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Effects of urbanization on groundwater quality in the Gafsa Town (Southwestern Tunisia)

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ABSTRACT

In Tunisia, and in most semi-arid countries, problems related to water access by populations are very frequent, especially when irregular rainfall and arid climate combine with the insufficiency of natural water resources, as well as possible anthropic pollution. The city of Gafsa (south western Tunisia), is relatively highly populated due to its economic activity. In addition, Gafsa has always been threatened by water scarcity generated by the increasing rate of urbanization, and thus there is growing need for drinking water, agriculture and industry. This has led to an overexploitation of groundwater by around 132% and provoked not only the reduction of water availability but also the deterioration of water quality. Proper understanding of the hydrochemical characteristics of groundwater is important for sustainable development of water resources in this region. For this purpose, a sampling campaign was carried out in aquifers of Gafsa to measure major dissolved ions (Ca, Mg, Na, SO4 and Cl), pH and salinity in order to evaluate the origin of groundwater chemistry and the main mineralization processes occurring in this aquifer system. Obtained data showed high concentrations of the following elements: SO_4^{2-} (1156.63 mg/l), Cl^-(911.34 mg/l), Na^+ (645.40 mg/l) and Ca^{++}(384.66 mg/l). Other elements show low contents in the analysed waters which are: Mg^{2+} and K^+, salinity ranging from 0.96 to 15.03 g /l for all analysed waters. The pH values oscillate between 7.24 and 8.29. Groundwaters seem to have acquired their mineralization from two sources. The first one has a natural origin principally by the dissolution of halite, gypsum and/or anhydrite, as well as by the dissolution of dolomite. The second one has an anthropogenic origin, probably from fertilizers–pesticides and discharge of domestic and industrial wastewater directly into the aquifers by septic pits. The acquired mineralization seems to play a principal role in the degradation of quality of aquifers in the town of Gafsa.

Keywords: Gafsa; Tunisia; Groundwater; Salinity; Major elements; Urbanization; Mineralization

1. Introduction

Tunisia falls in the category of countries that are least endued in water resources in the Mediterranean basin, and in most of the semi-arid countries. It suffers from frequent periods of drought, particularly in the south. In this context, the measurement of physic-chemical water parameters study is one of the methods adopted in order to monitor the quality of

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water. This approach is applied in the region of Gafsa which has a desert climate. The management of water resources in the town of Gafsa in the economic, social, institutional and technical levels knew important changes and rehandling. In front of the challenges of the increasing water demand caused by population growth, the rapid urbanization and the improvement in living standards, water resources suffer a qualitative decrease and a quantitative degradation. For this, it was proposed to study the chemical quality of water from the aquifers in the town of Gafsa by measuring the major elements: Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, and SO_4^{2-}. These analyses will allow us to determine if there is a possible influence of urbanization on water quality.

2. Studied area

The region of Gafsa is located in south-west Tunisia. It covers an area of 8.990 km^2 and has about 341,600 inhabitants. The city is divided into two parts on the banks of the Bayech Wady: Gafsa city and El Ksar (Fig. 1). The city has an industrial area, an international airport, railway and roads that make Gafsa a principal crossroad.

Gafsa population is distributed between three sectors: craft (carpets of Gafsa), mining exploitation (phosphate and sulphur) and agriculture (dates and olives). This region is characterized by high temperatures, averaging 32.2°C in the summer and with an annual average precipitation of 150.8 mm. Strong evaporation occurs mainly in July with an average of 357.12 mm (annual average of 200 mm).

3. Geological and tectonic setting

The sedimentary rocks outcropping in the town of Gafsa and its surroundings belong to the Jurassic, Cretaceous, Mio-Pliocene and Quaternary (Fig. 2).

However, some Triassic deposits have been recognized in Jebel Ben Younes, composed of massive gypsum [1]. The Jurassic outcrops in Jebel Ben Younes are just at the base of the Gafsa fault and consist of alternating marly and dolomitic limestones [2].

The Upper Cretaceous series begins with a thick Cenomanian–Turonian dolomite and claystone unit, locally interbedded with gypsum levels, belonging to the Zebbag Formation [2]. The Zebbag Formation constitutes the main aquifer captured at the threshold region of Gafsa.

This unit is overlaid by the Aleg Formation deposits consisting of thick late Turonian–early Campanian marly and calcareous claystone [3]. On the Aleg Formation overlies the Early Campanian–Late Maestrichtian limestone and dolomitic limestone of the Abiod Formation outcropping in Jebel Orbata and Bou Ramli[4] and represents the end of the Upper Cretaceous series [5].

The lower and the middle parts of this formation are dominated by clayey and marly thin layers, while the upper part is distinguished by a fissured feature [6].

Above the Abiod Formation comes the Early Maastrichtian-Paleogene claystone of the El Haria Formation, which it is mainly composed of marls with limestones and phosphates.

