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Water Quality in an Arid Weather Area, Case: Ground Water of Terminal Complex Algerian Southeast

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Abstract

The region of Oued-Souf (SE Algeria) is characterized by the superposition of three aquifer layers, from top to bottom: the surface aquifer, the terminal complex aquifer (CT), and the intercalary continental aquifer (CI).

The terminal complex aquifer is the main source for drinking water supply and agricultural uses. The study of the chemical quality of these waters shows that they are non-potable, highly mineralized, and have major elements (sodium, magnesium, sulfate, chloride, and calcium) exceeding the standards recommended by the WHO and the Algerian standards for drinking water, so this is an obstacle to theiruse.

To highlight the origins of this mineralization, we used the hydro chemical tool. Thus, the chemical analyses in our possession were processed using the software «Statistica, which allowed us to carry out a principal component analysis (PCA). The latter showed a competition between sodium or magnesium chlorinated water and calcium bicarbonate water, rich in potassium. The thermodynamic simulation carried out showed a variation of the saturation indices, which do not exceed zero, for the waters of the CT complexes, thus indicating a sub-saturation of the waters with respect to the minerals. The mineralization starts with the breakdown of evaporates (gypsum and halite) and the exchange of bases. This shows how the outcrop formations affect the water quality.

The waters of the CT terminal complex aquifer are of poor quality for irrigation because their representation on the Richards diagram shows that they are arranged according to two classes, C4S2 and C4S3, and must be treated (dematerialized) before they are distributed to consumers.

Keywords: Terminal Complex, Mineralization, Saturation Indices, Oued Souf.

1. Introduction

In the El Oued region, groundwater is the only source of drinking and agricultural water. This region is characterized by the superposition of three aquifer layers: top-to-bottom, free surface aquifer, terminal complex aquifer (CT), and intercalary continental aquifer (CI). The surface water table has become less used for more than 20 years because of its excessive mineralization and its high degree of pollution, either mineral or organic [1]. Recent drilling is oriented towards the exploitation of the aquifer of the terminal complex, either for AEP or irrigation, because of the relatively bearable cost of drilling. The objective of this work is to evaluate the physicochemical quality of terminal waters for their different uses and to understand the geochemical behavior of waters in response to certain natural and anthropogenic sinks through a combined study of ion ratios and statistical analyses of hydro chemical data.

2. Description of the Study Area

The valley of El Oued Souf is located (Figure 1) in southeast Algeria. It occupies an area of 11,738 km2 and has a population of 523,656 inhabitants. The region is part of the Great Eastern Era, formed mainly by continental sand dunes. The slope is generally oriented south-north, with altitude values ranging from -3 m (Follia) to 125 m (Soualah). Many depressions in the form of artificial funnels characterize the region, used to plant palm trees and vegetables, locally called «Ghout».

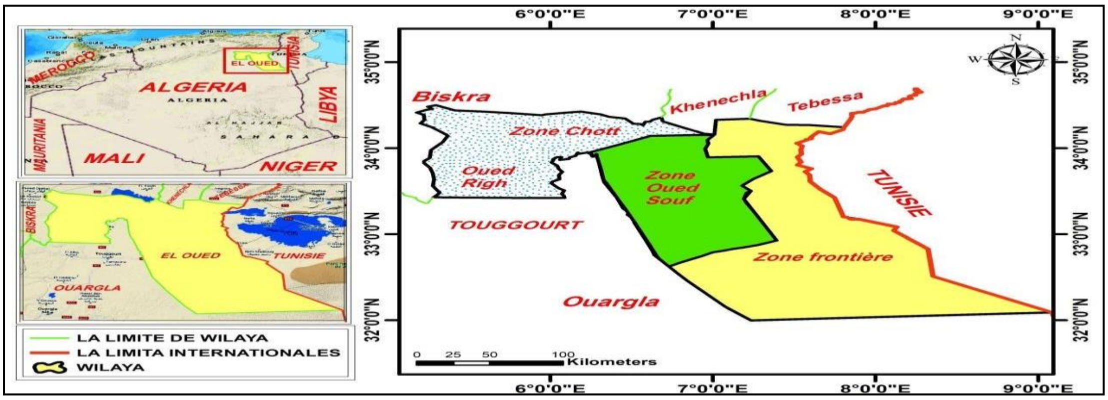


Figure.1.Geographical location of the study area

The study area is part of the Northern Sahara Sedimentary Basin, which covers an area of 780,000 km2. This basin constitutes an important topographical depression, which is supported by a structural basin in the form of dissymmetric syncline. The sedimentary series is marked in the center of the pit by significant sub vertical tectonic accidents. Bank drops are generally low, with the exception of the edge area northeast of the basin [2,3,4]. This series comprises, at its base, marine Paleozoic formations surmounted in discordance by continental secondary and tertiary formations, several thousand meters thick. The quaternary succeeds. It consists essentially of sand dunes, whose thickness can reach a few hundred meters. Only the higher series is of hydro geological interest. The El-Oued aquifer system (Figure 2) is characterized by the superposition of three aquifer layers [5, 6, 7, 8]. These are bottom to top, the Continental Intercalary (CI) aquifer, the Terminal Complex (CT) aquifer and the surface aquifer.

