the most frequently used technique for analyzing groundwater interpolation [Gorai et al., 2013; Agung Setianto et al., 2013].

RESULTS AND DISCUSSION

The physico-chemical parameters of the analyzed groundwater samples used in this study include the minimum and maximum values, standard deviation and mean, are shown in Table 3.

Characterization of the groundwater samples

The groundwater pH ranges from 6.82 to 7.48. The average pH of the groundwater samples in the area of study is 7.17. All the water samples analyzed were within the guidelines of Algerian standards and the World Health Organization (WHO) limits. The groundwater in this study area is slightly acidic to alkaline. Figure 4a shows the spatial analysis of pH.

The electrical conductivity EC of the Ain Oussera groundwater has shown variations from one point to another. The maximum value is recorded at 47/250 boreholes, it is 3760 μS/cm. On the other hand, the minimum value is recorded at 102/221 boreholes, it is 470 μS/cm. The result of the CE indicates that 80% of the samples have conductivity within the required limit for Algerian norms of 2800 μS/cm [JORADP 2011], while 75% of the whole samples are under the guidelines of the World Health Organization of 1000 μS/cm [WHO 2011].

The spatial variation of the electrical conductivity EC in Figure 4b shows that the high values of conductivity are concentrated in the southwestern part of the plain, especially along Oued Touil, particularly in the north of the Taguine area. This is probably due to the natural groundwater recharge occurring as surface water drained by Oued Touil. In the eastern part of the plain, the conductivity is low, which can be attributed to the freshwater inflow from the groundwater recharge area (the Albian outcrops in the south of the plain).

The TDS values of the Ain Oussera groundwater vary from 386 to 3074 mg/L in the groundwater samples. It was concluded that 17% of the samples are at the World Health Organization's recommended level of 500 mg/L [WHO 2011]. It should be noticed that the Algerian standards do not specify any TDS limits [JORADP 2011]. The spatial analysis for TDS in the study shown in Figure 4c, indicates that the significant TDS concentrations are located near Oued Touil and the city of Ain Oussera.

The calcium values in groundwater range from 60 to 397.7 mg/L, with an average value of 151.09 mg/L. Figure 5a shows that 70% of calcium concentrations are within the acceptable limits of the Algerian standards of 200 mg/L [JORADP 2011], and 90% exceed the World Health Organization standards of 75 mg/l [WHO 2011]. The high values are located in the southwestern part of the plain. The calcium supply is provided by the infiltration of surface water of Oued Touil which is loaded in its course by gypsiferous elements.

The spatial distribution of magnesium contents in the study area is identical to that of calcium. The maximum content is recorded south of the town of Ain Oussera at the (47/250) borehole with 119.3

Table 3. Statistical summary of hydrochemical characteristics of the study area

Parameters	Unit	Maximum	Minimum	Average	Algerian Standards (JORADP 2011)	WHO (2011)
PH		7.48	6.82	7.17	6.9 < pH < 9.0	6.5 < pH < 8.5
TDS	mg/L	3074	386	1269.15	No-Limit	500
EC	µS/cm	3760	470	1770.7	2800	1000
Ca^{+2}	mg/L	397.7	60	151.09	200	75
Mg^{+2}	mg/L	119.3	17	57.83	150	50
Na^{+}	mg/L	528	19	132.5	200	200
K^{+}	mg/L	52	2	14.15	12	12
Cl^{-}	mg/L	652.38	19.97	215.77	500	250
SO_4^{-2}	mg/L	1502	7.08	270.85	400	250
HCO_3^{-}	mg/L	1418	137.25	374.77	No-Limit	120
NO_3^{-}	mg/L	78.5	0.01	26.67	50	50

mg/l, and the lowest value is 17 mg/l at (102/221) borehole in the plain's center. Figure 5b reveals that the magnesium values are within the Algerian norms of 150 mg/L [JORADP 2011], although 45 percent surpass the WHO criteria of 50 mg/L. [WHO 2011].

