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Assessment of groundwater chemistry for the Reg Basin (Oriental Anti-Atlas), south-eastern Morocco

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Abstract
In this work, a geochemical study was undertaken to assess the chemistry of ground waters in the Reg basin (Oriental Anti-Atlas, Morocco). This region is characterized by an increasing demand of water resources which is the main source for drinking and irrigation due to the uncertain rainfall in the south-eastern of Morocco. Groundwater samples were collected at over Twenty-four locations in the Reg Basin in summer 2015. Physical characteristics (temperature, electrical conductivity, dissolved oxygen, pH, oxidation reduction potential (eH) were measured at the well-site. Alkalinity titrations were performed on filtered samples in the field. All wells were sampled for analysis of major cations by ICP-AES and major anions by ionic chromatography. For geochemical calculations we used PHREEQCI program. The results showed that the waters from the North-West of the basin are Ca-SO4 type, in the center of the Reg, the waters have a mixed facies (Ca-Na and SO4).The North eastern part of the studied area show two distinguished water families the Ca-SO4 waters. The second family is slightly Na-Cl, both of those two families are circulating in the Paleozoic formations. The majority of the studied waters record medium salinity to brackish waters similar to the recorded waters in the great Tafilalet. The chemical compositions of groundwater are determined by a number of processes which include: Rainfall, recharge from the wadi or Rivers, anthropogenic activities, interactions of water with soil and rock-water (Barite, sulphate, pyrite, Lithium, and Silver…) that could indicate a diffuse mineralization of these elements. Also, there are very high levels of Iron, Manganese and Aluminum in the studied waters. They exceed in several cases the OMS recommended values for drinking waters. Unfortunately their existence in the groundwater of this area reduces a lot the quality and its ability to drinking purposes. This aims study is to supporting the development of appropriate management tools for groundwater in the Tafilalt area.

Keywords : Groundwater- water quality- Hydrogeochemistry- Mineralization- Reg Basin- Anti Atlas (Morocco)

1. Introduction
Geochemical processes occurring within the groundwater and their reactions with aquifers materials are responsible for changes in groundwater chemistry [1-2].
This paper aims to study the chemical characteristics of groundwater in the "Reg basin" (South-eastern Morocco) (Figures 1-2) and to understand the process of water rock and human interaction in this area.

The Works in the South-eastern Morocco have worn both on the hydrological and hydrogeological flow modeling of surface water [3-4], and groundwater of Ziz basin [5-6] and also on water quality of the surface water [7-8].

Thus, it's generally assumed that the water resources conditioned the human life; however the life of humans in arid and desertic area is largely dominated by the water disponibility .Nevertheless, and through the recent decades, in the great Tafilalet oasis system and its neighboring area, the climate affect directly the human being. Here the climate change is more present in the common memory of the inhabitants; the dry periods have influenced the migration of the population, the soil desertification, sebkhas disappeared, sources, wells and several wadis and Rivers are dried.

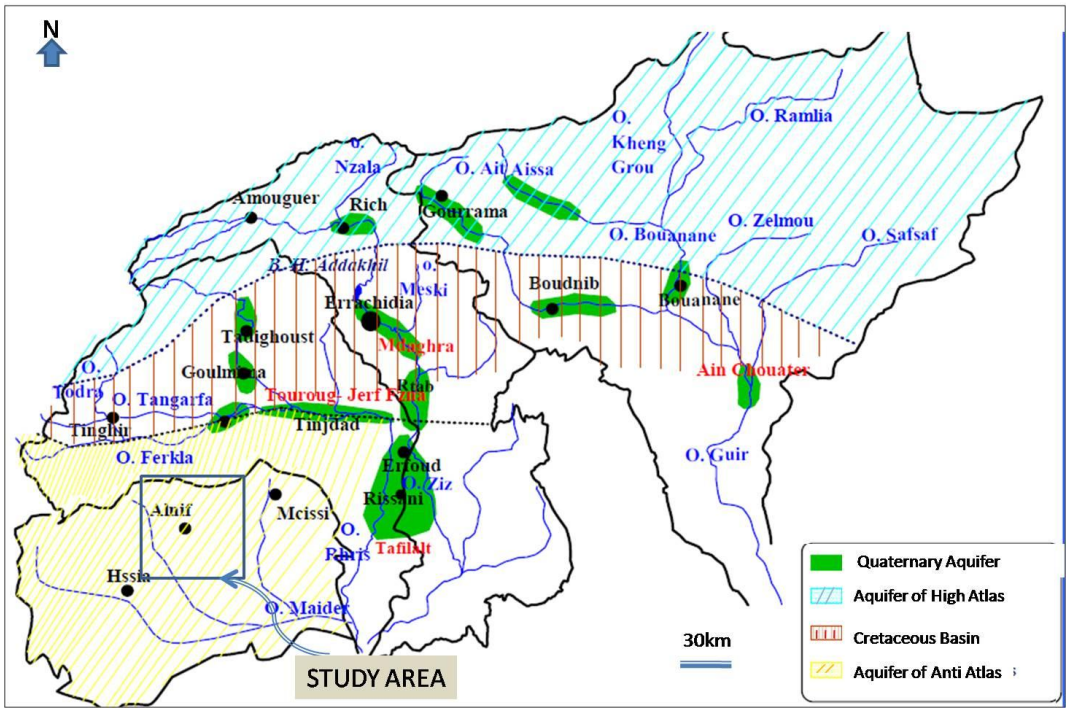

Figure.1: Main hydrogeologicals units in the Ziz-Rheris-Guir- Maider Basins and study area[9]

After the colonization period, new technologies have been adopted by the population, including water pumping machines, or at governmental scale building dams like Hassan Eddakhil on the wadiZiz section or other dams but with little water capacity contributed a lot to ensuring a permanent water supply to the population and guarantee a support of water to establish an interesting irrigated perimeter in the area of Errachidia province. They contributed to the settlement of the population especially on the alluvial plains in the principal wadis and their tributaries, where the surface water are available and mobilisable easily by the local inhabitant.

The developed technics of irrigation enhance population to invest and exploit more surface, and on the other hand the consumption of water increased a lot. The surface waters are not sufficient to respond to the demand; in the major cases the alluvial shallow aquifer didn't satisfy this demand on water. However, the ease of access of mechanic drilling facilities and their low price did encourage people to seek for more deep water even in alluvial plains and in other areas of the basin far from the alluviums. This new groundwater reservoirs are not "automatically recharged" by infiltration from the actual identified recharging area of the different water reservoirs in the area of study because they are localized generally in the alluvial plains. Several water resources have been stocked in the bottom when the weather was more humid and the precipitations were more abundant.