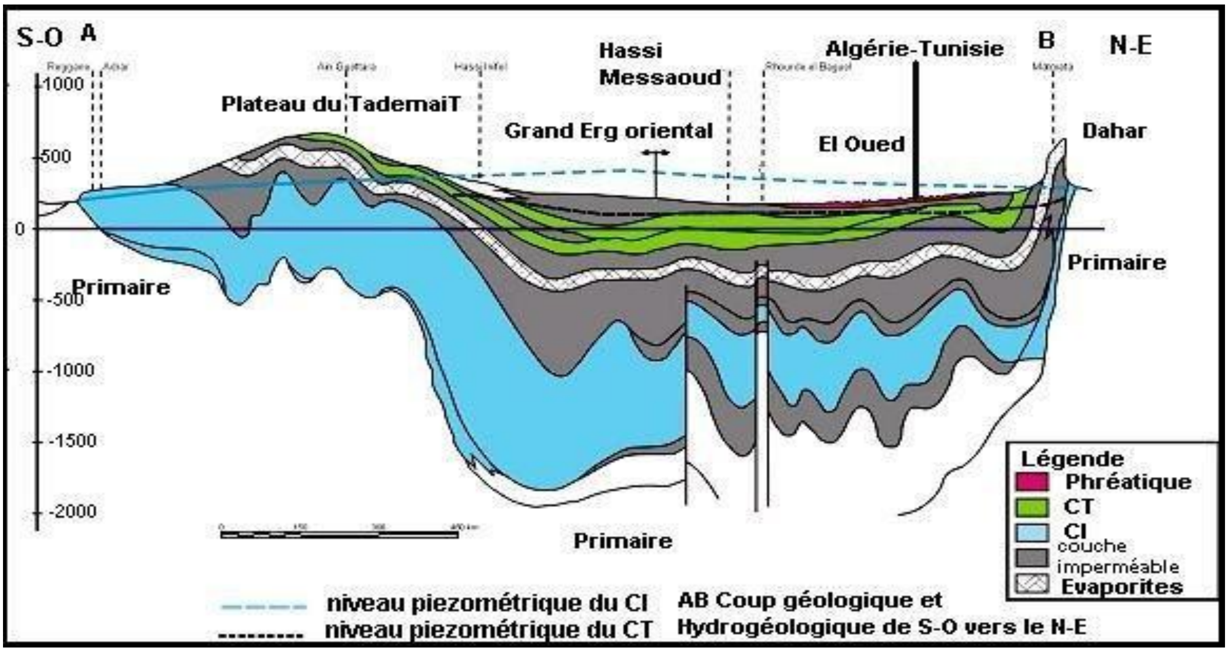
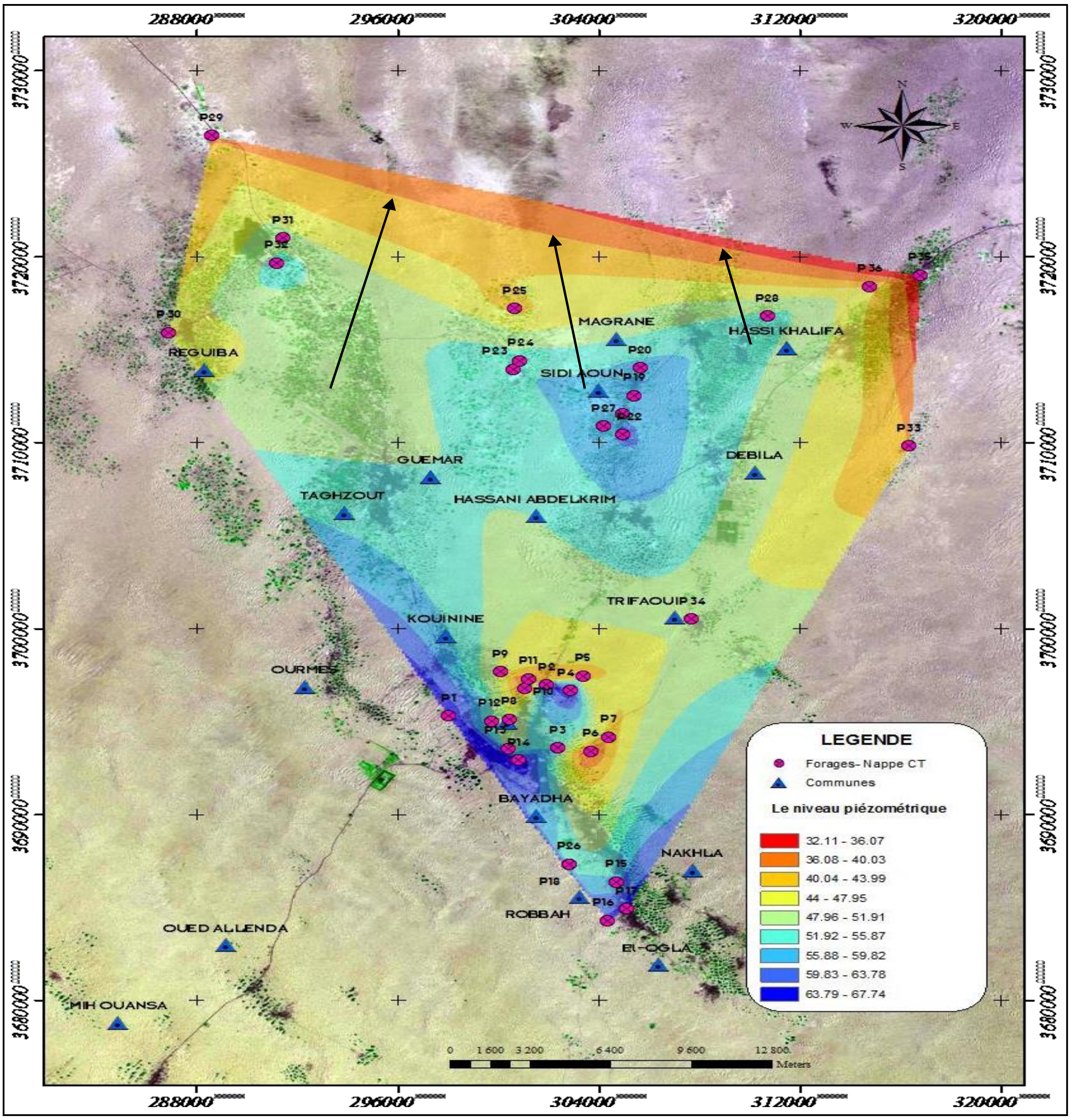


