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Research Article

CONTRIBUTION TO THE COMPARATIVE STUDY OF WATER QUALITY OF DIFFERENT AQUIFERS IN THE EL OUED REGION (SOUF)

Djamel Besser, Ali Ghomri*

Department of Hydraulics, Faculty of Technology, University of El -Oued.

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ABSTRACT

The aquifer system in the El-Oued region consists of three aquifers: the unconfined aquifer (phreatic), and two confined aquifers (the terminal complex aquifer and the interlayer continental aquifer). These aquifers are considered as a single water resource available in this region. Despite this wealth, the quality of these waters remains generally mediocre to bad quality. The contribution to the comparative study of the physico-chemical quality of waters from different aquifers in the Souf region reveals, in general, high mineralization (mainly originating from the geological nature of the surrounding formations) decreasing with depth, and exceeding the standards recommended by the WHO. Therefore, strict criteria must be demanded to improve the chemical quality of water and ensure its potability according to national and international standards before supplying it to consumers.

Keywords: Terminal Complex, Interlayer Continental, phreatic; Mineralization; Physico-chemical quality.

Author Correspondence, e-mail: ghomriali65@gmail.com

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1. INTRODUCTION

In developing countries with arid climates, the role of groundwater is even more important as it often constitutes the only source of drinking water supply and is therefore vital for the development of these countries. The management of water resources, in terms of quantity and quality, remains a central concern for the country given the inadequacy of resources, which is often exacerbated by drought.

In Algeria, water resources come from surface water and groundwater, both renewable and non-renewable. The exploitation of these resources is extremely intense due to population growth and the rapid development of economic activities, particularly irrigated agriculture and industry.

For the northern Algerian Sahara, the main resources consist of groundwater. These are contained in the continental formations of the Continental Intercalary (C.I) and the Terminal Complex (C.T) and constitute one of the largest hydraulic reservoirs in the world [1,2], with mobilizable potentials estimated at 5 billion cubic meters of water [3]. Despite the richness of this region in groundwater, it nevertheless has poor to mediocre quality.

The main objective of this study is to provide an overview of the physico-chemical quality of groundwater in the different aquifers of the Souf region through a sufficiently representative sampling of the nature of the region's waters, whether for drinking water supply, irrigation water, and to contribute to the comparative study of water quality in various aquifers.

2. IDENTIFICATION OF THE STUDY AREA

The province of El-Oued is located in the northeast of the northern Sahara (Figure 1), in the southeast of Algeria. It covers an area of 11.738 km^2 and has a population of 523,656 inhabitants. The region is located in the part of the Grand Erg Oriental, characterized by a series of sand dunes of continental origin and Quaternary age. These dunes are longitudinally deposited and can reach heights of over 60 meters. Between the dune ridges, depressions called "Sahanes" or plateaus form, often extensive and sometimes rocky or covered by old gypsum crust formations from the Quaternary period.

The relief of the Souf is characterized by the existence of three main forms:

- A sandy area, which appears in two aspects, the Erg and the Sahara.
- A rocky plateau that extends southward with an alternation of dunes and rocky ridges.

- A depression zone characterized by the presence of a multitude of chotts that plunges eastward.

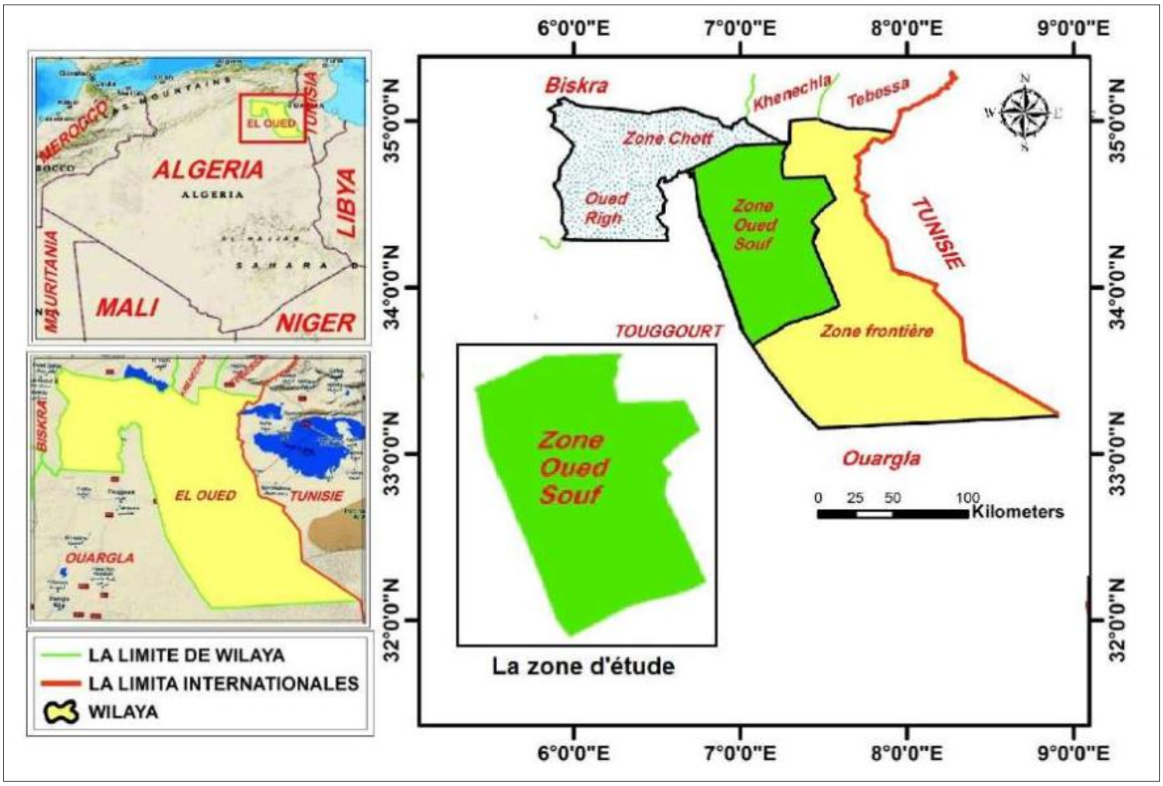

Fig.1. Geographic location of the study area

From a topographic point of view, the wilaya of El-Oued is characterized by a gradual elevation variation (Figure 2); the altitude decreases from south to north and from west to east to reach negative values at the level of chotts (75 m in El-Oued and -3m in Foulia). The slope of the study area is generally oriented south-north, with a very low average slope (on the order of 0.002 m/m to 0.003 m/m) and incidents related to the presence of dunes.