The Palaeocene consists of thin gypsum, clay and dolomitic intercalations belonging to the Selja Formation, which is overlaid by the phosphatic carbonates

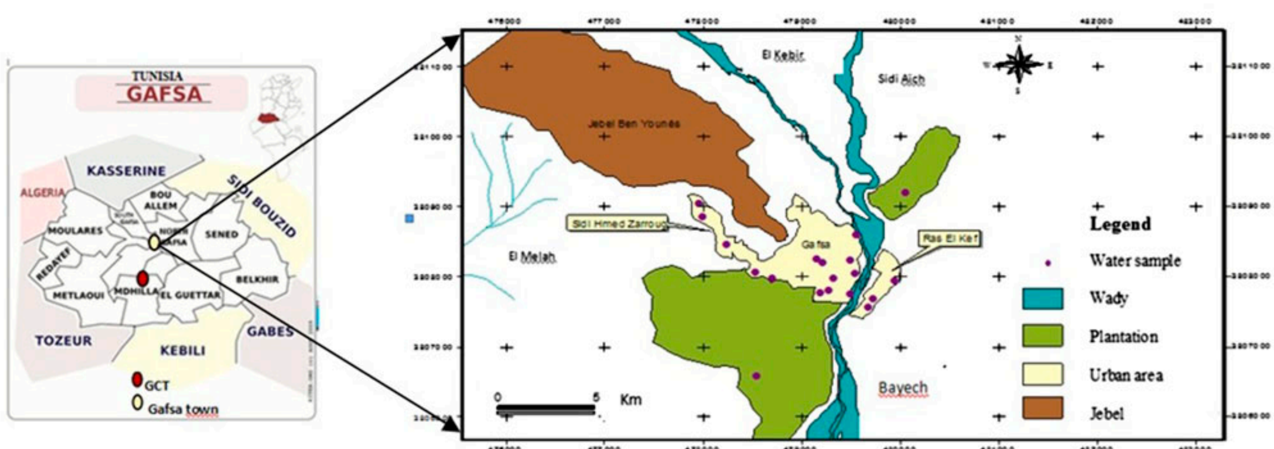

Fig. 1. Geography of the study area.

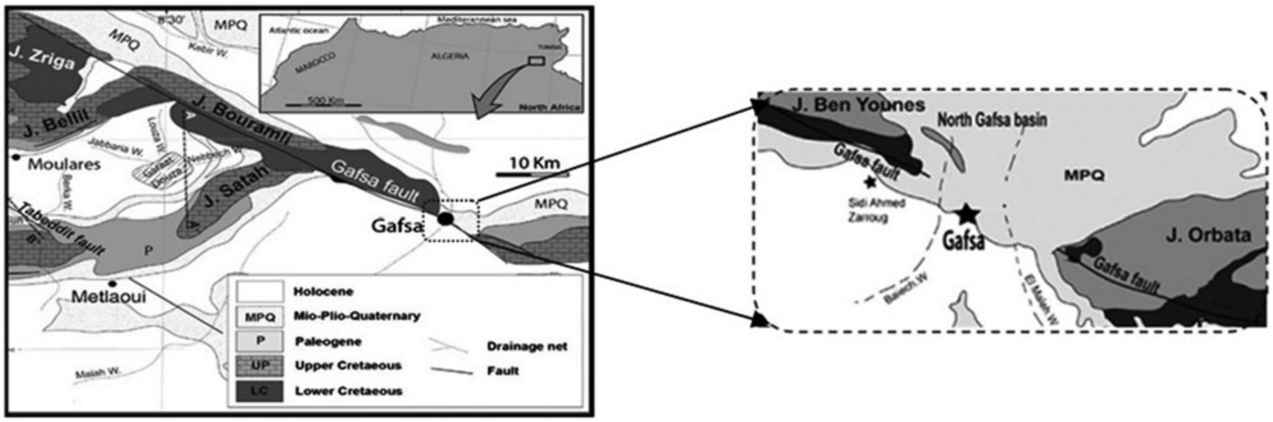

Fig. 2. Location and geologic map of the study area [5,13].