The sodium concentrations in the plain water range from 19 mg/l (borehole 102/221) to 528 mg/l (borehole 47/250). The highest values above 150 mg/l are detected in the western and southwestern part of the plain. Figure 5c shows that 80% of sodium concentrations are within the World Health Organization permissible limit of 200 mg/l [WHO 2011] and the Algerian standards [JORADP 2011].

The potassium values vary between 02 mg/l for the (102/221) borehole and 52 mg/l for the (47/250) borehole. The results show that most of the water points have a concentration below the World Health

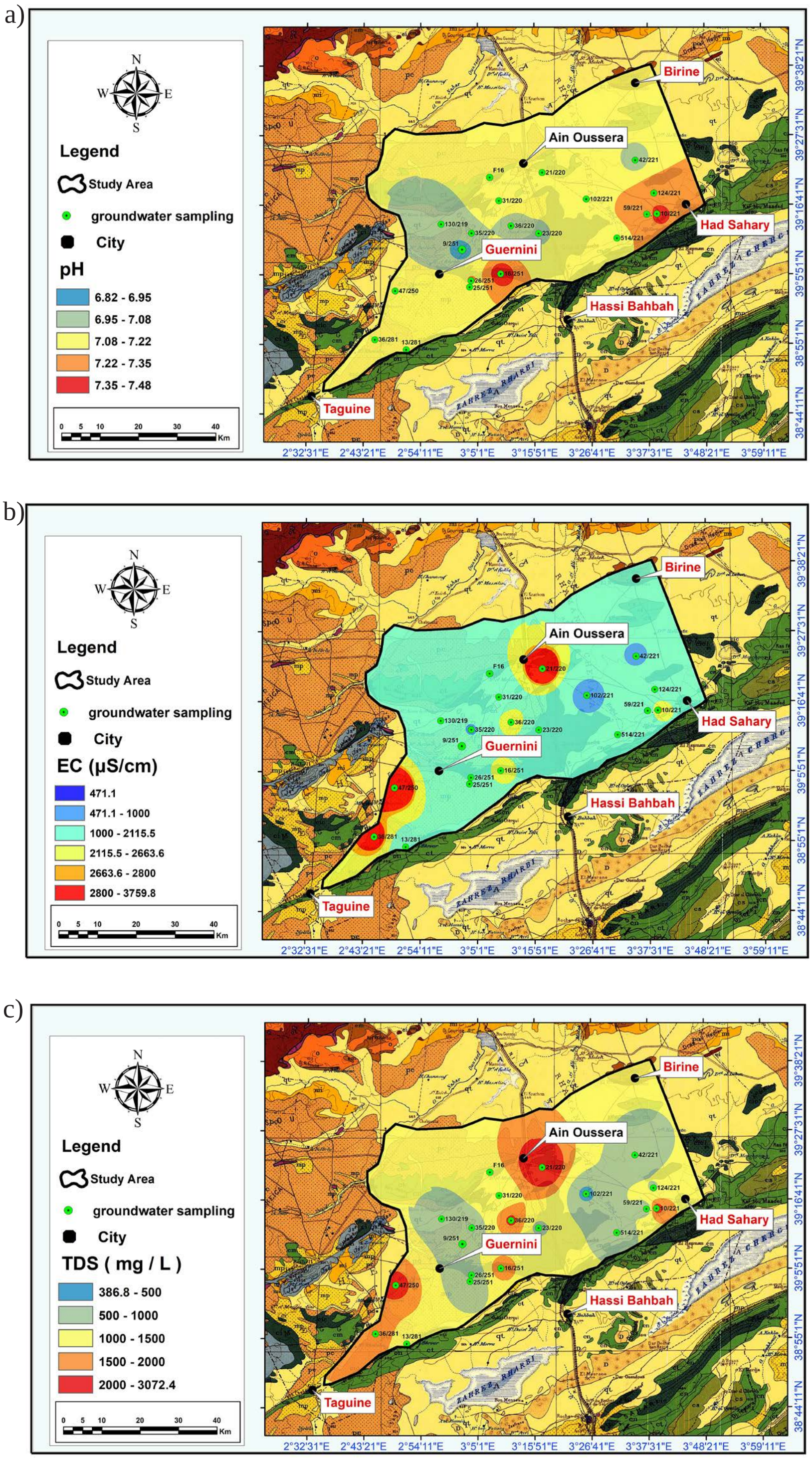


Figure 4. Spatial distribution map of pH (a), EC (b) and TDS (c)