Figure.2. Hydro geological section of the Northern Sahara aquifers (UNESCO, 1972).

Figure.3. Groundwater flow direction from a Piezometric map of the CT aquifer(March 2023).



The aquifer of the Terminal Complex encompasses the permeable bedrock of the carbonated Senonian and Mio-Pliocene. In fact, it is possible to distinguish three layers locally separated by semi-permeable or impermeable horizons. These three aquifers are represented by the sands of the Mio-Pliocene (the first CT1 sand table), by the sands, sandstone, and gravel of the Pontiac (the second CT2 sand table), and by the cracked limestone and dolomite of the Eocene and Senonian carbonate age [3] (CT3 limestone slick). The third layer of limestone is found at a depth of about 250 m and extends to 700 m.

The piezometric map (Figure 3) established in March 2023 shows that the upper part of the water table is south of Ogla with a coast of 67 m, while the lower part is north of Hassi Khlifa with a coast of 32 m.The direction of water flow is oriented from south to north.

3. aterials and Methods

For the purpose of this study, twenty-two (45) samples from boreholes in the El Oued Terminal Complex Aquifer (Figure 4) were collected and measured using a hydrochemical campaign in March 2023. Physico-chemical parameters (pH, temperature, and conductivity) were determined in situ, immediately after sample collection, using a portable multi-parameter. The samples were taken from polyethylene bottles after being filtered and acidified for laboratory analysis. Analyses were performed in the laboratory using standard techniques (Rodier, 1984) [9]. Nitrates, sulfates, and chlorides were dosed with the DR2000 type spectrophotometer (HACH), while calcium, sodium, and potassium were dosed with the flame spectrophotometer. Magnesium is determined by complexometry and deduced from the difference (TH = Ca2+). The CO2 and HCO3 concentrations were analyzed by titrimetry.