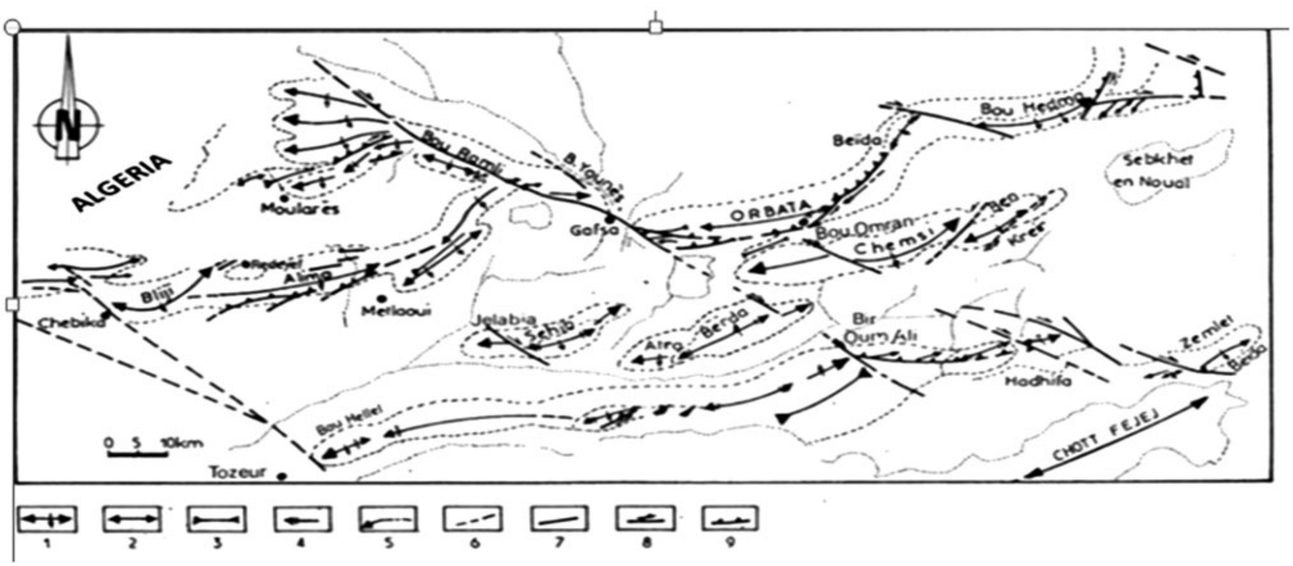

Fig. 3. Tectonic map of Tunisian South [8]. (1) Megastructure anticlinal axis; (2) axis structure; (3) axis synclinal structure; (4) axis of peri-anticlinal structure of megastructure internal envelopes; (5) axis flexure; (6) trace of the outermost envelope structures; (7) major accident; (8) dextral slip; (9) overlap.

and claystone series of the Chouabine Formation and the massive limestone layer of the Kef Eddour Formation.

On these formations lies the Late Eocene thick gypsum rich dolomite of the Seugdal Formation that constitutes the last marine facies [5].

The oldest continental Neogene Formation is represented by the Sehib clayey and silty conglomerate, which is overlaid by the Middle–Late Miocene sandstone of the Beglia Formation. The latter is made up of loose to locally friable well-sorted sands [3]. The uppermost deposits in the study area belong to the Segui Formation of Late Miocene–Pleistocene age. It is a heterogeneous formation represented essentially by silty and gypsiferous claystone and by sands, gypsiferous and argillaceous silts with thick sandy conglomerate layers [6].

Quaternary morphologies consist primarily of alluvial fans, glacis and terraces. Most of the Quaternary stratigraphic units consist of wind-eroded outcrops that have been interpreted as eolian, sebkha and lacustrine deposits [7].

The study area is part of the Southern Atlas and is located between two different geological areas named the North Central Atlas and the South Saharan platform.

This sector has been effected by extensive tectonics during the Mesozoic, leading to the setting up of normal east–west and north-west–south-east fault networks [8,9]. During the Cenozoic age, the Gafsa foreland basin was affected by compressive deformation events producing fault-related fold belts in relation to a thin-skinned mechanism [10,11]. These compressive tectonic events continued during the Quaternary [6,12].

The Gafsa chain formed by the alignment of corresponding anticlinal structures can be observed. From west to east, the anticlines of Bou Ramli, Ben Younes, Orbata and Bouhedma can be observed. These structures have a mean direction east–west orientation with segments and other N60, N110–120 west of Gafsa [8].

The region is also characterized by a large tectonic hallway (Fig. 6) which is the fault of Gafsa. It represents a very old basement accident [3,8] that controls the architecture of geological structures in southern Tunisia.

The hydrodynamic functioning of the Gafsa aquifer system is largely influenced by tectonics (Gafsa and Sehib faults), lithology variation and recharge conditions. The tectonics have contributed to the unconformity limits of the aquifer levels by creating some barriers which play the role of hydraulic sills [13]. It is worth noting that only the fault of Gafsa is of interest for the local hydrogeology. Indeed, it creates a hydraulic sill [14] at two locations, in Gafsa and Sidi Ahmed Zarroug.

4. Overpopulation, water resources and their exploitation

The governorate of Gafsa is characterized by a high rate of urbanization (73.8%) and an important demographic density (42.1 inhabitants/km^2). The spatial distribution of population is marked by the phenomenon of polarization pierced by the city of Gafsa. The south of Gafsa has a population of 98,098 inhabitants in 2009, as compared to 9,812 inhabitants in north of Gafsa, where the majority of economic activities are concentrated. Around 81% [15] of the total families live in urban areas, especially in the town of Gafsa.