This study aims to define the geochemistry of groundwater in the Reg Basin in the southeastern of Morocco and the processes controlling groundwater quality.

2. Presentation of the study area

2.1. The study area

The Reg river basin, subject of this study, belongs to the great basin Maïder in the Anti-Atlas domain (Figures 1-2). The Reg basin has important Alnif palms at the upstream of the basin, and Boudib and Reg palm sat the outlet of the watershed. It is bounded on the east by Hamada Guir, to the south by the river Hssiya basin, to the west by Tazzarine basin , to the north west by the extensive whole Saghro eastern-Ougnate (Figure 3), and submerged to the north by the Mcessi river basin. The basin has a boot shape of approximately 147 km lenght and 20 km wide.

The Regriver basin contains the southern side of Jbel Saghro, whichis drained mainly by the Reg wadi and its effluents. The Maïder Daya is the natural convergence zone of every wadiof the basin, and a spreading zone of their water flood when they are large enough.

The hydrological network is located entirely in the Saharan area. It is less dense and relatively straight, informing about the permeable nature of the soil near the river component dependencies. The altitudes of the basin varies from 600 m to nearly 2800 m.

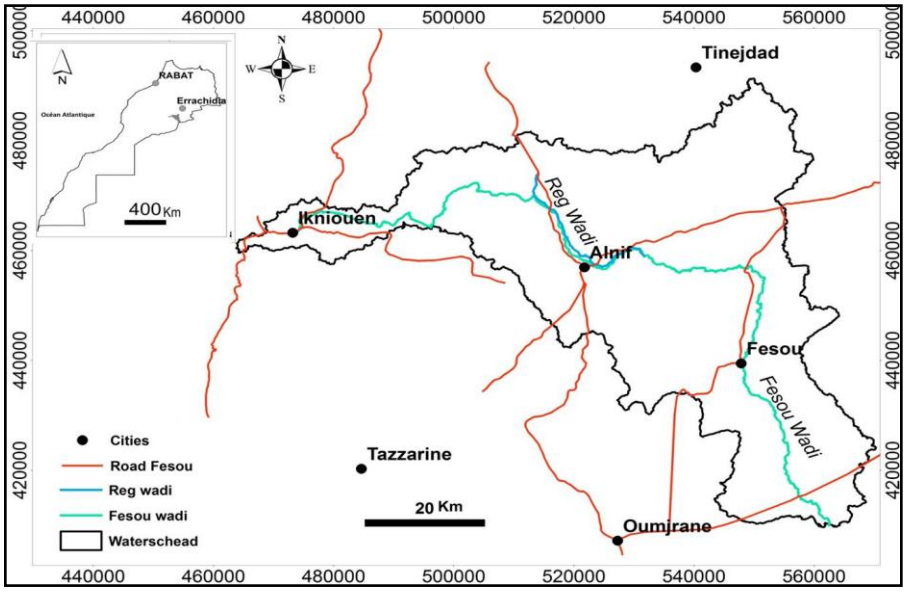

Figure 2: localization map of Reg Basin-Anti Atlas area (Study area)

Most of the groundwater in the Reg region is exploited in areas of basins where are deposited to the plio-quaternary formations. However, in earlier Pliocene formations, we can find a usable water reserves in alteration fringes or in particularly fractured zones.

In plio-quaternary formations, the permeability values vary between $10^{-2}$and 10^{-4}m/s, which allow an aquifer recharge during the passage of floods and during rainy episodes. However, it should be noted that the recharge of these aquifers can be done efficiently only by the contribution of floods. Rain infiltrations are clearly insufficient to ensure direct recharge. The general groundwater flow is from North to South, following a drainage axis comparable to Reg wadi.

2.2 Geological Frame and Lithostratigraphy

The geological substratum is highly complexe by its lithology and it's tectonic. In fact the Reg Bassin is located between the north-south Saharan area and the High Atlas Mountains in the north and is separated by the South Atlas fault. Below a summary of key stratigraphic and structural features of the region in order to identify the elements of analysis of the hydrogeology. The lithostratigraphy of the area of study began from the Precambrian. It appears in both belts of Saghro and Ougnate it comprises essentially schists and granites from Precambrian II and III and is surrounded by a powerful rhyolitic shell [11-12].

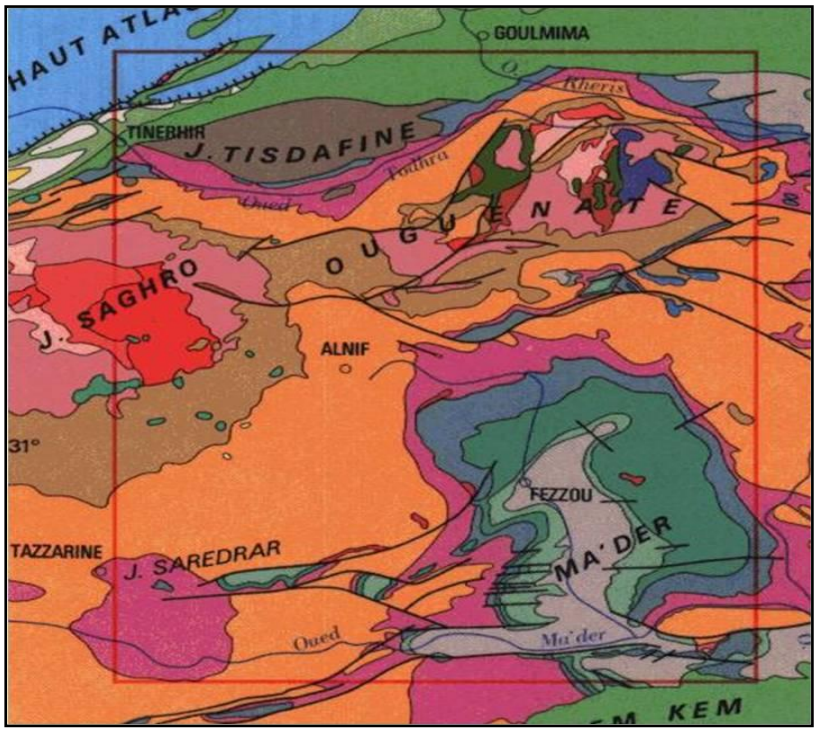

Figure 3: Structural schema (1/500 000) extract from geological map of Toudgha - M'ader (1/200 000)[10]

The Cambrian sandstone remains dominant and is morphologically, incorporated in the Precambrian buttonholes. Cambrian rests directly on the series of Ouarzazate from the terminal Neoproterozoic. It begins with a thick conglomerate, which follows the series "Lie-de wine," and ends with pink sandstone whose summit is recently attributed to Middle Cambrian [13].The Middle Cambrian is characterized by monotony and the continuity of its facies [14]. It starts with the breach in Micmacca. The upper limit is marked by discordant and transgressive transition to Ordovician shale of Regata. Two detrital marine sedimentations are distinguished through the Anti-Atlas: internal Feijas shale and sandstone of Tabanit.