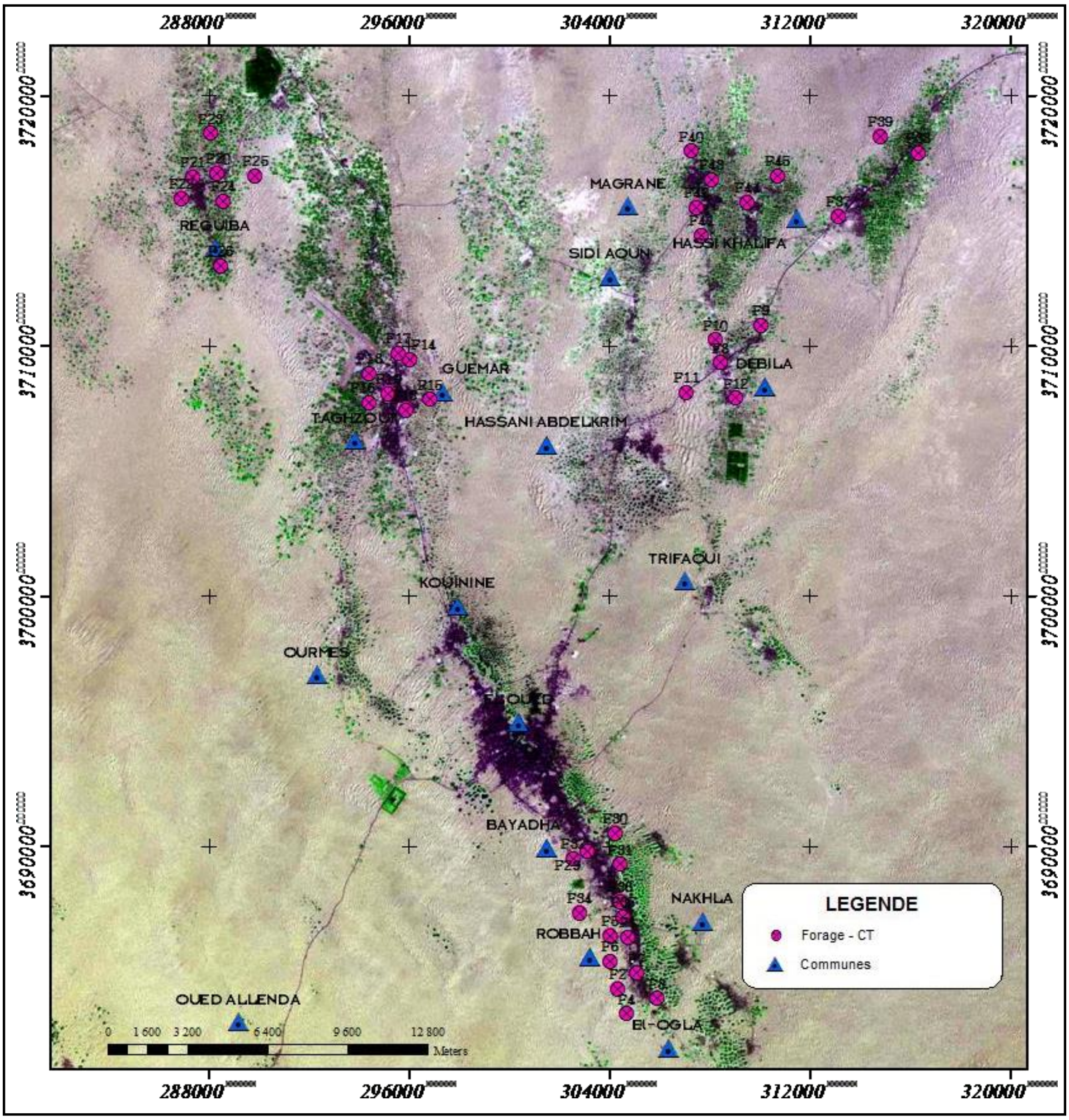


Figure.4. Distribution map of the boreholes of the terminal complex aquifer.

4. Results and Discussion

Water quality for consumption and agricultural use

Table 1 shows the variability of the physic-chemical parameters of CT waters, as well as the drinking water standards of the World Health Organization (WHO 2004) and the Algerian standards (N.A.) [10]. The comparison with the WHO guide values and the Algerian standards (N.A.) shows that the waters of the terminal complex are non-potable; they are very mineralized and have contents of major elements (sodium, magnesium, sulfate, chloride, and calcium) exceeding the standards recommended by the WHO and the Algerian standards (N.A.).

Table au.1 : Statistics of physic-chemical parameters, major ions (*n* = 34), World Health Organization (WHO 2004) and Algerian Standards (Journal Official 2011) for drinking waters of study area

Variables	Algerian Standards	WHO Standards	Minimum	Maximum	Mean	Standard Deviation
CE(µS/cm)	2800	1000	2252.1150	5463.3300	4105.6996	568.8714
Ca^{2+}(mg/l)	200	200	152.0000	286.0700	227.1365	35.2619
Mg^{2+}(mg/l)	150	150	67.5900	337.9700	144.0566	47.6775
Na^{+}(mg/l)	200	200	317.0130	582.9500	479.4970	58.1520
K^{+}(mg/l)	20	20	7.9000	43.1100	30.5490	7.8899
HCO3-(mg/l)	-	240	96.9430	183.9150	133.2136	17.8028
NO^{3-}(mg/l)	50	50	3.0100	21.9530	14.5609	4.3485
Cl^{-}(mg/l)	500	250	610.1500	1263.8000	892.0420	93.9973
$SO4^{2-}$(mg/l)	400	250	673.4000	1276.1000	990.9844	135.7015

Electrical conductivity:

Electrical conductivity is a measure that allows simple and rapid control of the mineralization of solutions. It depends on the ionic strength of the water and increases with the dissolved ion content, thenature of the different dissolved substances, their actual and relative concentrations, and the temperature at which it is measured.