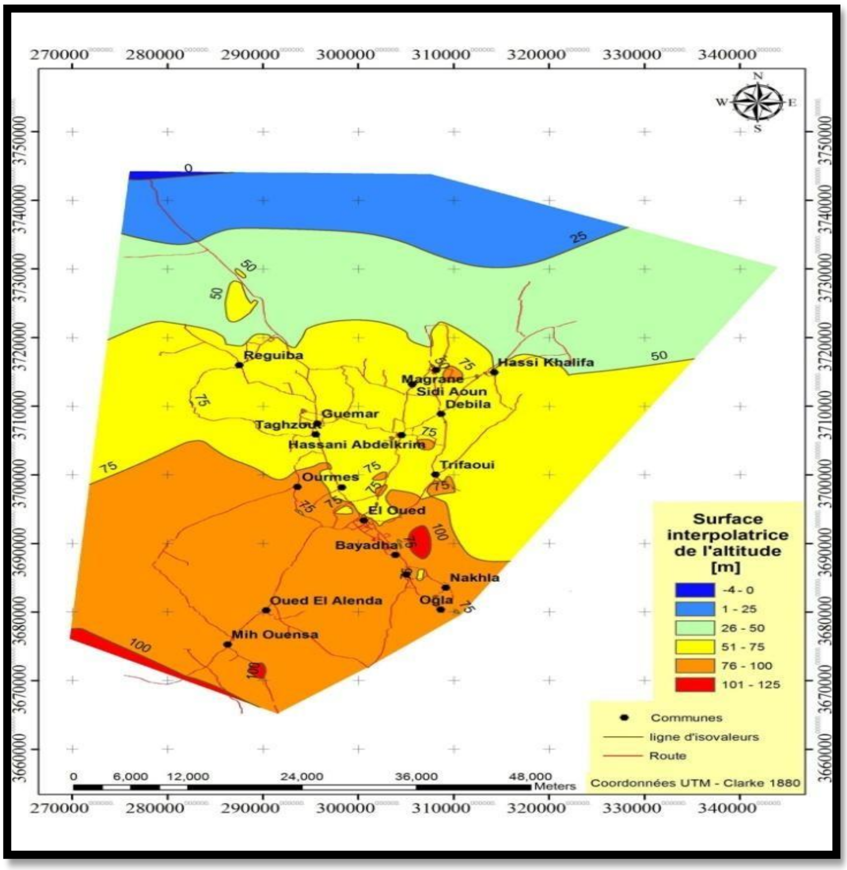

Fig.2. Topographic map of the Souf Valley (GIS 2009)

The study area is located in the sedimentary basin of the northern Sahara, covering a vast area of 780,000 km2. This basin, characterized by a significant topographic depression, is underlain by a structurally asymmetrical synclinal basin. In the center of the trough, the sedimentary series is marked by significant sub-vertical tectonic faults. The dip angles of the beds are generally low, except for the border zone located in the northeast of the basin [4,5,6]. At the base of this series are marine Paleozoic formations, covered by secondary and tertiary continental formations, with a thickness of several thousand meters. The Quaternary period follows, mainly composed of thick layers of dune sands that can reach several hundred meters in thickness. The hydrogeological importance lies solely in the upper series.

The Souf Valley encompasses a number of oases within the Great Eastern Erg, and like most oases in the northern Sahara, the only available water resources for irrigation are underground aquifers. Those in the Souf region are contained in aquifer formations of different natures. At the regional and national scale, the authors [7,8,9].

According to hydrogeological studies, we observe the existence of three types of aquifers (Figure 3): a superficial free aquifer; captive aquifers of the Terminal Complex; captive aquifer of the Continental Intercalaire.

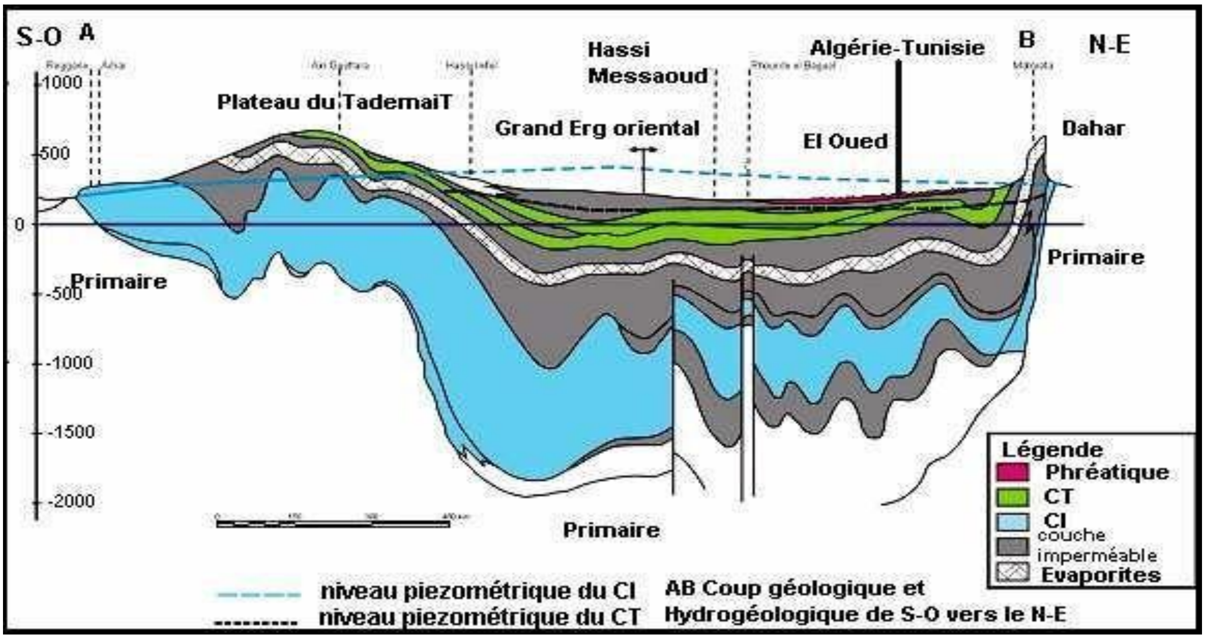

Fig.3. Hydrogeological section in the Sahara aquifer system [9]