Recharge and discharge of groundwater systems are highly climate-dependent. Southern Tunisia suffers from limited surface water resources [16].

Water resources in the study area are divided into surface water and groundwater. The hydrographic network is endoreïc. The western part of the plain is crossed by Wady El Kebir and Wady Sidi Aïch. In the eastern part, wadis originate from the surrounding jebels and reach Wady El Melah but only during rare flooding periods [17]. In the south, the two wadis, Sidi Aich and El Kebir crossing the north of the town of Gafsa form the Bayech Wady. The resources corresponding to the contributions of their watersheds are estimated at 54.5 millions of m^3.

Gafsa basin has two types of aquifers: the first is contained in the coarse Mio-Pliocene formations, while the second is situated in the Cretaceous limestone [18]. Only the groundwater of Gafsa north and south will be studied because the town of Gafsa is located between the two groundwaters near the sill of Gafsa.

The main aquifers of northern Gafsa are the Mio-Plio-Quaternary alternation of more or less coarse sand with argillaceous intercalations and those of Cretaceous formed by the dolomitic limestones with argillaceous intercalations. The whole area acts as a single hydrogeological entity due to lack of an impermeable layer [19]. Farhat and Moumni [20] showed that the Sidi Aich Wady appears as an axis of supply. The groundwater input occurs from the foothills of the reliefs neighbouring the watershed of the Sidi Aich Wady, Jebel Sidi Aich, Jebel Souinia and El Kebir Wady, as well as meteoric waters. Chemical and isotopic data show that the different aquifer levels are recharged by flood-water infiltration in the valley of El Kebir Wady and Sidi Aïch Wady and by direct infiltration of rainwater through carbonate Cretaceous outcrops in the north [5].

Groundwater in the south of Gafsa is limited mainly to the upper part of the alluvial fan of Bayech Wady (alluvial, sandy clays, clayey sands, gravels and conglomerates with argillaceous intercalation). The piezometric maps established by Frappa [21] and Ben Marzouk [22] revealed that the El Maleh Wady is an axis of drainage in the north of Lalla, while the Bayech Wady contributes to the groundwater supply. In the south of the fault, the flow is almost cylindrical and divergent, reflecting water inputs from the groundwater of north of Gafsa across the sill [23]. Sebkhat El Melah and Chott El Guettar constitute the outfall of the phreatic groundwater. Deep groundwater in south Gafsa–El Guettar flows through a continental Mio-Pliocene formation which has several aquifer levels. This aquifer consists of heterogeneous formations composed of alluvium, sand and clayey sand. The deep groundwater also contains the groundwater of Sidi Ahmed Zarroug located to the west of the town of Gafsa. The aquifer of the north of Gafsa is a more permeable reservoir and predominantly sandy than in south of Gafsa, which is not very permeable and is formed by a clay-sandy complex [1].

Once, water was derived solely from natural groundwater sources and Bayech Wady and many sources that lined along the route of the Gafsa fault. Over time, the sources began to dry up as a result of drought cycles and exploitation of ground water wells and deep drilling [24].

In the last few years, the drilling of several wells in the south of Gafsa, and especially in the north of Gafsa, has generated a lowering of the piezometric level inducing the drought of the natural sources. The groundwater of Gafsa is exploited for agricultural purpose (43.33 Mm^3), industry with an increasing demand from chemicals at M'Dhila (20.05 Mm^3) and drinking water (12.22 Mm^3) [25].

The exploitation of groundwater in northern and southern Gafsa presents a deficit of 3.9 and 1.5 Mm^3/year, respectively.

The exploitation of the phreatic groundwater over the period 2005–2006 shows that these two water bodies are overexploited by 132%. The deep groundwater of north Gafsa has known an increase in its exploitation mainly because of the start in the production of new public and private drillings with a deficit of −2.8 Mm^3/ year.

The drinking water exploitation is 4.78 Mm^3, while it is 37.34 Mm^3 for agricultural use. The exploitation of Sidi Ahmed Zarroug groundwater is evaluated to be 1.82 Mm^3 for the year 2010 (in 2007, it was 1.78 Mm^3) covering the water needs of the GCT (Tunisian Chemical Group) of Gafsa.

Finally, the exploitation of deep groundwater in the south of Gafsa during the year 2010 has been evaluated to be 6. 24 Mm^3 (3.81 in 2007), of which 2.26 Mm^3 is used for irrigation and the rest to satisfy the needs of the GCT of Gafsa. The groundwater in northern Gafsa presents a deficit of 2.8 Mm^3/year [15].