The mapping of the electrical conductivity parameter of the water allows for an idea of the mineralization of the CT water. The map shows that electrical conductivity ranges from 2252 µS.Cm-1 in the south-east to 5463 µS.Cm-1 in the south-west of the study area (Figure 5). It is also noted that the electrical conductivity increases in the flow direction of the water because the waters are increasingly loaded with salts from the dissolution of the rocks surrounding them. These values measured in the study area in March 2023 exceed the Algerian standard for drinking water (2800 µS.Cm-1).

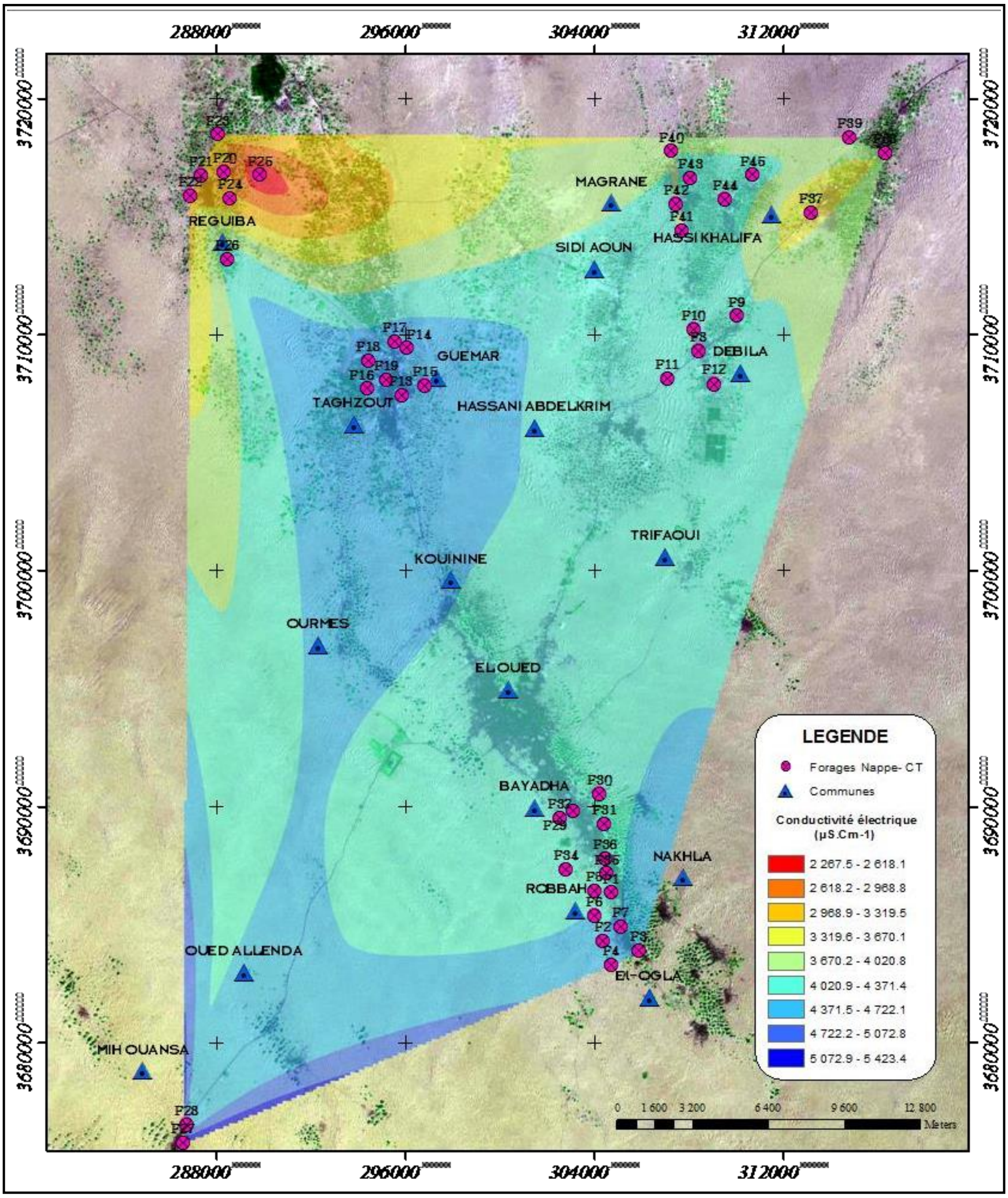


Figure.5. Electrical conductivity spatial distribution map (March 2023).