3. MATERIALS AND METHODS

For the realization of this study, a campaign of sampling and hydrochemical measurements was carried out on twenty-seven (27) samples taken from wells of different aquifers (in March 2016): 12 improved wells (phreatic aquifer), 12 CT wells and 03 Albian CI wells. The choice of these stations is based on reasons of accessibility and proximity, and to cover the entire study area, these are the operational stations (Figure 4). The physico-chemical parameters (pH, temperature, and conductivity) were determined on-site, immediately after sample collection, using a portable multiparameter device. Water samples were collected in polyethylene bottles after filtration and acidification for analysis at the ADE laboratory (Algerian Water Unit of El Oued). The analyses were carried out in the laboratory using standard techniques (Rodier 1984) [10].

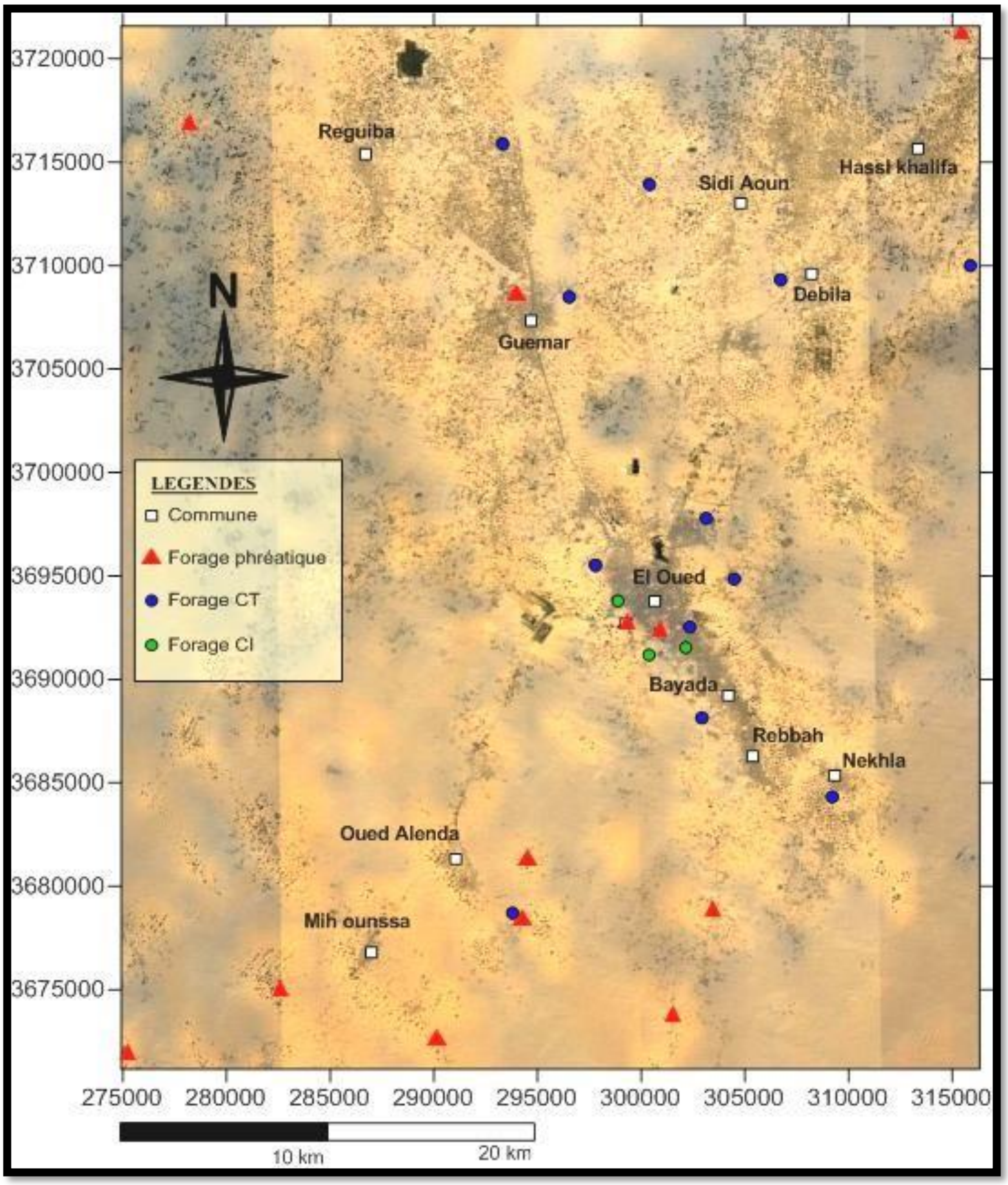

Fig.4. Location of the sampled water points in the region

Table 1. The chosen Continental Intercalaire CI water drilling (Albian) [11]

water drilling (Municipality)	Year of completion	Coordinates			Depth (m)	Flow (l/s)	S L (m)	D L (m)	Use
		X	Y	Z					
Route Touggourt	1986	298884	3693421	87	1850	100	13 bars		DWS
Chouhada	1987	302075	3690921	77	1842	140	14 bars		DWS
19 mars	2011	300311	3690629	105	1883	180	15 bars		DWS