The annual potential recharge of the groundwater of Gafsa south–El Guettar by rainfall is 1,637 (1,000 m^3), while for north of Gafsa it is 7,137 (1,000 m^3). Annual recharge of groundwater run-off for Gafsa north and south is 18,622 and 847 (1,000 m^3).

5. Analytical methods

Chemical analysis is a major step to study the hydrochemical characteristics of water of the aquifers of the town of Gafsa. That is why a network of 19 sampling points was chosen for analysing the water quality parameters for the hydrological year 2010–2011. Water wells are distributed over the groundwater of North Gafsa and (04) South Gafsa (12), including the groundwater of Zarroug (03), because of the extension of the urban area (Fig. 1).

Coordinates were measured with a GPS (global positioning system) of the Trembles type. Measures of salinity and pH were made *in situ* using a pH meter and geochemical analyses for the major elements (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^- and SO_4^{2-}) were made at the Research Centre of Metlaoui (Gafsa). The analysis of $Ca^{2+}$and Mg^{2+} was carried out by flame atomic absorption spectrometry. Na^+ and K^+ were analysed by atomic emission, while SO_4^{2-} by gravimetry and Cl^- by the method of Mohr.

6. Results and discussion

Field measurements expressed as pH and salinity, together with analytical data of the major ions in groundwater samples, are represented in Table 1.

6.1. Physico-chemical characteristics of water

The pH values range between 7.24 and 8.29 (Table 1), indicating an alkaline environment. The pH measurements show that all wells are in the interval for WHO (World Health Organization) norm of potability (between 6. 5 and 8.5).

According to the maps of the aquifer salinity of Gafsa north and south (Fig. 4) elaborated by Hamed (2011), we note that the distribution of the groundwater mineralization is relatively irregular. The salinity of the groundwater in the south of Gafsa ranges between 2.00 and 4.2 g/l. This higher mineralization is mainly due to the lithology of the aquifer which is more clayely in the southern part of the basin. For the salinity of the water in the north of Gafsa, it varies from 1.0 to 2. 5 g/l. This lower salinity content compared to South Gafsa probably reflects a larger contribution of rainwater that seeps into the deep aquifer. However, we detected a strong mineralization at Jebel Ben Younes natural outlet for the deep aquifer in North Gafsa [19].

Salinity of groundwater in the town of Gafsa is about 3.74 g/l (Table 1). It is higher than the Tunisian norms (1 g/l). Groundwater from the lower Cretaceous (piedmont of Jebel Ben Younes) Sidi Ahmed Zarroug shows the highest salinity values ranging from 6.91 to 15.03 g/l at Z3, Z2 and F. Hbib Errabhi (Fig. 5). This high salt content could be due to the leaching of the Triassic evaporite series of Jebel Ben Younes. For the groundwater of southern Gafsa, average salinity is about 2.5 g/l (Fig. 6), whereas it is lesser (Fig. 6) in the North Gafsa groundwater (1.58 g/l), probably due to contributions of rain water by the Sidi Aich Wady and El Kebir Wady. The enrichment in the salt water of the groundwater of southern Gafsa is certainly due to the bed rock nature of enclosing land downstream of the Gafsa fault which is enriched in clay-gypsum.

The salinity variations are closely related to the lithology of the aquifer reservoir, the climatic conditions and water infiltration mainly from excess irrigation, combined with the nature of halomorphic soils at Gafsa south.

Table 1
In situ measurements, geochemical data of the aquifers

Drilling number	pH	Salinity(g/l) mg/l	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
1	7.32	2.75	269	1,050	346.14	130	198.33	6.38
2	7.24	4,08	312.4	2020	641	158	245	6.25
3	7.26	12.91	5,220	1803	727.14	161	3,385	120
4	7.28	4.27	469	2020	580	159	404	9.38
5	7.5	1.6	199	1,000	124	68	405	3.4
6	7.57	1.62	152.65	797	242	80	160	4.8
7	7.28	4.44	497	1,800	530	244	400.5	17
8	7.82	2.38	241	1,005	304.43	100	250.3	6.88
9	7.52	1.81	142	860	277	79	140	10
10	7.59	0.96	106.5	366	136	49	133	3.5
11	7.36	1.67	142	747	268	55	150	5.9
12	7.73	15.03	6,526	1,776	740	162.5	4,002	160
13	7.53	6.91	2,202	1,793	474	140	1,650	62
14	8.29	1.94	137	1,020	349	82	120	4
15	7.78	1.89	170	755	320	80	91.67	3.9
16	7.9	1	125	488	270	32	70	3
17	8.1	1.12	140	610	290	55	80	2.5
18	7.8	2.9	170	1,500	450	166	300.3	5
19	7.6	1.87	95	566	240	58	77.5	3.1