- The terminals Sandstone: These sandstones are more developed in the West. The flaw of the wadi Smile (Southern Ougnat) is an important limitation in the facies changes and the sandstone thicknesses terminals and those of the Lower Cambrian.
- The internal Feijas shale (shale to Paradoxides): The Lower Paleozoic formation of the Anti-Atlas, is composed of alternating mudstone and sandstone[15].It is distinguished by its greenish argillites with variable thickness up to 200m.
- The Tabanit Sandstone: These sandstone form a morphological ridge separating the internal Feijas-schists, Ordovician overlying sediments [14**]**.

The Ordovician clay consists of two sets (external Feijas shales at the base and at the top Shale Ktaoua) separated by a first peak sandstone: the first Bani. The whole is crowned by second peak sandstone: the second Bani. This morphological subdivision of the Central Anti-Atlas is laterally complicated by the appearance of sandstone bars within argillaceous units in the Oriental Anti Atlas. The complexes of external Shale Feijas (Tremadoc - Llanvirn) correspond to Regata shale and shale of Tachilla:

- Regata Shale (Tremadoc- lower Arenig): is a silty clay formation split into two units: lower Regata and upper Regata[12]. The lower unit is a gap in the northern and southern slopes of Saghro and Ougnat. The upper unit begins with a micro-conglomeratic level,and it is rich in ferruginous elements, which marks the beginning of the Ordovician transgression.

– Shale of Tachilla (Llanvirn): They constitute a large clayey silts monotonous sequence, interspersed with thin sandstone or carbonate levels. It has variable powers from 20 to 150m in the eastern Anti Atlas and is separated from Regata shale through ferruginous levels. The upper limit of this formation is marked by another level of Oolitic iron constituting the basis of the first Sandstone of Bani.

Sandstones of Prime Bani (Llandeilo): They are the most Ordovician characteristic element of the Central Anti-Atlas; their thick is about 25 to 300m in the Central Anti-Atlas and shows considerable thinning eastward where it is no more than 20m.

Ktaoua's Shale (Caradoc-Ashgill): They usually correspond to the schistose series between the first Bani sandstone at the base or second Bani at the top. The shale Ktaoua show reductions in thickness to the east and west of the Anti-Atlas [14].

The sandstones of the second Bani: They are the second most characteristic of the Central Anti-Atlas and part of the eastern Anti-Atlas [15].

The Silurian series are formed from bottom to top [12].by a basal conglomerate, siliceous shale and sandstone with graptolite characterizing the lower Llandevery [16].

The Tamrghout formation is made by clay and limestone below graptolites and is defined between Alnif and Mecissi locations.

The Devonian: It is characterized by limestone and sandstone formations.

The Carboniferous: Carboniferous sediments show a return of detritic sediments which follows the Famennian sandstone. After a thick series of shales, it becomes sandstone.

The morphological types of Quaternary deposits differ in extension, power, distribution and lithology. Several kinds of deposits can be distinguished it concerns: the regs, scree and slipped masses, alluvial fans and alluvial, terraces, lake deposits plateau and dunes.

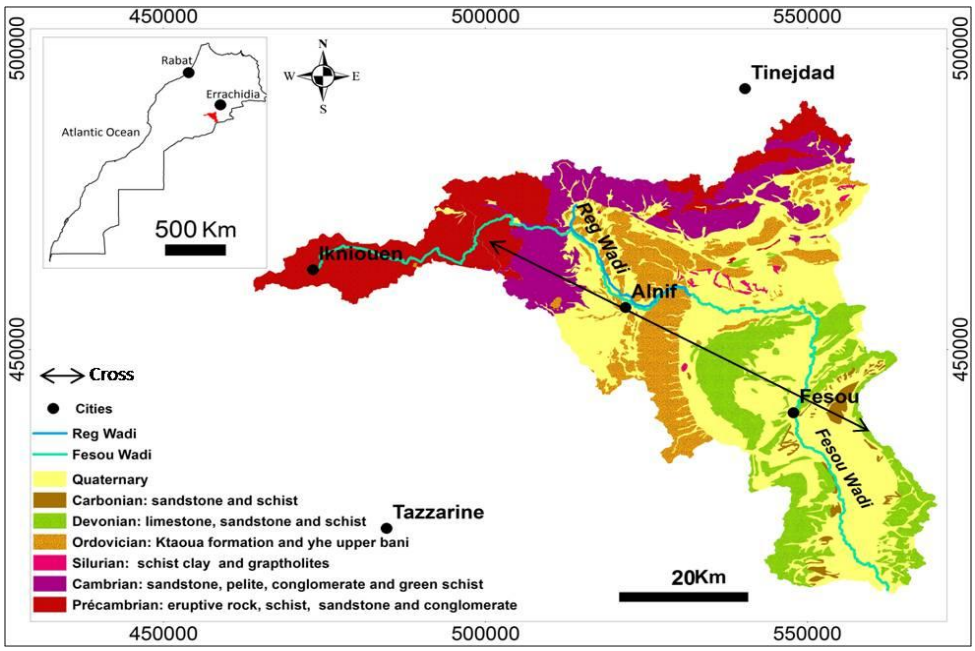

Figure 4: Dominant geology in the Reg Basin-Anti Atlas area (study area), Extract from geological map of Toudgha - M'ader (1/200 000)[10].