5. Hydro chemical Fancies Characterization

The Piper (1944) diagram was used to represent the different groundwater fancies of the Terminal Complex aquifer. The representation of the results (Figure 5) shows two hydro chemical fancies: The water type Mg2+, Ca2+, and SO42- represents 68%, distributed in the central and western parts. The Na2+-Cl- type represents 32%, distributed in the eastern part, which reflects the dominance of sodium and chloride, suggesting the influence of evaporate deposits.

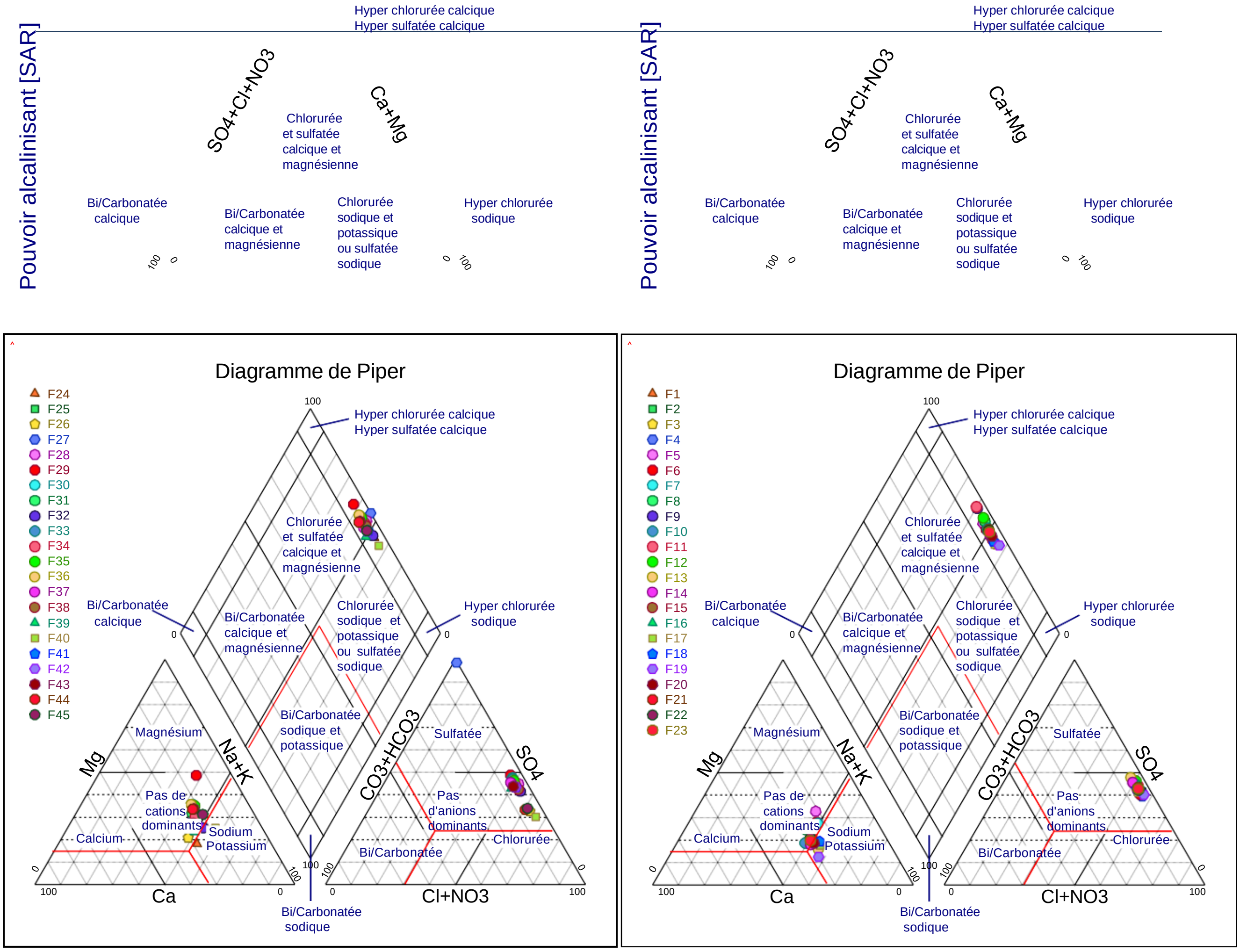


Figure .5. Piper diagram of terminal complex aquifer (March 2023).