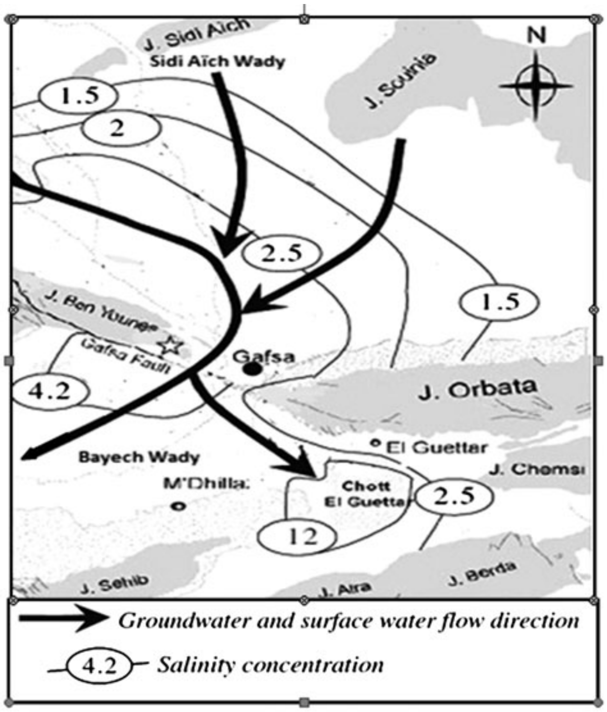

Fig. 4. Salinity distribution of the basin of Gafsa [5].

6.2. Major element contents

Relatively high mineralization in waters contain the following ions by order of importance: SO_4^{2-} with almost 1156.6 mg/l, Cl^-, Na^+ and Ca^{++} with 911.3, 645.4 and 384.7 mg/l (respectively). Mg^{2+} and K^+ show rather low contents (Table 1).

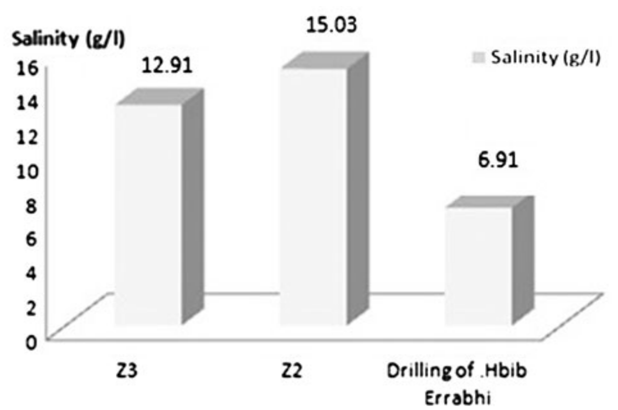

Fig. 5. Variation in salinity in g/l in the groundwater of Sidi Ahmed Zarroug.

- About 85% of drillings exceed the standard in sulphate content (500 mg / l) of the potability of water. The average content is 1156.6 mg/l, due to the dissolution of gypsum. It could also be affected by a minor anthropogenic source from the industries that employ sulphate and sulphuric acid, such as mining and foundering industries. The groundwater of

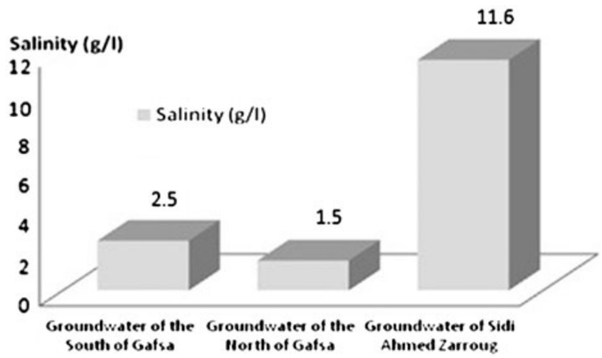

Fig. 6. Variation in salinity in g/l in different aquifers of the town of Gafsa.

South Gafsa shows higher levels of sulphates than North Gafsa, which probably related to the dissolution of gypsum which is very abundant in this region.

- Magnesium follows almost the same evolution as that of calcium. Calcium has an average content of 384.7 mg/l. It is probably derived from the dissolution of sulphates (gypsum and anhydrite) in view of the correlation between constituents of these minerals Ca^{2+} and SO_4^{2-} (Fig. 7).

The value of magnesium varies between 32 and 244 mg/l. It is high especially in the groundwater of Sidi Ahmed Zarroug (average of 154.5 mg/l). The existence of a dolomitic facies in the reservoir may explain the origin of Mg^{2+} and the dissolution of magnesium sulphate gives good correlation between magnesium and sulphate (Fig. 7).

- The groundwater of de Sidi Ahmed Zarroug presents the highest level in sodium, potassium and chlorine: 3012.3, 114 and 4649.3 mg/l, respectively.