2.3 *Tectonics*

From a structural viewpoint, the Anti-Atlas represents a broad anticlinal structure globally oriented E-W. In the Western Anti-Atlas, structural directions are inflected towards the NE-SW to NNE-SSW to become parallel to the structural directions of the chain of Zemmour further south. In the eastern Anti-Atlas, these directions are

increasingly moving in directions oriented NW-SE [17]. Along the axis of the chain, the anticlinal structure is eroded and there are flush Precambrian grounds in the buttonholes that mark the Western Anti-Atlas. The most important are those in the area of Saghro and Ougnate. Paleozoic series are underdeveloped on the northern flank of the anticline but outcrop extensively on the southern flank, where they form the Jebel Bani.
The folded rock material corresponds to a 6-8 km-thick Cambrian-Serpukhovian sedimentary pile that includes alternating competent and incompetent formations. The basement of the Paleozoic succession is made up of rhomboedric tilted blocks that formed during the Cambrian rifting of north-western Gondwana and the Devonian dislocation of the Sahara platform[15].The latter event is responsible for an array of paleo faults bounding the Maider basin with respect to the adjoining high axes.
The Variscan Orogeny began during the Bashkirian-Westphalian with a N-S direction of shortening that converted the NW-trending Ougnat-Ouzina paleogeographic high into a mega dextral shear zone. Folds developed on top of a moving mosaic of basement blocks, being oriented en echelon on the inverted paleo faults or above intensely sheared fault zones. However, a dominantly NE-SW compression responsible for the building of the Ougarta belt also affected the studied area, presumably during the latest Carboniferous-Early Permian [22].

3. Hydrogeologic units

The hydrogeological frame of the area of study is conditioned by the Paleogeography. In Fact, during the lower to the middle Paleozoic this region evolutes as a tunnel valley, this conditioned it's morphology and consequently it defined the groundwater reservoirs characteristics.
Different aquifers are identified through the wadi Fesou basin, they differ by their dimensions and their reservoir lithology. Unfortunately the piezometric maps follow only the alluvial Plains. Outside this area there is no piezometric maps data so far. But several rural localities and haciendas extract important water volumes at different depths. Thus, two groundwater reservoirs can be identified, the shallow aquifers in the alluvial plains their dimensions depend on the alluvial plains in different wadis and their affluent.

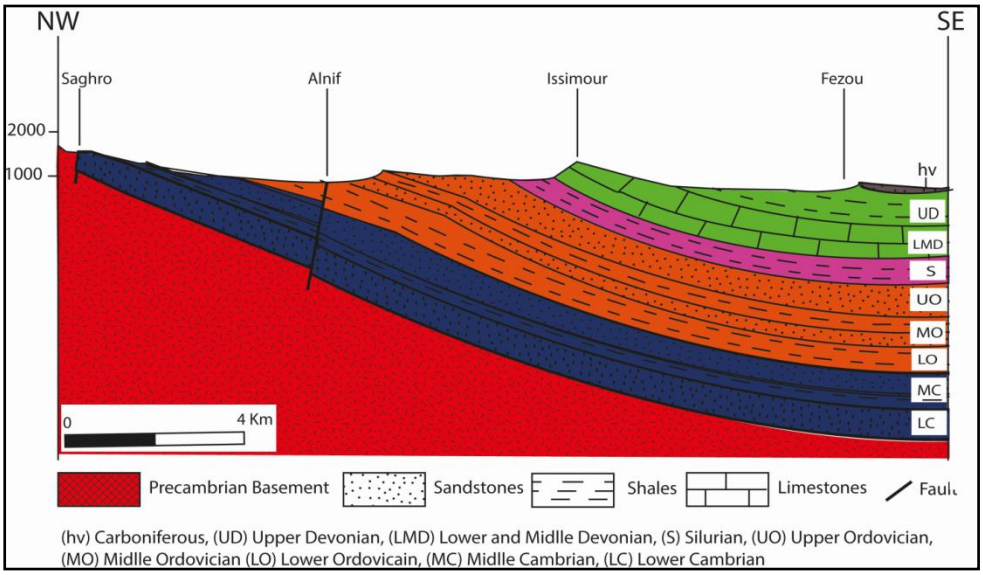

Figure 5: Synthetic cross section some tunnel valleys in the study area

The reservoir nature is made by different kinds of rocks, but they remember the point bar deposits essentially plio-quaternary. A second series of aquifer localized out of the alluvial plains. But their geographical distribution follows the topography of the study area, this morphology was commanded since the palaeozoic where the Reg basin evolute as a tunnel valley. In fact the center of the majority of the tunnel valley is now occupied by the actual wadis (Figure 5). Out of this alluvial plain the tunnel valley contains important water resources. Also the water is present in sub-horizontal plains out of the valleys.

This second family of water is recently discovered when the Moroccan Authorities started up an ambitious initiative called Green Morocco Plan and gave a huge support to the agriculture, by supporting water exploration drilling and the acquisition of the irrigation equipment. Face to this initiative, large area in the Tafilalet and Anti-atlas land's have been recovered; Although, those water resources didn't have any hydrogeological characterization and do not have any apparent source of alimentation and recharge. However, the exploration on the field the majority of this "new" groundwater exploiters did drilled more and more wells and/or make them deeper in order to ensure water demand.

The piezometric level for the first aquifer depends on the recharge and the extractions destinated to the irrigation purposes essentially. That shallow aquifer has an interesting fluctuation of their piezometric level, and the dry periods show the higher reduction of water volumes [17]. Regarding the second kind of aquifers the piezometric level, which is at the same deep like the first one, but during the last two years, it didn't register any fluctuation regarding to the alluvial aquifer, thus several piezometric missions are programmed to follow the piezometric evolution in this area. The bedrock of these palm groves consists of calcareous marl-lower Devonian formations that favor their presence near the surface a rise in the water table. The Boudib palm grove, located downstream of the limestone barrier is above the limestone formations Middle Devonian. Water resources are found in this sector of the substratum, located on a small section of alteration but also in a karst system which concentrates the flow and contributes to the lowering of the piezometric surface.