Table 2. The chosen Terminal Complex CT water drilling [11]

water drilling (Municipality)	Year of completion	Coordinates			Depth (m)	Flow (l/s)	S L (m)	D L (m)	Use
		X	Y	Z					
Ouled rehouma (Sidi Aoun)	2013	301241	3714412	44	354	40	34.41	42.21	DWS
Erg Souari Ghamra (Guemar)	2012	294364	3716709	54	364	40	37	55	DWS
EST (Guemar)	2013	297270	3708836	55	348	42	37.54	47.70	DWS
Sahine (Trifaoui)	2013	316326	3709779	50	341	39	36.10	53.05	DWS
Sommam (Bayada)	2013	302810	3687309	77	255	28	54	99.04	DWS
Dabadib (OuedAlenda)	2013	293882	3677485	97	222	42	32	68	DWS
Debila Garbia (Debila)	2007	307296	3709370	66	358	40	33.94	51.76	DWS
Nekhla Garbia (Nekhla)	2013	308873	3683112	80	238	34	37.56	59.64	DWS
forage 8 Mai (Eloued)	2010	303370	3697411	68	293	41	37.5	42.05	DWS
Bouhmid 01 (Eloued)	1988	304611	3694298	75	275	45	32	41.62	DWS
cité Nassime (Eloued)	2008	302423	3691932	92	266	43	33.8	40	DWS
Teksebt Ghar (Eloued)	2010	298031	3695243	79	278	40	42.3	47	DWS

Table 3. The chosen improved wells (phreatic aquifer) [11]

Well (Municipality)	Year of completion	Coordinates			Depth (m)	Flow (l/s)	S L (m)	D L (m)	Use
		X	Y	Z					
El Katef (MihOuanssa)	2008	282328	3674223	96	64	13	8.9	14.4	DWS
Geddachi (Rebbah)	2016	300875	3672224	95	56	12	17	25	DWS
Debidibi (Rebbah)	2014	303007	3677535	86	56	8	15	19.9	DWS
Herouila (MihOuenssa)	2014	289682	3671458	102	60	6	14	19	DWS
Bougssisia (HassiKhalifa)	2008	316310	3721585	45	61	18	3.9	16.22	DWS
Dmirini (MihOuenssa)	2008	274919	3671156	103	56	13	12,5	21,7	DWS
Nadour (Reguiba)	2008	279486	3718261	56	50	6	-	-	DWS
Chegamet (OuedAlenda)	2008	294296	3680396	94	60	7	14,8	22,5	DWS
Dabadibe (OuedAlenda)	2008	293882	3677485	97	52	10	11,3	20,2	IRR
Piscine 19 Mars (ElOued)	2006	300938	3691739	96	58	-	-	-	Pool
Forg Irrg Centre de finance (ElOued)	2007	299397	3692210	91	58	-	-	-	IRR
Piscine (Guemar)	2009	294704	3709082	63	48	7	18	24	Pool

4. RESULTS AND DISCUSSIONS

4.1 Identification of the chemical facies of the waters

There are several classifications of natural water facies; two fundamental classification criteria are distinguished: The chemical composition and the origin and deposit of the waters.

The main classifications based on the chemical composition of natural waters and the most used are those of PIPER, STABLER, and SCHOELLER.

4.1.1 Piper Diagram

The diagrams of our analyses are represented in figures: (05) (06) (07). According to these diagrams, we note that: a- In cases concerning groundwater, the majority of samples are located at the poles: chloride and calcium and magnesium sulfate facies, which is probably due to the dissolution of evaporites. b- In the case of CT groundwater, this piper diagram allows for a comprehensive approach to the chemical composition of groundwater. We notice that most of the waters analyzed (75%) present a Chloride and sulfate calcium and magnesium facies, and (25%) present chloride sodium and potassium facies, in connection with the lithological nature of the aquifer formations.

c- In the case of CI groundwater, we note that the analyzed waters present a Chloride and sulfate calcium and magnesium facies in connection with the geology of the aquifers.

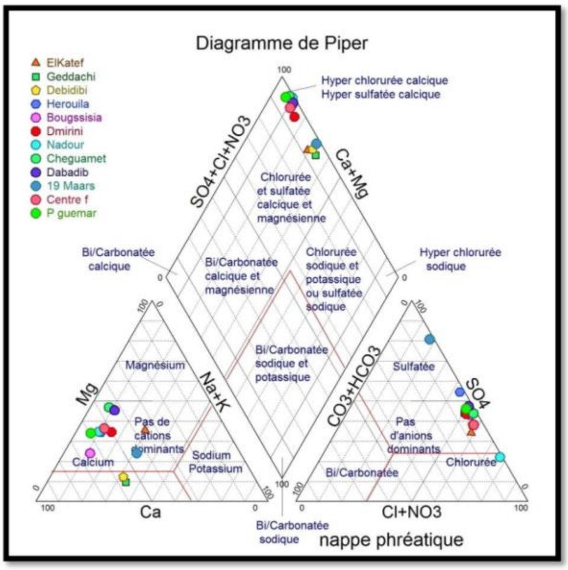

Fig.5. Piper diagram of the waters of the Oued Souf groundwater table, March 2016