Organization permissible limit of 12 mg/l [WHO 2011] and the Algerian norms [JORADP 2011]. Spatial analysis of potassium is presented in Figure 6a.

Chlorides are always present in natural waters in variable proportions. Their presence in groundwater results from the dissolution of natural salts; chloride is an important parameter for analyzing the water quality. The chloride values in groundwater vary from 19.97 to 652.38 mg/L, with an average value of 215.76 mg/L. Figure 6b shows that 90% of chloride concentrations are within the acceptable limits of Algerian standards of 500 mg/L [JORADP 2011], and 30% exceed the World Health Organization standards of 250 mg/l [WHO 2011].

The presence of sulfate ions in the sandstone table of the Albian is linked to the dissolution of gypsiferous formations. The sulfate values in the groundwater vary from 7.08 to 1502 mg/l, with an

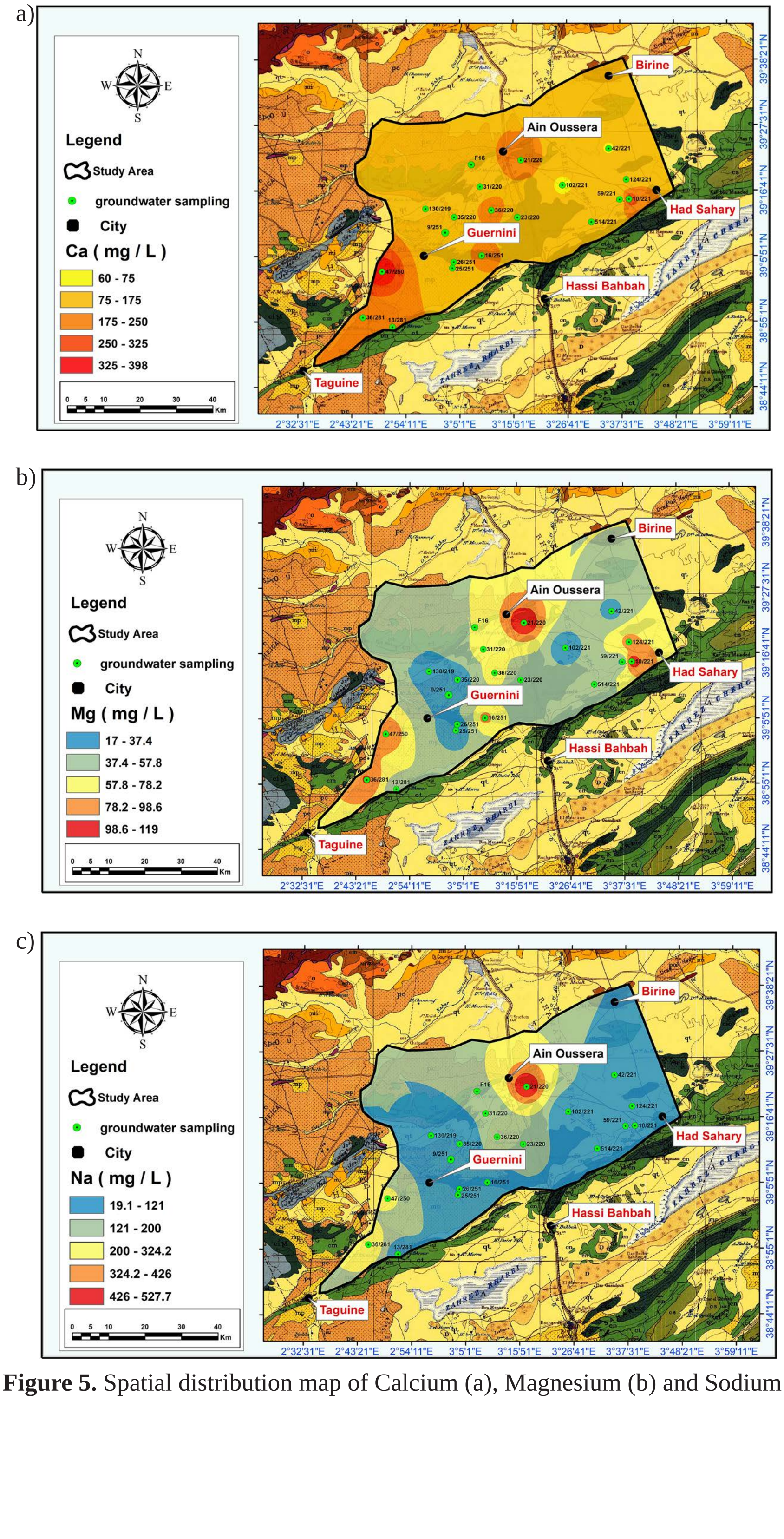


Figure 5. Spatial distribution map of Calcium (a), Magnesium (b) and Sodium (c)

average value of 271 mg/L. The high values are located in the southwestern part of the plain and south of the city of Ain Oussera and are related to the dissolution of the Cenomanian gypsiferous formations that outcrop at the southern edge of the aquifer. The spatial variation of sulfate in Figure 6c shows that 85% of sulfate concentrations are within the required limit for the Algerian norms of 500 mg/L [JORADP 2011], and 25% exceed the World Health Organization guidelines of 250 mg/l [WHO 2011].

Bicarbonate is the dominant anion in the study area. The groundwater of the study area has the levels of bicarbonate that vary between 137.25 mg/l (borehole 102/221) and 1418.25 mg/l (borehole 47/250). The extreme values of this element are recorded in the aquifer western zone. The contribution of bicarbonates to