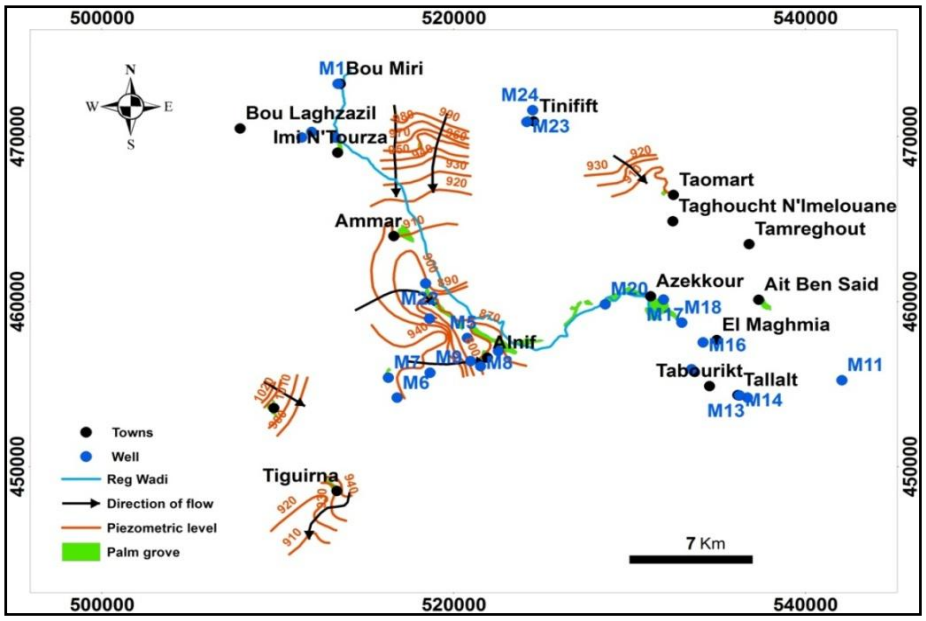

Figure 6: Piezometric map of the recognized groundwater and the geographical distribution of the sampling point in the study area

4. Groundwater sampling and Analytical methods

On a basis of 24 water samples collected in the Reg Basin according to each facies and alimentation area, the sampling locations are shown in Figure 6.

Physical parameters were measured in situ such as of the electrical conductivity, temperature, pH and the redox potential. Alkalinity was measured by titration; dissolved oxygen was measured by specific electrode in the field. At the laboratory, the major anions (chloride, sulfate, and nitrate) were measured by ionic chromatography and the cations have been filtrated by 45µm pore filter and have been acidified by high quality nitric acid and have been destined to the ICP-AES (Ultima 2 –JobinYvon).facility to perform their analysis (calcium, magnesium, potassium and sodium and Silice. In addition a set of several heavy and trace element was performed using the same facility. And for geochemical calculations we used PHREEQCI program.

Physical parameters and Chemical compositions are displayed on Table 1 and 2.

5. Results and discussion

5.1 *Physical parameters (in situ analysis)*

The pH ranges from 5.8 to 8.5(Table 1). The lower pH value was observed in the Silurian black shells were a pyrite mineralization occurs in the area (Figure 2); all the other .water samples have pH values in the range of good water quality. The water electric Conductivity of ranges from 600 µS/cm to 4000µS/cm showing different water facies and different reservoir nature. The water temperature does not show any indication of thermal source or a mixture of a thermal source except for the sample M17 which could indicate a thermal source.

Table.1 Physical parameters of the studied groundwater's

sample	Conductivity µS/cm	pH	T (°C)	sample	Conductivity (µS/cm)	pH	T(°C)
M1	1048	8	25	**M13**	**3064**	8.1	24
M2	1600	7.3	28.1	**M14**	658	7.8	26
M3	1047	8.5	25.3	**M15**	**4063**	7.5	24
M4	811	7.5	24.9	**M16**	1750	7.8	25
M5	1339	7.8	25.4	**M17**	1190	7.8	33.7
M6	1691	8	28.5	**M18**	812	7.2	26
M7	844	8	25	**M19**	2317	7.7	24
M8	700	7.7	26	**M20**	813	7.7	21
M9	**2610**	7.2	26	**M21**	1044	8	21
M10	411	8	25	**M22**	1301	7.4	20
M11	671	7.8	25	**M23**	1183	8	19
M12	**8211**	5.8	23	**M24**	602	7.9	19

5.2. Groundwater chemistry

The results of the groundwater chemistry in Reg basin are represented in Table 2.

5.2.1 Water families

Following the Hydrogeology, the water chemistry changes in the study area, although it can be subdivided on two groups that show similar chemical characteristics occurring in the Reg basin. A family ranging from Ca-SO4 type to Na-Cl waters and interests the water circulating in the Precambrian to Paleozoic substratum and the second family circulates in the alluvial sediments.

- The waters from the North-West of the basin are Ca-SO4 type. They are circulating in the Complex of the first Bani (Serie of Ktaoua) from middle Cambrian, made of grey. The samples are localized upon the Boulaghzazil fractured area. The alimentation of this small aquifer is assured by the alimentation of the very weak rainfall during the thunderstorms period and the waters which was accumulate in the sub-surface for centuries is being extracted since the last decade for irrigation purposes. Fortunately, the topography and the state of the soil is reducing the exploited areas and so the extracted water volumes, the area testimony of a diffuse mineralization of barite (BaSO4), that seems to be at the origin of the high levels of sulfate in the area (Figure 7 a).
- The center of the Reg, at the locality of Alnif, the waters have a mixed facies (Ca-Na and SO4). Essentially Na-SO4, the waters in the Alnif are circulating in the alluvial plain made by the WadiReg), the relatively high levels of sodium in the area is due to the intense evaporation in this sub-desertic area and the fact that the alimentation of the aquifer is based on rainfall but essentially by the recharge from the wadireg during the inundation period. Thus the accumulated salts in the soil during the dry season on the alluvial plain are

dissolved in pluvial period and reach the subjacent aquifer. thus the sample M21 collected from the center of Alnif and localized on the Alnif accident axis show the same chemical characteristics of the waters from the North-eastern aquifer Ca-SO4 facies and its waters smells H_2S and are yellow-orange color (Figure 7b).