The average sodium content in the groundwater in the north and south of Gafsa is 201.6 mg/l whereas

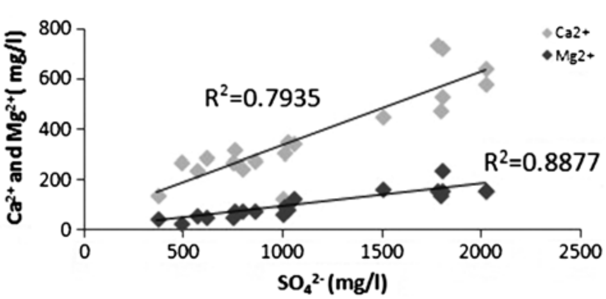

Fig. 7. Correlation sulphate–calcium and sulphate–magnesium.

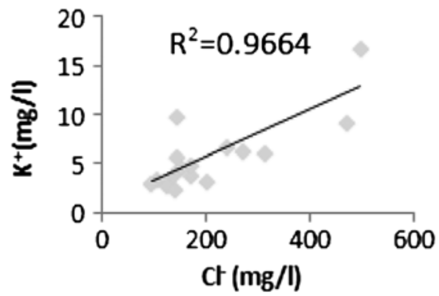

Fig. 8. Correlation chlorine–potassium.

for potassium it is 5.81 mg/l. Chlorine varies between 95 and 497 mg/l, with 50% of the samples contents higher than the (WHO) norms (250 mg/l). Given the strong correlation between Na–Cl and K–Cl, these three elements probably find their origin from the dissolution of evaporite sediments, such as sylvite (Fig. 8) and halite (Fig. 9). These deposits are located mainly in the south of Gafsa, especially in the piedmonts of Jebel Ben Younes (3012.3 mg/l). In addition, high levels may be due to the dissolution of chemical fertilizers used extensively by farmers and the discharge of domestic wastewater, as the highest values in potassium are in the wells of Abderrazak Souid near the water treatment station (Aguila) and in drilling in Hammem Karaouli just near to the cemetery (on average 10 mg/l).

6.3. Chemical facies

In order to clearly identify the hydrochemical facies and indicate the qualitative aspects of groundwater, we reported the measured chemical composition of water in Piper diagram. It is very clear that the waters are of calcic and magnesian sulphated type, almost dominant in the groundwater of South Gafsa, facies extending to North Gafsa, and found in

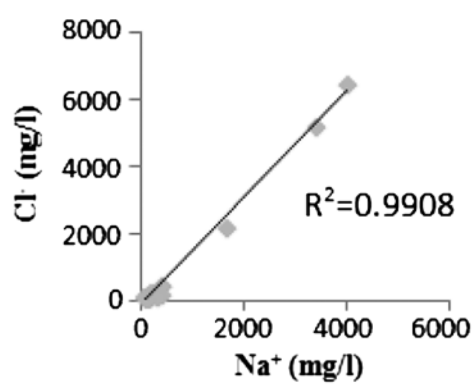

Fig. 9. Correlation sodium–chlorine.

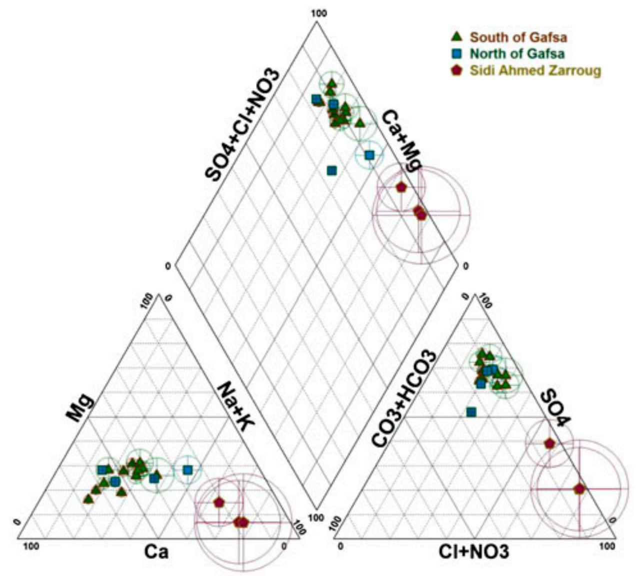

Fig. 10. Groundwater chemistry represented in a Piper diagram.

the waters of the Upper Cretaceous and in the Mio-Plio-Quaternary [25]. The sodium chloride facies extends to the groundwater of Sidi Ahmed Zarroug.

Each sample has also been represented with a circle having a diameter proportional to the TDS (total dissolved salt) content (Fig. 10). This helps in deducing the hydrochemical water facies of different groundwaters of South and North Gafsa showing a chemical relationship, though waters are separated by the sill of Gafsa. The groundwater of Sidi Ahmed Zarroug does not present any relationship with other groundwaters. This difference reflects compositions or differentiated nature from aquifer materials, combined with high evaporation (Fig. 10).