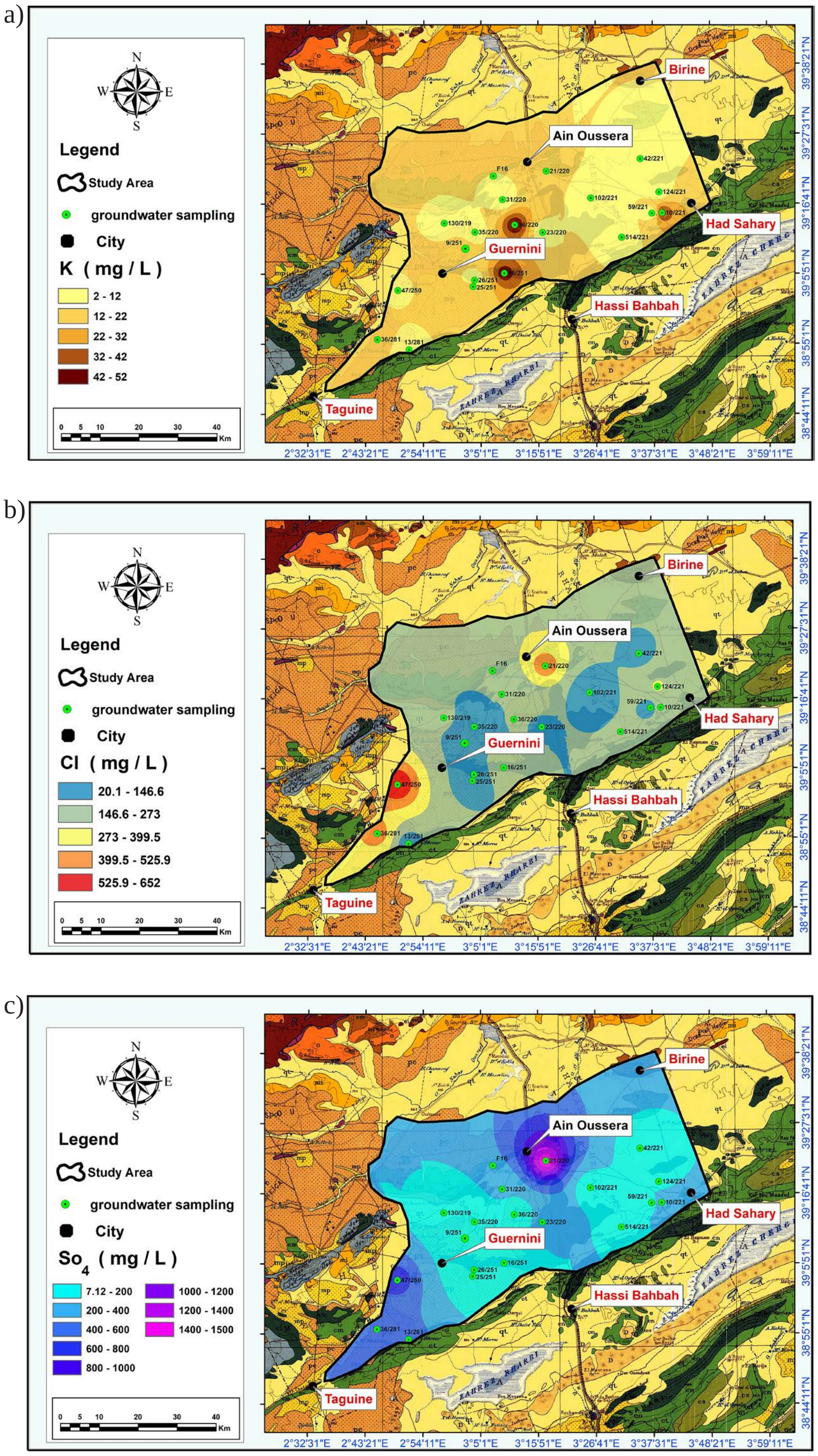


Figure 6. Spatial distribution map of Potassium (a), Chloride (b) and Sulfate (c)

the water of the Ain Oussera aquifer is probably linked to the dissolution of the limestone formations that outcrop at the southern and south-eastern edges of the plain. Figure 7a shows that all bicarbonate concentrations exceed the acceptable limits of the World Health Organization standards of 120 mg/L [WHO 2011].

The nitrate concentrations range from 0.01 mg/l as the minimum value detected at Borehole 10/221 to 78.59 mg/l as the maximum value recorded at Borehole 124/221. Spatial analysis of the map (Fig. 7b) shows that high concentrations exist in the following areas:

The south-eastern part of the plain (Had Sahary area): nitrate levels are above 75 mg/l, which is probably due to the sewage discharge and domestic waste, thus causing nitrates to increase. The northwestern area of Ain Oussera city and the area of Guernini: nitrate levels exceed the Algerian norms of 50 mg/L and the World Health Organization standards of 50 mg/l. The high concentrations are the result of the over-fertilization of farming lands with Nitrogen-based fertilizers.

WQI for the assessment of drinking water

The analysis of data was carried out by mapping the spatial distribution of WQI through the use of the Inverse Distance Weighting (IDW) method (Fig. 8), in which it was concluded that water quality can be divided into five groups according to the WQI value (Table 2).

The WQI calculated value of the groundwater of the Ain Oussera plain varies between 31 and 173 with an average value of 81 (Table 4). The WQI highest values (100< WQI < 200) are found at the following boreholes, 16/251, 36/220, 21/220, 10/221, 36/281, 47/250, which have high electrical conductivity, high total dissolved solids. This water quality deterioration was mainly related to the domestic and industrial wastewater discharges (Ain Oussera Area, Had Sahary area) and the agricultural practices like the excessive fertilizers leaching of soils (Oued Touil, commune of Guernini).