Table 2: Results of chemicals analysis of study area

Sample	HCO3	Cl	SO4	Ca	Mg	Na	K
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
M1	244	72.67	3813.64	107.1	32.92	63.1	11.47
M2	402.6	167.13	762.63	172.86	41.96	138.57	35.13
M3	366	98.32	602.23	91.84	34.05	89.45	16.47
M4	183	73.01	552.4	97.37	23.1	27.83	12.05
M5	231.8	112.06	496.11	87.658	42.81	184.9	22.52
M6	305	189.35	402.32	136.19	55.46	160.82	25.46
M7	305	58.12	580.63	78.49	26.48	65.3	8.56
M8	231	45.07	473.38	41.28	23.47	109.45	26.26
M9	854	136.39	447.77	136.3	69.95	449.16	152.75
M10	146.4	24.2	443.38	28.03	10.99	46.65	20.98
M11	97.6	13.02	87.7	87	21.97	28.08	11.47
M12	164.7	1650.69	<0,1	686.24	475.5	557.69	70.91

Sample	HCO3	Cl	SO4	Ca	Mg	Na	K
M13	427	314.74	1869.71	184.8	103.07	420.8	142.3
M14	183	56.4	157.15	56.64	24.52	82.77	14.44
M15	122	409.87	216.86	481.54	216.63	302.79	38.83
M16	219	6.21	670.77	148.32	61.86	186.59	24.41
M17	292.8	62.86	700.35	109.63	41.87	106.41	27.99
M18	244	33.08	1340.76	90.03	27.69	50.07	12.31
M19	305	202.34	721.33	101.173	83.25	309.26	80.85
M20	231.8	52.11	697.42	60.13	23.69	82.49	10.89
M21	183	70.56	567.03	88.421	27.968	92.165	17.473
M22	414.8	78.94	318.54	48.548	23.633	220.105	67.111
M23	292.8	86.17	577.03	125.18	31.674	58.204	11.222
M24	244	36.21	366.89	68.585	18.26	25.639	7.509

– The North eastern part of the studied area show two distinguished water families the Ca-SO4 waters that are the most significant in this area and corresponds to the first Bani series. The second family is slightly Na-Cl and they are in the series of Tabanit sandstone and the interne feijas shale (Figure 7c-7d) both of those two families are circulating in the Paleozoic formations.

The waters show similar chemical characteristics because they share the same reservoir nature in general, the difference between the water circulating in the substratum and in the alluvial formation is due to the physical characteristics of the aquifers. The alluvial aquifers are more exposed to the climatic change in fact the water level increases and decreases with seasons and years; the general tendency is to the reduction of the water level. However, the intense evaporation in the area and the intense exploitation of water resources across all the alluvial valleys in those arid areas permits the precipitation of the salts upon and inside the soil structure. By the

continuous irrigation the salts reaches the alluvial aquifer localized few meters under and so the water became more saline. This phenomenon will be responsible to the deterioration of the water quality in all the great Tafilalet area.

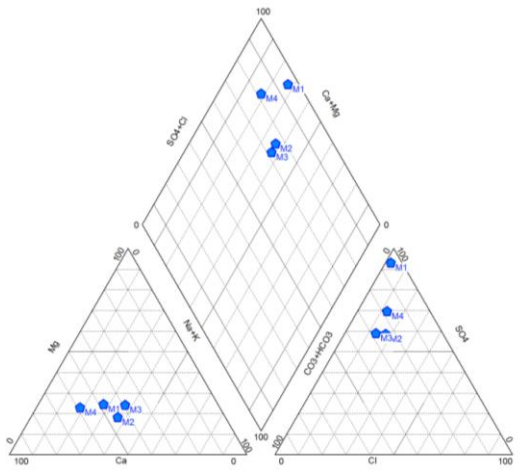

Figure 7a: Piper diagram of the groundwater from North-West the Reg

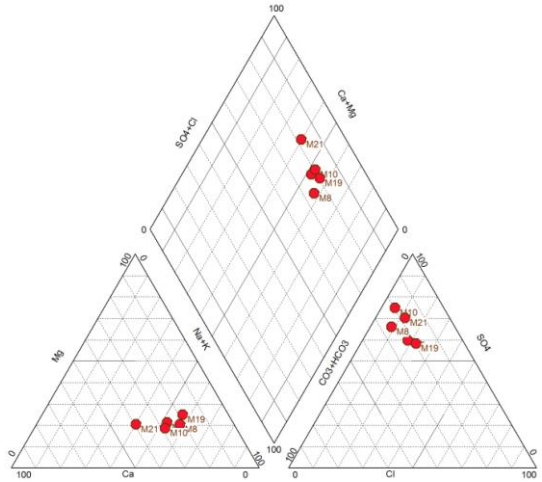

Figure 7b: Piper diagram of the groundwater from Center the Reg

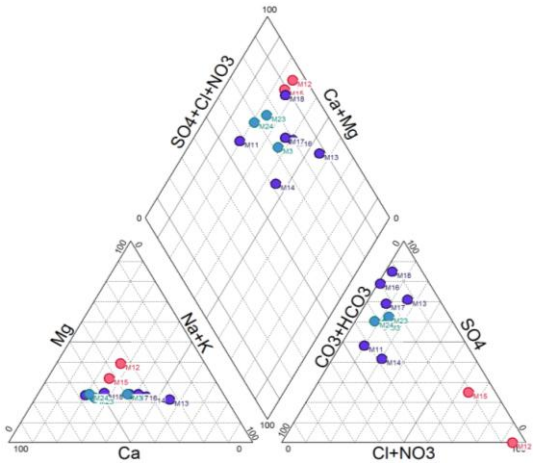

Figure 7c: Piper diagram of the groundwater from North (*bleu circles*) and the North-East the Reg

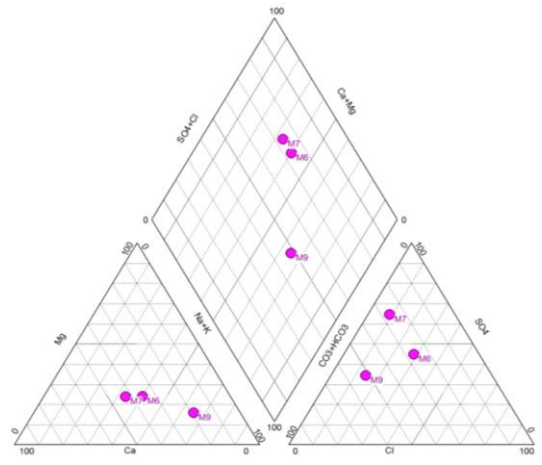

Figure 7d: Piper diagram of the groundwater from the south-eastern part of the Reg

Figure 7: Piper plot showing the different water families in the study area

5.2.2 Major elements

Starting from the fact that all these waters have a meteoric origin and the aquifers are mostly made by aluminosilicates, silicates and carbonates, thus mineral dissolution depends on their different reaction rates. The studied waters show a wide range of TDS starting from a very low TDS that record a very good water quality, but it's due only to a specific situation where the sampling was made in a rainy days. This could inform about the velocity of the alluvial aquifer spectacular recharging process. However, the majority of the studied waters record medium salinity to brackish waters similar to those recorded in the great Tafilalet [19].