7. Statistical analysis (applying PCA method)

To explain the evolution of chemical elements and to find similarities in the behaviour of several components, we try to process the data by a multivariate analysis method, such as principal component analysis (PCA) using STATISTICA 6.0 software package.

Our present study focuses on the major elements that influence the evolution of mineralization. This includes salinity, whose evolution depends on the latter.

A principal component analysis (PCA) was made on a data table of seven (07) individuals and 19 variables. We pushed the analysis to two factors from which 96.91% of the variance could be expressed.

On the correlation matrix of Table 2, it can be seen that almost all variables are correlated. There is a strong correlation between the major elements (sulphate, sodium, calcium, potassium, magnesium and chlorine) and salinity.

This allows us to suggest that the salinity of the water is mainly related to the nature of the salt formations leached by waters, i.e. the occurrence of gypsum, anhydrite, sylvite and halite. The strong relation between calcium sulphate, on one hand, and chlorine, potassium and sodium, on the other hand, confirms this trend.

The analysis of the space of variables (Fig. 11) shows:

- The projection of the variables on the factorial plane F1–F2 indicates that F1 axis expresses 78.36% of variance and is determined by Cl^-, SO_4^{2-}, Ca^{2+}, Na^+, K^+ and salinity.
- Factor F2 vertically expresses 18.55% of variance. It is determined by magnesium and calcium sulphate.

The projection of individuals on the F1–F2 plane revealed that in the presence of two different aquifers, one aquifer is dominated by calcium, magnesium and sulfate and the other is highly mineralized in chlorine and sodium.

All these analysis methods lead to the same results. Thus, the quality of groundwater in the town of Gafsa is characterized by a high degree of mineralization that could have been induced by the nature of the aquifer matrix and high evaporation, on one hand

Table 2
Correlation matrix between variables

	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	Salinity
Cl^-	1.00						
SO_4^{2-}	0.51	**1.00**					
Ca^{2+}	0.72	**0.88**	**1.00**				
Mg^{2+}	0.41	**0.89**	0.80	**1.00**			
Na^+	**1.00**	0.53	0.71	0.43	**1.00**		
K^+	**1.00**	0.51	0.71	0.42	0.99	**1.00**	
Salinity	**0.98**	**0.67**	0.83	0.58	**0.98**	**0.97**	**1.00**

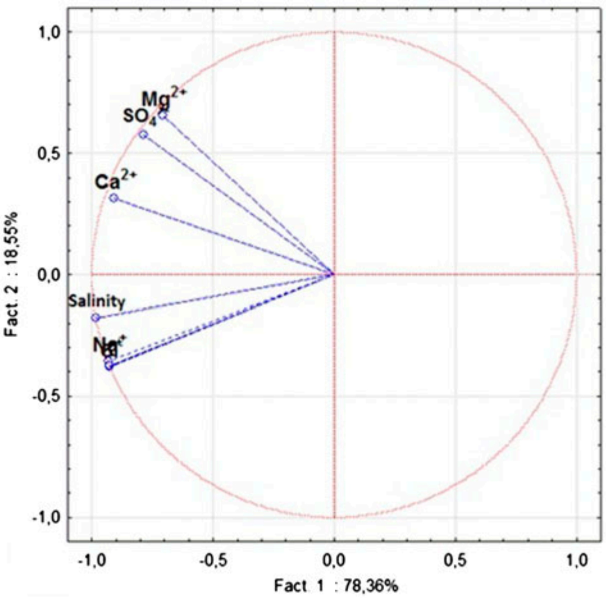

Fig. 11. Variable space of overall PCA.

(natural processes), or by anthropogenic activities, on the other hand. These activities are related to the over-exploitation of groundwater and the pollution derived from the urban development of Gafsa (industrial, agricultural and domestic wastewater). This is what has been observed from the correlations. In most cases, aquifers' quality exceeds the norms for water potability. All these processes have engendered several deleterious problems, such as water-level decline, diminished artesian activity, salinization and deterioration of groundwater resources.

8. Conclusions

The historical examination of the exploitation of aquifers in the town of Gafsa allowed concluding that these reserves are limited, considering the increasingly abundant demand for water, due to the anarchic urban sprawl that will create a growing need of water for industrial, agricultural and drinking necessities. The phenomena of evaporation and pumping of groundwater during the summer period deteriorate water quality, increasing the mineral content. In urban areas, other factors make water quality very vulnerable, such as the increase in concrete and paved surfaces which favour run-off and reduce the areas of infiltration of rainwater, where groundwater will be less fed. This effect will result in modifications on water supply, of flow rate and in the physical and chemical qualities of water. This situation pushes us to seek solutions to put an end to the pollution of groundwater and to conduct exploration in order to satisfy the water requirements, qualitatively and quantitatively, for the Gafsa area.

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