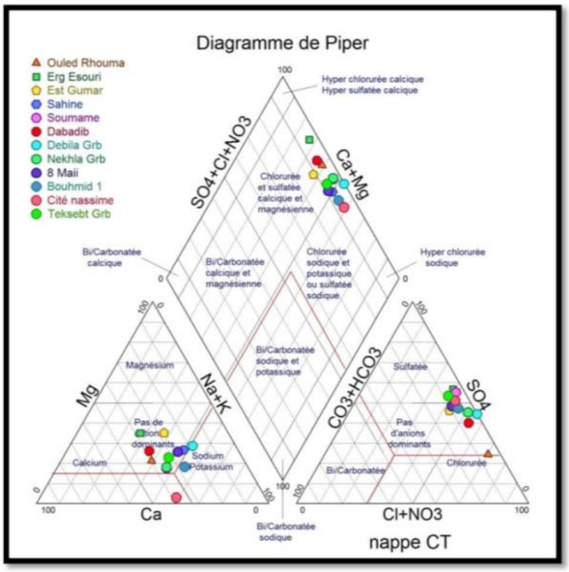

Fig.6. Piper diagram of the CT aquifer waters of Oued Souf, March 2016

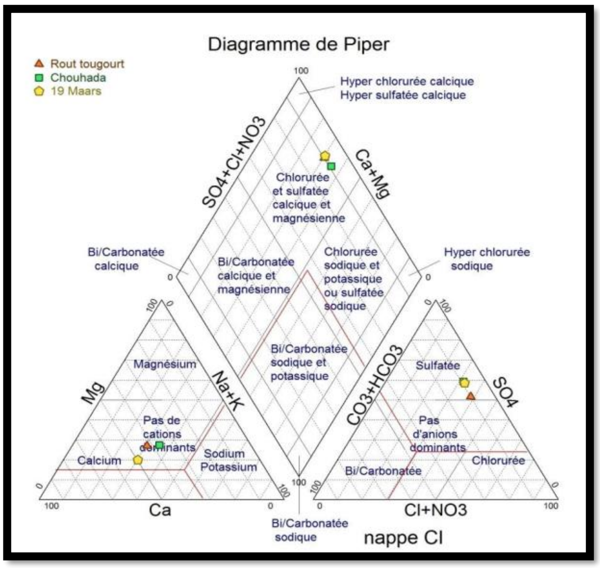

Fig.7. Piper diagram of the CI aquifer waters of Oued Souf, March 2016

4.1.2 Schoeller-Berkaloff Diagram

It allows to represent the chemical composition of several waters at once. The concentration of each chemical element is represented by a vertical line on a logarithmic scale. A broken line is formed by connecting all the points representing the different chemical elements. The concentrations are expressed in mg/l or meq/l.

a- According to figure 08 (groundwater), it is noted that there is a large variation in the content of waters from the wells of the groundwater, but in general, the predominant facies is calcic sulfate. The dominant anions are: SO_4^{-2} > Cl^- > HCO_3^-, and the dominant cations are: Ca^{++} > Na^+ > Mg^{++}.

b- According to figure 09 (CT groundwater), it is observed that the lines almost overlap on the anion side and show a slight divergence on the cation side. But they all indicate the dominance of sulfates and sodium, and therefore facies for all samples of sodium sulfate type. The dominant anions are: SO_4^{-2} > Cl^- > HCO_3^-, and the dominant cations are: Na^+ > Ca^{++} > Mg^{++}.

c- According to figure 10 (CI groundwater), it is noted that there is an overlap on the anion side and a slight divergence on the cation side. But in general, the predominant facies is calcic sulfate. The dominant anions are: SO_4^{-2} > Cl^- > HCO_3^-, and the dominant cations are: Ca^{++} > Na^+ > Mg^{++}.

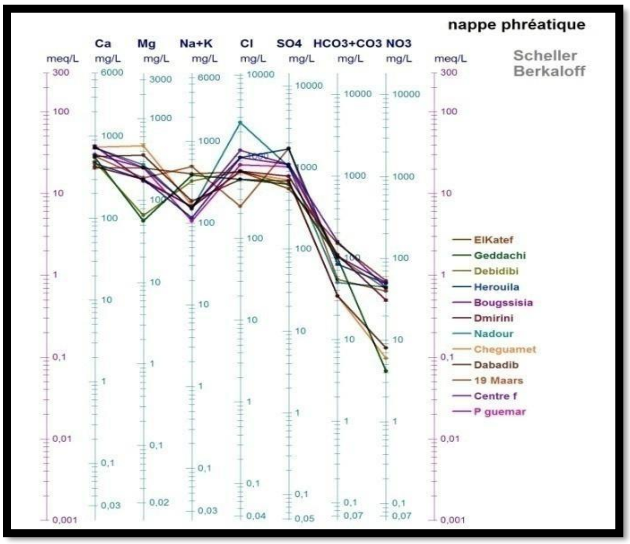

Fig.8. Schoeller-Berkaloff diagram of the Oued Souf groundwater table waters, March 2016

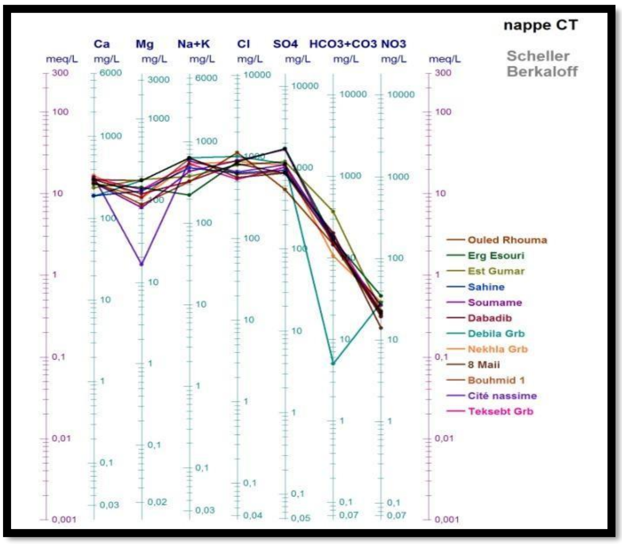

Fig.9. Waters of Oued Souf, March 2016

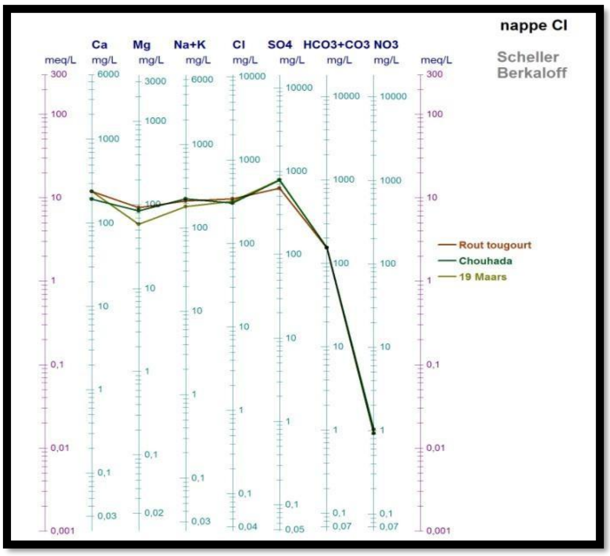

Fig.10. Schoeller-Berkaloff diagram of the CI aquifer waters of Oued Souf, March 2016

4.1.3 Water suitability for irrigation

The suitability of water for irrigation can be evaluated by a number of more or less reliable coefficients, among which: Sodium percentage (% Na) and Sodium adsorption ratio (S.A.R).