The classification of groundwater based on WQI is presented in Table 4 and Figure 8. A total of 20 samples were analyzed to determine

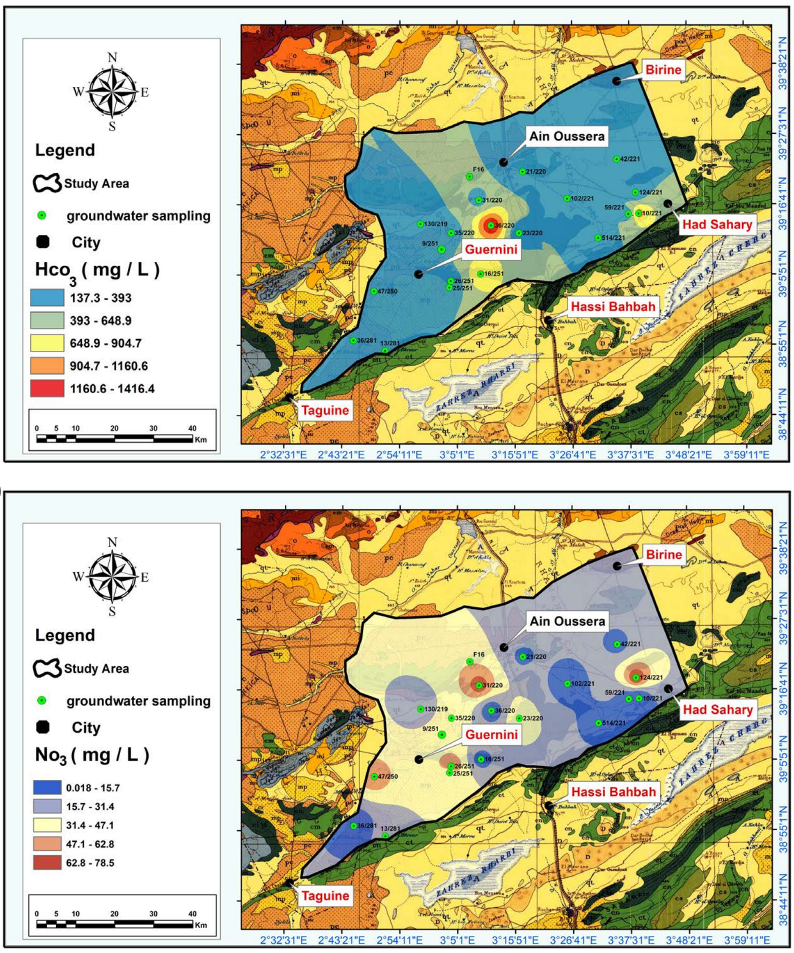
a)
b)


Figure 7. Spatial distribution map of Bicarbonate (a), and Nitrate (b)

WQI. Out of these samples, 55% are of good water quality, 30% belong to the poor water category, and 15% to the excellent water quality category.

Quality of irrigation water

In the area of study, the SAR values range between 1.08 and 13.77 meq/L. The water quality for irrigation can be categorized, according to the values of SAR [Guettaf et al., 2017; Sadashivaiah et al., 2008], The mapping (spatial distribution) of the SAR index in the plain of Ain Oussra is shown in the figure below (Figure 9). High values were found in the Ain Oussera drill site (21/220), and drill hole (F16) located west of the Ain Oussera area. The SAR results index is given in Table 5.

The analysis of Table 5 reveals that most groundwater samples were found within the range of excellent to good categories.

The United States Salinity Laboratory (USSL) has categorized water quality on the Richard diagram [Richards, 1954]. Adsorption of sodium is regarded as a risk of alkalinity, while electricity is regarded