24 samples of shallow groundwater were collected in the Reg sector. Their chemical characteristics, which are shown in Figure 5, appear very heterogeneous: the TDS of some water samples have a very low salinity for instance at the Alluvial plane of Mimarighene sample number M11 (358 mg/l) this low TDS is explained by the fact that during the sampling in the summer of 2015 there was some spectacular thunderstorm that contributed to the dilution of the waters in this locality. However the relatively low TDS is recorded in the study area especially across the different alluvial plain formed by the principal wadi of the area (wadi Reg). On the other hand some wells show a very high salinity influenced by the reservoir lithological nature (Figure 8).

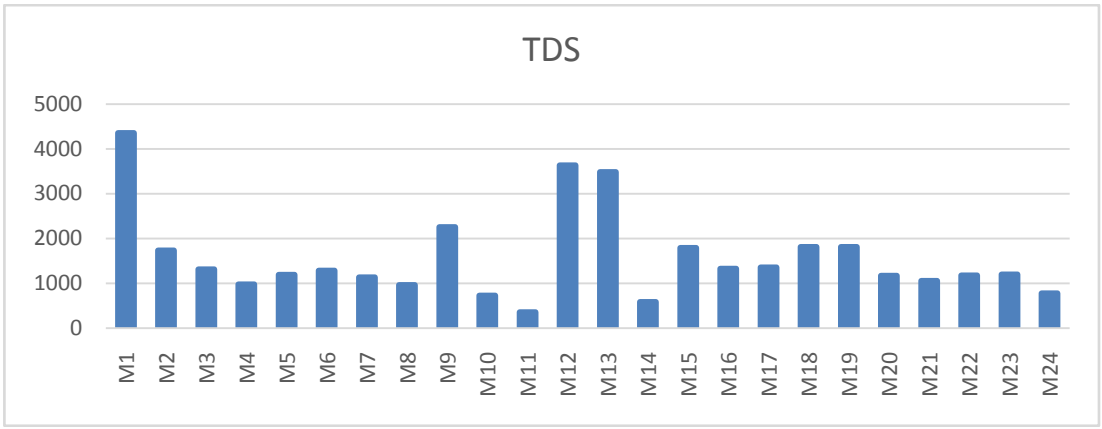

Figure 8: TDS variation in different samples from the study area

Water moving through the ground will react to varying degrees with the surrounding minerals (and other components), and it is these rock-water interactions that give the water its chemical characteristic. The silicate minerals that comprise most rocks do not react readily with most ground waters .while, carbonate minerals and evaporitics do react quite easily with water, and they play an important role in the evolution of many groundwaters. The Major elements are responsible of the water total salinity and evolute in linear mode with it (Figure 9). The Na/Cl ratio is respecting the sea water dissolution line.

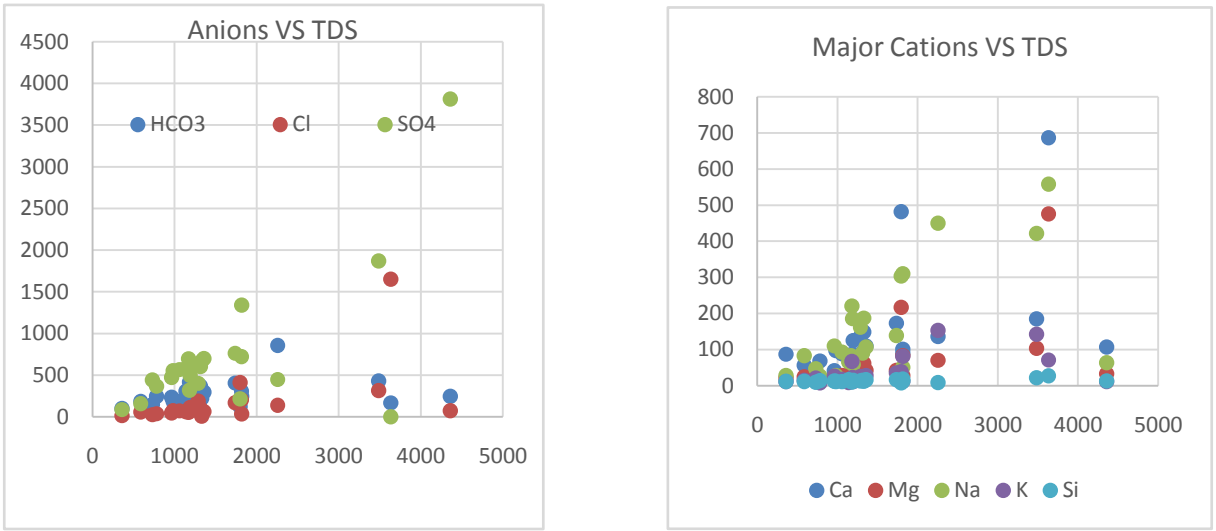

Figure 9: Plot of major elements anions (a) and cations (b) versus TDS in the studied waters.

To determinate the natural dissolution precipitation processes, the water samples were used for geochemical calculations using PHREEQCI program to proceed to the calculations of saturation indices and the element speciation. As assumed, the dissolution of carbonate minerals is always important and fast; whereas, that of the silicates is less important. Studied water are in equilibrium to saturated on calcite, dolomite and gypsum, the explanation of this could be the residence time that permits to the waters to reach saturation with limestone minerals. On the other hand the study area did show an intense hydrothermal activity that permits the deposition of very large hydrothermal minerals such as Barite which is extracted in different sites in the study area. However the BaSO4 could be at the origin of the enrichment of the ground waters on sulfate that react easily with Calcium to generate gypsium [20-21] (Table 3).