4.1.2 Sodium Adsorption Ratio (S.A.R)

The S.A.R is an index that measures the risk posed by the presence of a certain sodium content in water.

It is calculated by the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Mg^{++} + Ca^{++}}{2}}}$$

Where all elements are expressed in meq/l. SAR values were calculated from chemical analysis data.

The results show that the groundwater in the Oued Souf region belongs to three classes (figures 11, 12, 13, and Table 4 and 5).

These are C4-S1, C4-S2 of poor quality, and C4-S3 of bad quality. The water quality for irrigation is therefore of mediocre to bad type. In general, highly mineralized water may be suitable for irrigation of certain salt-tolerant species on well-drained and leached soils.

Table 4. Classification of water in the study area by irrigation suitability levels

	Classes		% of water points
Groundwater phreatic	Mediocre	C4 S1	66.66
		C4 S2	33.33
CT aquifer water.	Mediocre	C4 S1	8.33
		C4 S2	75
	bed	C4 S3	16.66
CI aquifer water.	Mediocre	C4 S1	100

Table 5. Classification of water by irrigation suitability levels using the S.A.R method (In M. Louvrier 1976 - B.R.G.M.) [12]

Degree	Quality	Class	State of use
1	Excellent	C1-S1	Water safe for irrigation of most crops on most soils.
2	Good	C2-S1 C2-S2	Generally, water suitable for irrigation of moderately salt-tolerant plants on soils with good permeability.
3	Acceptable	C3-S1 C3-S2 C2-S3	Generally, water suitable for irrigation of salt-tolerant crops on well-drained soils, salinity evolution should be monitored.
4	Mediocre	C4-S1 C4-S2 C3-S3	Generally, highly mineralized water suitable for irrigation of some salt-tolerant species on well-drained and leached soils.
5	bed	C3-S4 C4-S3 C4-S4	Water generally not suitable for irrigation but can be used under certain conditions. Very permeable soil, good leaching, plants very salt tolerant.

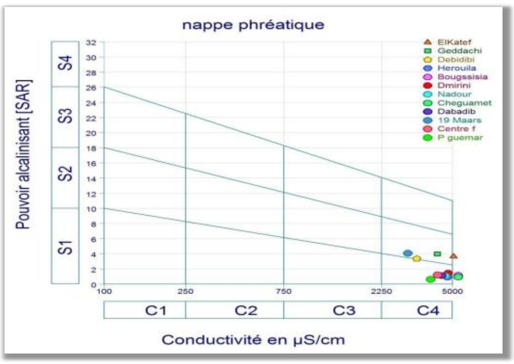

Fig.11. Classification of groundwater for irrigation according to the SAR method in the Oued Souf region march 2016

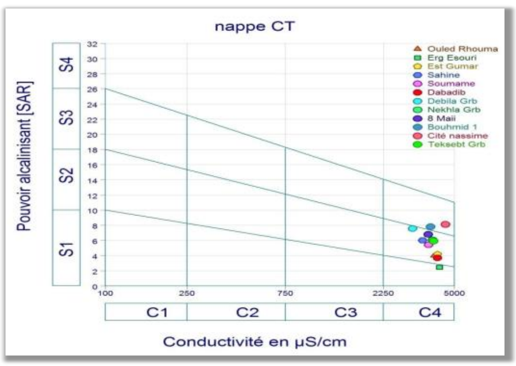

Fig.12. Classification of CT aquifer waters for irrigation according to the SAR method in the Oued Souf region, march 2016

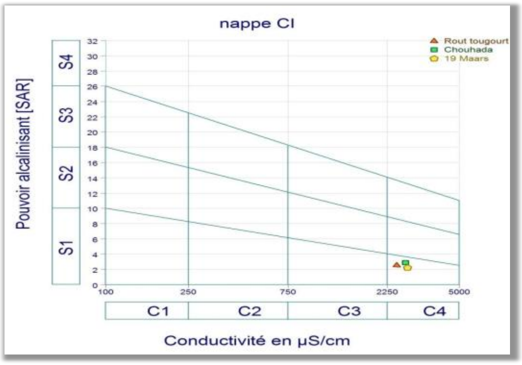

Fig.13. Classification of CI aquifer waters for irrigation according to the SAR method in the Oued Souf region.march 2016

4.2 Chemical potability of water

4.2.1 Potability standards

In our study, we use Algerian potability standards (defined by the decree of July 26, 2000 (Official Journal No. 51/0).

In our study, we use the Algerian drinking water standards (defined by the decree of July 26, 2000 (Official Journal No. 51/00)) and the WHO guidelines (2006), which are presented in the following Table:

Table 6. Algerian Standards (2000) & WHO Drinking Water Guidelines (2006)

Parametres	Unit	Algerian Standard (Drinking Water)	WHO Guideline Value
Temperature	°C	25	12 à 25
pH	-------	6.5 – 8.5	6.5 à 9.5
Conductivity	$\mu S.cm^{-1}$	2 800	400
Dry residue	mg/l	2000	1500
Total hardness	mg/l	500	200
HCO3	mg/l	--------	--------
Cl	mg/l	500	250
NO3	mg/l	50	50
NO2	mg/l	0.1	3

NH4	mg/l	0.5	0.3
SO4	mg/l	400	500
Ca	mg/l	200	100
Mg	mg/l	150	50
Na	mg/l	200	200
K	mg/l	20	10
Turbidité	NTU	2	0.3