Table 4. Calculated WQI of each groundwater samples

Sample. NO	Location Name	Lambx	Lamby	WQI	Type of water
102/221	Benhar	535231	229765	31.03	Excellent water
59/221	Had Sahary	550976	225867	41.23	Excellent water
42/221	Had Sahary	547972	239900	40.37	Excellent water
35/220	Ain Oussera	505456	220947	51.43	Good water
25/251	Guernini	504975	206950	55.51	Good water
26/251	Guernini	505363	208624	61.87	Good water
514/221	Bouira lahdab	543230	219665	47.67	Good water
130/219	El Khemis	497575	223256	51.21	Good water
9/251	Guernini	502957	216664	59.82	Good water
23/220	Ain Oussera	522887	220883	67.34	Good water
13/281	Guernini	488500	190700	69.28	Good water
31/220	Ain Oussera	512539	229334	80.35	Good water
124/221	Had Sahary	552812	231331	77.69	Good water
F16	El Khemis	510173	235398	95.06	Good water
16/251	Guernini	513025	210419	115.49	Poor water
36/220	Ain Oussera	515709	222839	125.79	Poor water
10/221	Had Sahary	553600	226000	135.16	Poor water
36/281	Oued Touil	480375	193350	114.54	Poor water
21/220	Ain Oussera	523780	236659	173.28	Poor water
47/250	Guernini	485650	205950	140.65	Poor water

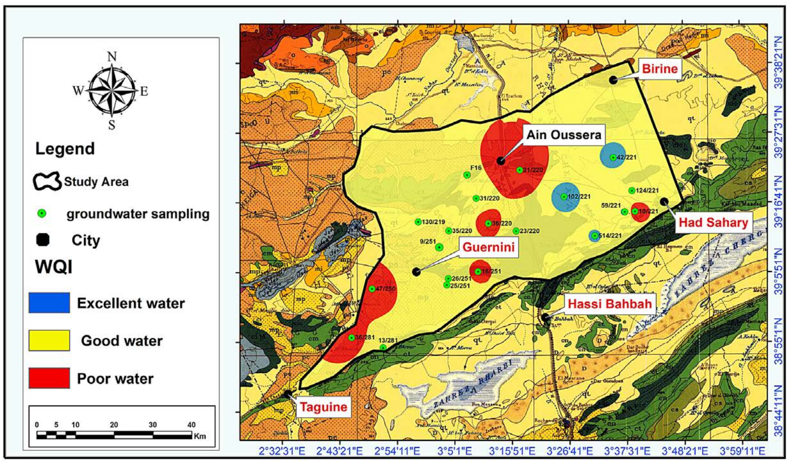


Figure 8. Spatial distribution of Water quality index (WQI) in the Plain of Ain Oussera

as a risk of salinity. The water samples from the Ain Oussera Plain were analyzed and classified into four classes, according to the diagram (Figure 10):

It should be noted that 60% of the groundwater samples are categorized as high-salinity and low-sodium hazards (C3−S1), which is therefore moderately suitable for irrigation. About 20% of the groundwater samples fall in (C4–S1) very high-salinity hazard and low-sodium hazard class, this water will be suitable for good salt tolerance plants and it restricts suitability for irrigation; 15% of samples of class (C4-S2) indicate very high salinity and medium sodium hazards and 5% of samples of class (C2-S1) with medium salinity-low sodium hazard can be used for irrigation on almost all types of soils.

Table 5. Classification of irrigation water based on SAR

Types of water and SAR value	Quality	Number of samples	Percentage of samples
Low sodium water SAR value : 0–10	Excellent	18	90
Medium sodium water SAR value : 10–18	Good	02	10
High sodium water SAR value : 18–26	Fair	0	0
Vey high sodium water	Poor	0	0