Sample	IS Calcite	IS dolomite	IS gypse	Sample	IS Calcite	IS dolomite	IS gypse
M1	0.7	1.25	-0.01	M13	1.29	2.68	-0.06
M2	0.6	0.98	-0.35	M14	0.36	0.73	-1.38
M3	1.48	2.89	-0.68	M15	0.6	1.19	-0.54
M4	0.23	0.18	-0,67	M16	0.74	1.45	-0.46
M5	0.57	1.18	-0,79	M17	0.88	1.78	-0.54
M6	1.12	2.23	-0,69	M18	-0.04	-0.22	-0.4
M7	0.85	1.57	-0.75	M19	0.57	1.4	-0.63
M8	0.18	0.49	-1.09	M20	0.24	0.38	-0.8
M9	0.67	1.43	-0.71	M21	0.61	1.03	-0.72
M10	0.13	0.21	-1.25	M22	0.1	0.18	-1.22
M11	0.28	0.32	-1.42	M23	0.92	1.52	-0.58
M12	-0.95	-1.71	-3.85	M24	0.54	0.77	-0.97

Table.3 Saturation indices regarding calcite, dolomite and gypsium in the studied waters

5.2.4 Heavy metals and trace elements

A set of some heavy metals is carried out. Globally a very high levels of Iron , Manganese and Aluminum in the studied waters that exceeds in several cases the OMS recommended values for drinking waters (Figure 8).Those high levels are explained by the mobilization of reduced spices of Iron and Manganese in low redox conditions, and the existence, in the study area, of a diffuse Ferruginous mineralization that permits locally its extraction [13].

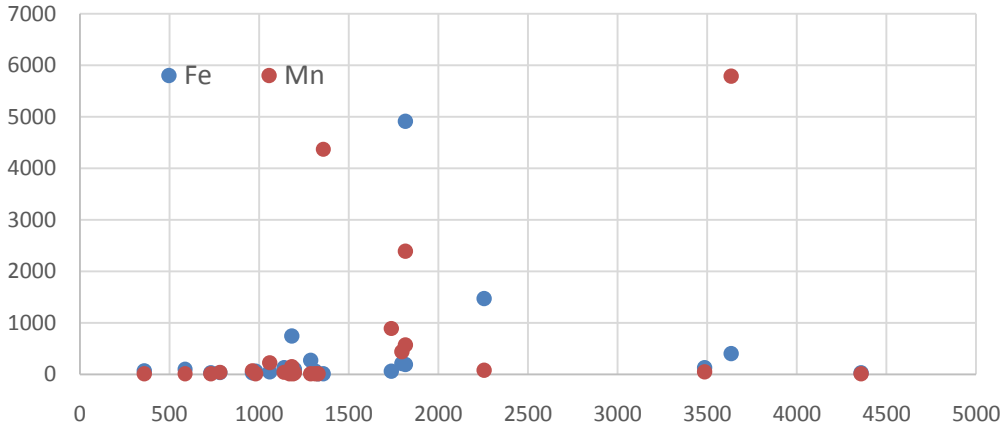

Figure 10: Plot of Iron and Manganese versus TDS in the studied waters.

However, during the sampling campaign, around several new wells, especially who were excavated manually fragments of pyrite appears especially in the Silurian black shell formation. The pyrite oxidation seems to be at it first stages because the majority of the wells are recent and may in the future and during the dry seasons, the fresh pyrite, will enter in reaction with the atmospheric oxygen and in high moisture condition liberate the sulfuric acid. So it's highly recommended to establish a strategy to follow this phenomenon that could contribute the degradation of the water resources on large surfaces in the study area.
In addition to this mineralization, the first lectures on the analysis result show high levels of alkaline earth minerals such as Lithium (Figure 11). Also Silver is also present at high levels in the study area (Figure 11) with traces of Zinc and Barium. Those high levels could threat mineralization of those minerals and their associates in the study area, where Iron, Barite or barium sulfate (BaSO4), Fluorine and others are extracted. Further around this area precious metals are exploited such as of Gold, Silver, Platine, Nickel are exploited.

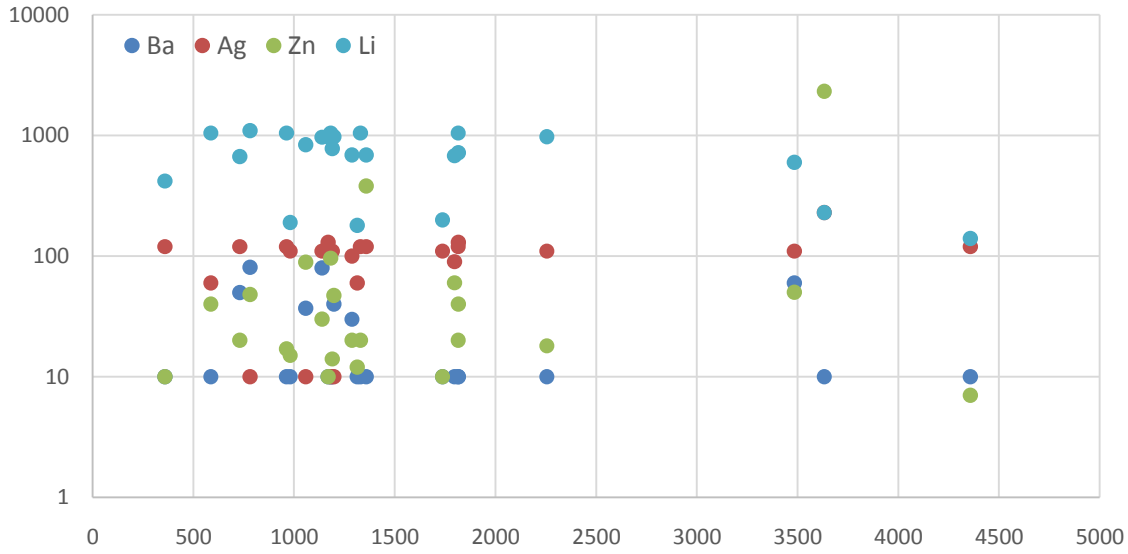

Figure 11: Plot of Ba, Ag, Zn, Sr, Li versus TDS in the studied waters.

Conclusion

Water quality is the critical factor that influence on human health .Water resources in the arid area, in addition to their scarcity, are subject to intensive exploitation. In the Anti-Atlas and in all the Moroccan Oasis system, water is an opportunity to ensure the population settlement and to guarantee a sufficient income from agriculture and tourism activities. The intense evaporation the salts precipitate in the soil column and contribute to the salinization of the alluvial aquifers which are already Na-Cl type.
The study highlighted on non reported water resources in the area of study in the national data base and warms also that this type of aquifers do not show any recharge area and may be they were made during last centuries where the weather was more wet. This waters if exploited intensively will disappear. In the other hand the studied waters show high levels on Lithium, and Silver that could indicate a diffuse mineralization of these elements. Unfortunately their existence in the groundwater reduces a lot its quality and its ability to drinking purposes. In these arid areas the rainfall is low and water resources are limited, so they will disappear if exploited intensively.

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