4.2.2 physicochemical parameters

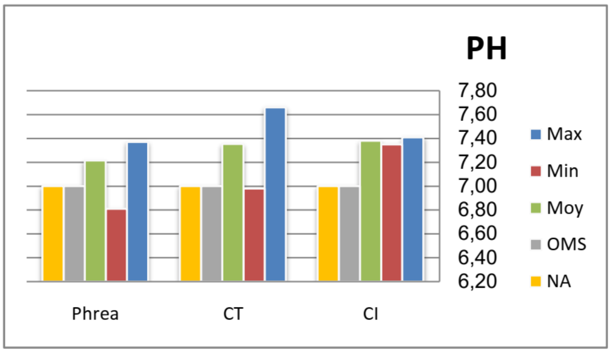

Fig.14. pH Variations

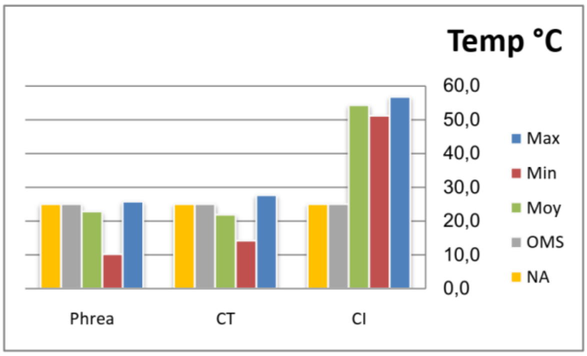

Fig.15. Temperature Variations (°C)

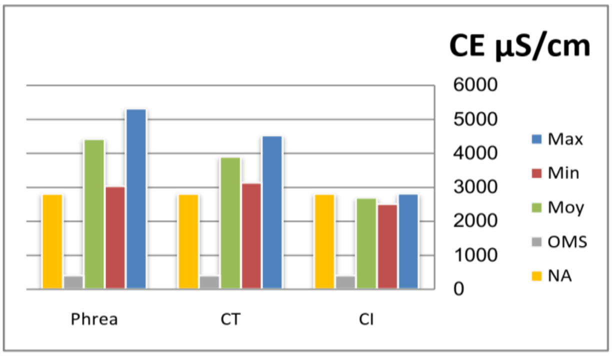

Fig.16. Electrical conductivity variations (µS/cm)

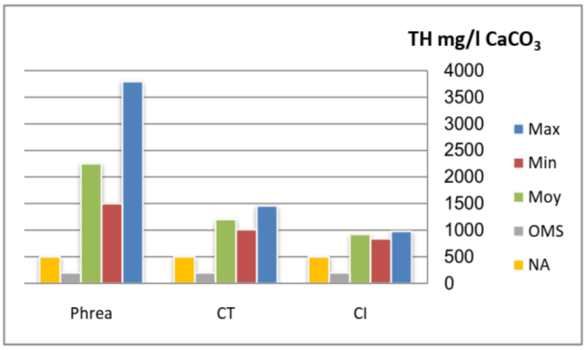

Fig.17. Water hardness (mg/l)

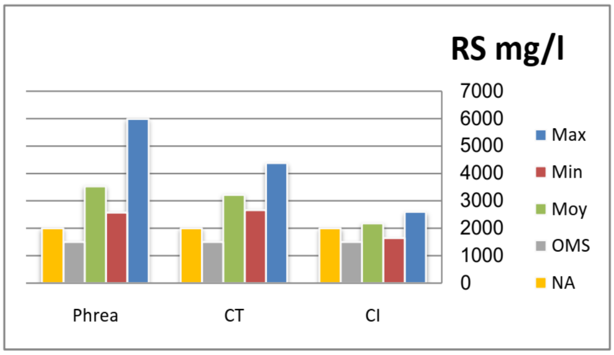

Fig.18. Variation of Total Dissolved Solids

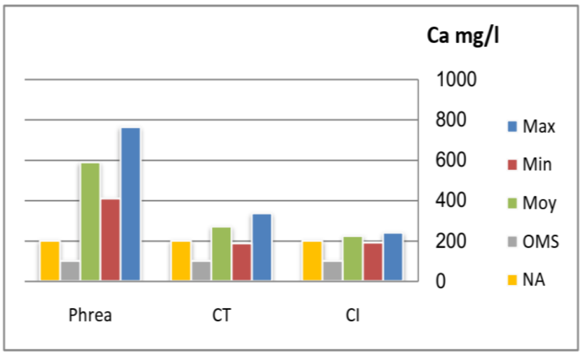

Fig.19. Variation of calcium Ca++ (mg/l)

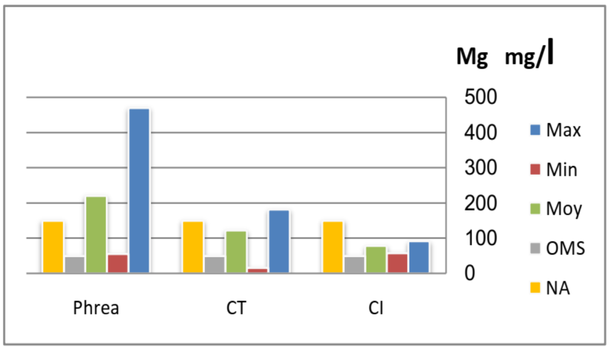

Fig.20. Variation of Magnesium Mg++ (mg/l)

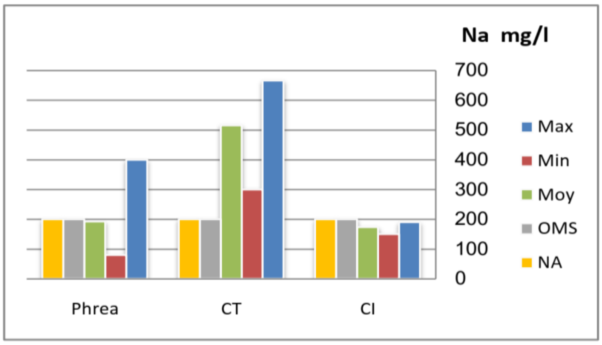

Fig.21. Variation of Sodium Na+ (mg/l)