6. Irrigation Terminal Complex Water Skills

The abundance of sodium in irrigation water can cause dispersion and destruction of the soil structure, if the sodium content is at least three times that of calcium, under such conditions, it can become extremely difficult to meet the water needs of the crop. The risk is determined from the value of the absorbable sodium "Sodium Absorption Ratio" (S.A.R) for the same conductivity, the risk is greater as the coefficient is higher.

The SAR (Sodium Adsorption Ratio): is an index that assesses the danger of the existence of a given sodium content; it is calculated by the equation:

$$SAR = Na^{+} / ((Ca^{2+} + Mg^{2+}) / 2)^{1/2}$$

Richards's (1954) method is based on a combination of SAR and electrical conductivity (Figure 6). Theresult of the classification of the chemical quality of water from the Richards diagram shows that the samples are arranged according to two classes:

a. Poor water (C4S2): Waters in this class are highly laden with salts. They are likely to be suitable for irrigation of salt tolerant plants and well drained and leached soils.

b. Bad water (C4S3): the water in this class is not suitable for irrigation, Their use for irrigation mustbe subject to certain conditions: very permeable soils, good leaching, very salt tolerant plants.

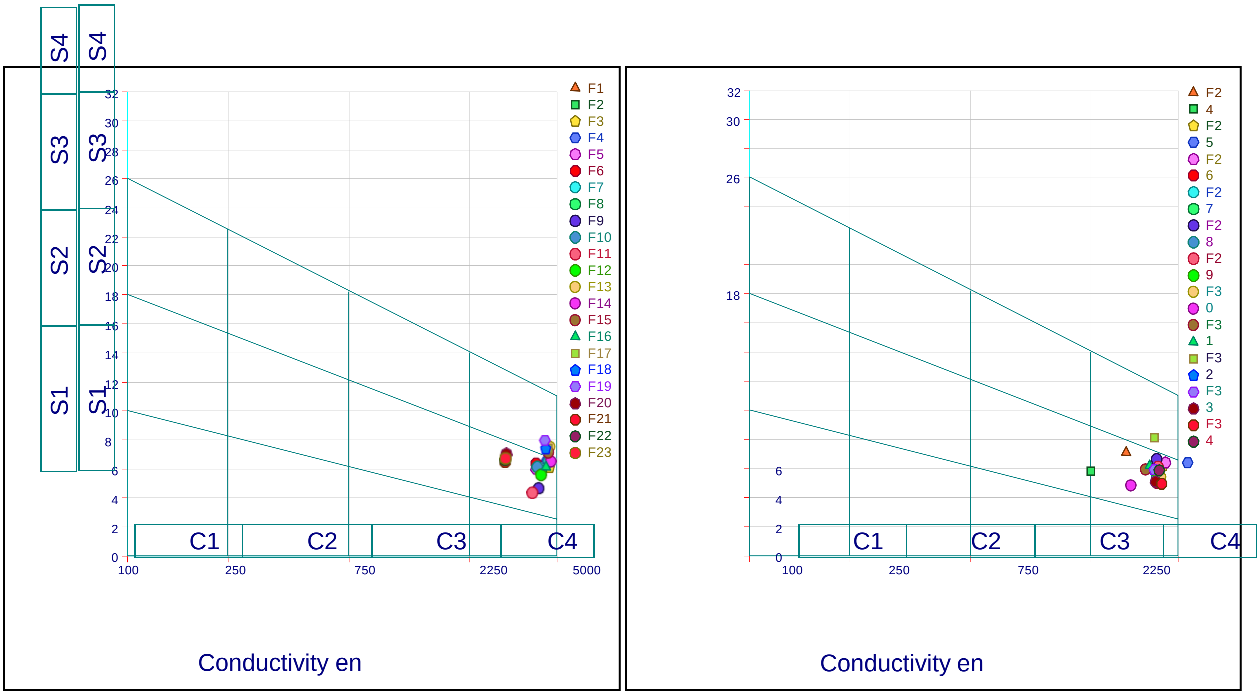


Figure.6. Richards diagram of terminal complex aquifer (March 2023).

7. Terminal Complex Water Saturation Index

To determine the influence of chemical elements, we used the thermodynamic tool by calculating thesaturation index. According to the law of mass action, for an aqueous solution in equilibrium with a mineral, the product of ionic activity (PAI) of the mineral is equal to the equilibrium constant (KSP) thermodynamic. The degree of saturation of a water can be represented by:

IS = Log (PAI/KSP)

This constant K characterizes the equilibrium established in a reversible system that ceases to evolve (for a given temperature). Note that IS will respectively be zero, positive and negative for a solution in equilibrium with the mineral solid phase considered, for an over- saturation and for an under-saturation vis-à-vis the ionic elements concerned.