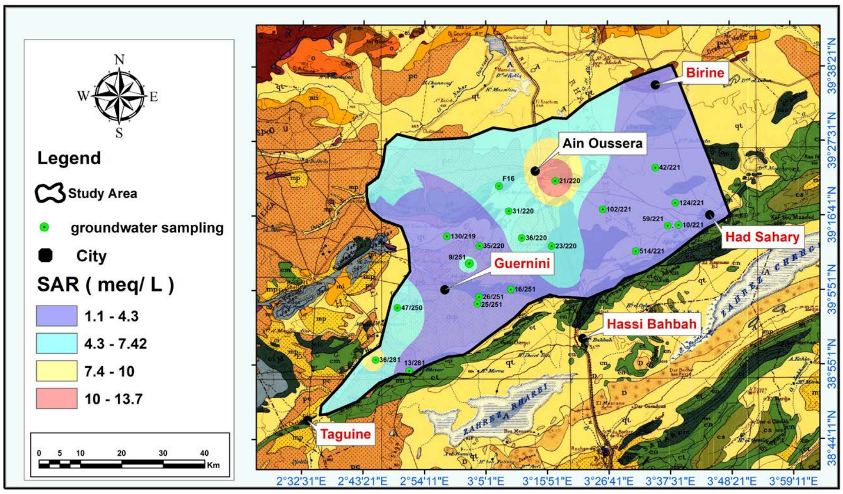


Figure 9. Spatial distribution of Sodium adsorption ratio (SAR) in the Plain of Ain Oussera

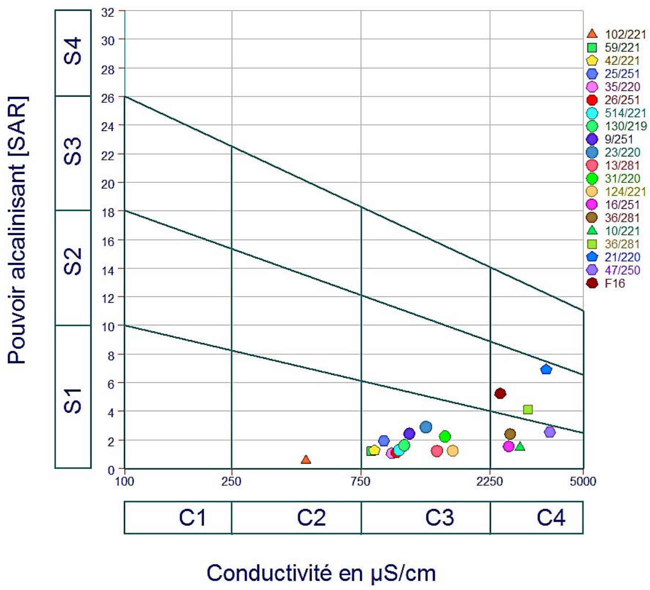


Figure 10. USSL diagram for irrigation water quality assessment

CONCLUSIONS

This work was carried out in order to understand the assessment of the suitability of groundwater of the Ain Oussera plain for various uses (drinking, irrigation) through the treatment of the water quality index QWI to evaluate the suitability of water quality for human consumption, and the sodium adsorption ratio to irrigation, with the map representation of spatial distribution using the inverse distance weighting (IDW) interpolation method of these two precise indices. This has enabled us to achieve the results summarized below:

The groundwater samples studied were collected and analyzed for major cations and anions, electrical conductivity, hydrogen potential, and total dissolved solids. The different parameters in the study area were within the guidelines fixed by the Algerian standards [JORADP 2011], except for a few areas.

In general, 70% of the samples from the Ain Oussera plain belonged to excellent and good quality categories. Its water is suitable for consumption (WQI < 100), whereas 30% of it is poor water, which is primarily due to the discharge of domestic and industrial waste water (city of Ain Oussera, city of Had Sahary) and agricultural practices such as excessive fertilizer leaching of soils (Oued Touil, commune of Guernini).

The quality of groundwater used for irrigation is assessed by a determining factor, the sodium adsorption ratio (SAR). From the calculation of SAR values, it was found that 90% of the groundwater samples are considered excellent and suitable for irrigation. A plot of groundwater data on the US salinity diagram shows that the Ain Oussera groundwater is poor for irrigation purposes; it can be used for irrigation of some salt-tolerant species of plants and on well drained and leached soils.

The evaluation of water quality of the Ain Oussera plain should include supplementary parameters such as microbiological parameters and heavy metals in WQI calculations and water quality monitoring.

Once released and distributed to decision makers, this work will aid in the decision-making processes for better water resource management, taking into account the various interests involved (social, economic, and environmental).

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