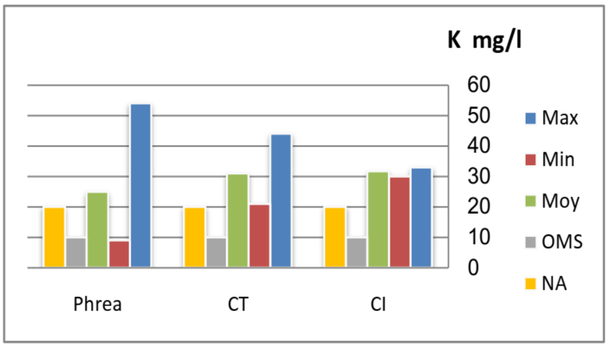

Fig.22. Variation of Potassium K+ (mg/l)

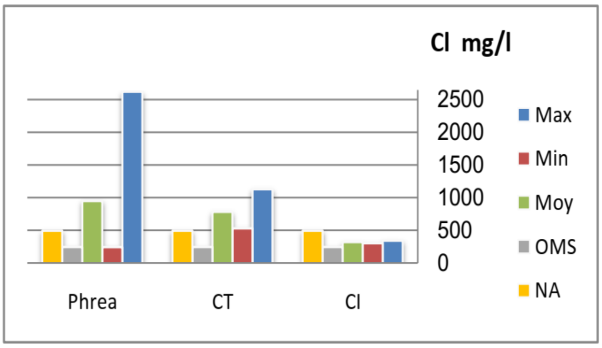

Fig.23. Variation of Chloride Cl- (mg/l)

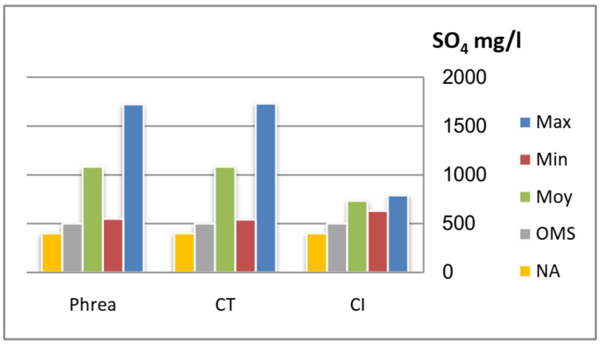

Fig.24. Variation of Sulfates (mg/l)

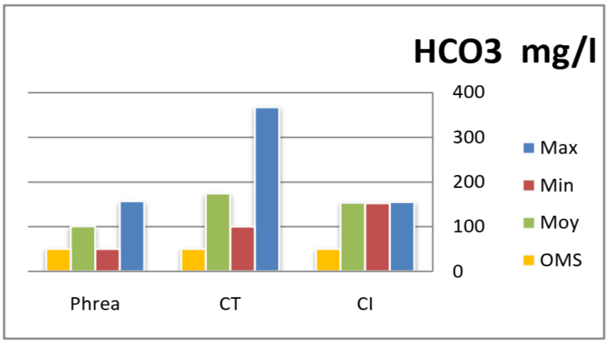

Fig.25. Variation of Bicarbonates HCO3- (mg/l)

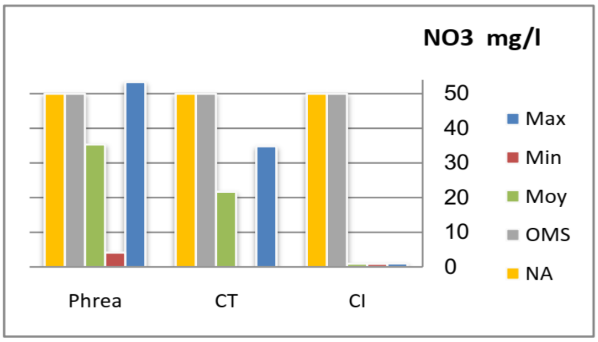

Fig. 26. Variation of Nitrates NO3- (mg/l)

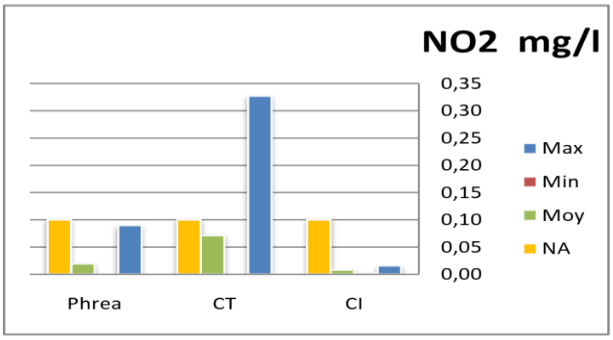

Fig.27. Variation of Nitrites NO2- (mg/l)

5. CONCLUSION

The Souf Valley is a water resource unit located in southeastern Algeria, covering an area of 11738 km2, with a population of 486170 inhabitants. The El-Oued aquifer system consists of three aquifers: a free aquifer (phreatic), and two confined aquifers (terminal complex aquifer and interlayer continental aquifer). These aquifers are considered as a single water resource available in this region. From a physico-chemical analysis perspective, these waters are characterized by a pH close to neutral to slightly alkaline and high conductivity in the CT and phreatic waters. With a high concentration of some chemical elements (generally of geological origin) such as: (Ca^{+2}, Mg^{+2}, Na+, K+, Cl-, SO4-, and HCO3-) in all the studied aquifers, exceeding the WHO guideline values. The total water hardness is mainly attributed to the amount of calcium and magnesium in the water. For all the water points studied in each aquifer, the TH is higher than the WHO guideline value of 200 mg/l. Comparing the physico-chemical parameters to Algerian drinking water standards and those of the specific WHO guidelines.

The comparison of physico-chemical parameters with Algerian drinking water standards and those of the WHO specific to drinking water shows that the majority of water points exceed the threshold set by these standards and are not suitable for human consumption. The use of these waters for AEP (especially with regard to the most exploited CT and CI aquifers) without prior treatment is not recommended, which requires rigorous criteria to improve the chemical quality of the water. This necessitates the creation of demineralization stations using universal processes (reverse osmosis, electrodialysis, ion exchange, etc.) before supplying it to consumers, especially humans.

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