The results obtained after calculation (Figure.7) show that the saturation indices are; positive, indicating an oversaturation with respect to the minerals of calcite, dolomite and aragonite, and negative, indicating an under saturation with respect to For anhydrite and gypsum minerals (and even forhalite and Sylvie). Indeed, a possible dissolution of anhydrite, gypsum and halite contribute to the acquisition of groundwater mineralization.

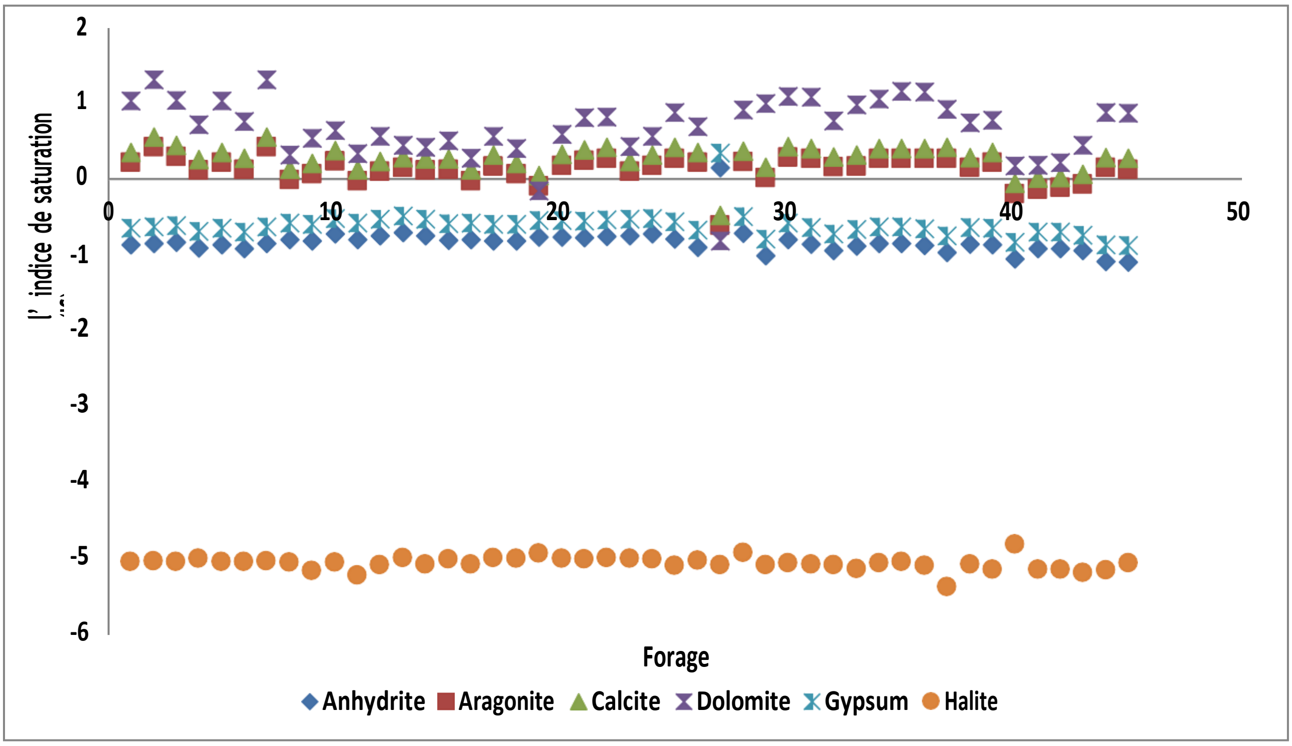


Figure.7. Change in the mineral saturation index of the complex aquifer

8. Conclusions

The valley of El Oued Souf located in the south-east of Algeria, occupies an area of 11,738 km2 and encompasses a population of 523,656 inhabitants. The El-Oued aquifer system consists of three aquifers from top to bottom, we distinguish: free aquifer, the terminal complex aquifer and the continental interlayer aquifer. The layer of terminal complex encompasses permeable bases of the Senonian carbonate to Mio -Pliocene. There are three aquifers, separated locally by semi-permeable or impermeable horizons. The piezometric map of the water table established in March 2023, shows that the flow of water is oriented from south to north. The interpretation of the chemical analyses of the waters shows the dominance of the evaporate fancies (sodium sulphate, sodium chloride, calcium chloride and calcium sulphate). These waters are non-potable because they are highly mineralized and contain major elements (sodium, magnesium, sulfate, chloride and calcium) that exceed the standards recommended by the WHO for drinking water. They are also of poor to poor quality for irrigation according to the American salinity diagram (Richards 1954). The study of the characteristic relationships between the major elements has shown that the mineralization of the waters of the terminal complex aquifer is linked to the dissolution of the evaporates (gypsum and halite in particular) and to the basic exchange phenomenon.

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