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PROSPECTS AND GEOTHERMAL POTENTIAL OF MILA

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That work deals a determination the geothermal potential and prospects of the Mila region. Thermal baths in Algeria are characterized by a high concentration of hot springs in the North-East of the country. At the last census, more than 282 thermal resurgences have been inventoried in northern Algeria, with temperatures varying between 30°C and 96°C. Geothermal resources in Algeria are of the low-energy type. Three geothermal zones have been delineated according to some geological and thermal considerations: the first: the Tlemcenian dolomites in northwestern part of Algeria, the second: is the carbonate formation in the northeastern part of Algeria and the third: the sandstone Albian reservoir in the Sahara in southern Algeria. Our study area is Mila, is located in the North-East of Algeria, 50km from Constantine, which is part of the Kebir Rhumel watershed, it is characterized by a rugged relief. The geothermal resources of Mila region emerge in favor of tectonic conjugate directions N-S, E-W and NW-SE. Mila region is characterized by a Mediterranean climate, sub-humid in the north and semi-arid in the south. All types of geochemical facies are found: bicarbonate, sulphated and chloride from carbonate formations, gypsiferous and evaporate. Exploitation of geothermal energy remains very limited given the existing geothermal potential, crenotherapy is the main use. Except for a few cases in the south of the country

***Keywords**: thermal, geothermal potential, low-energy, Mila, crenotherapy.*

INTRODUCTION

Today, geothermal energy is the third most widely used renewable energy in the world after biomass and hydro. The use of geothermal energy is expanding rapidly; it is developed in about sixty countries, such as the United States, Japan, Iceland, New Zealand, the French Antilles and Switzerland. In Algeria, more than 280 springs have been identified in the North, of which more than 50% are located in NE Algeria.

The emergence temperature varies between 30°C and 96°C. The highest temperature is located in Guelma (Hammam Debagh). These resources would generally come from geothermal reservoirs of Mesozoic age of limestone, sandstone and sandstone type. At depths between 1500 and 2500m [1], their temperature at depth can reach 120°C. The so-called high-energy geothermal resources are characterized by a temperature higher than 150°C and are mainly used for electricity production.

The medium and low energy geothermal resources are characterized by a temperature between 30°C and 150°C and are intended for housing heating (60°C to 80°C), heating of greenhouses, fish farming, etc.

The geothermal resources in Algeria are of low energy type. The first study of the geothermal exploitation program in Algeria began in 1852, M.Ville published his work on "Research on rocks, waters and mineral deposits of the provinces of Oran and Algiers", followed in 1888, J.Bails by a notice on "Thermal and mineral springs of the department of Oran", in 1889 M.Ville publishes a notice on "

Thermal and mineral springs of Algeria". In 1911 Professor Hanriot with the collaboration of Dr. Trolard published his work "The mineral waters of Algeria"; In 1923, 1926 Pouget.I and Chouchak.D published a detailed study on the radioactivity of Algerian waters for the three provinces of Oran,

Algiers and Constantine; In 1940 and 1947 S. Guigue published "The main thermal springs of Algeria". Guigue publishes "the main thermal springs" within the framework of the geological map of Algeria (35 springs and 75 griffons) concerning the geochemistry of the thermo-mineral springs; we can also quote the works of Cornet 1964, in 1966 the company (EURAFREP 1966) with the participation of Cormy. G, Demians D'aurchimbaud. J (Cormy & Demians d'Archimbaud 1970), Jacqmin. M.A, Facca. G in 1966, Marinelli. G and Tonani. F under the direction of the national company of hydrocarbons SONATRACH really begins the research related to the geothermalism in the Algerian North-East; In 1974, the works of the doctor B. Laissoub on the thermalism in Oranie; In 1982 the national company of electric energy SONALGAZ undertook the study of geothermal recognition of the Northern and Eastern part of the country in association with the Italian company ENEL. In the first stage, the geothermal studies concerned mainly the North-East part of Algeria. From 1983, the geothermal work was continued by the Center for Renewable Energies of Algeria (CDER) and the program was extended to the entire northern part of the country; In 1985, H. Dib-Adjoul " Le thermalisme de l'est algérien " ; 2008, Fekraoui 1988; Rezig 1991; Bouchareb-Haouchine 1991).
In 1992, A. Issaadi " Le thermalisme dans son cadre géostructural" ; In 1993 ; Kedaid and Mesbah ; 1996, Lahlou Mimi et al ; 1998, Saibi et al ; 2006, Kedaid; In 2006, M. Athamena " Etude des ressources thermales de l'ensemble allochtone sud sétifien"; 2007, Bahri et al; In 2008, H. Dib published " Le Guide pratique des sources thermales de l'Est algérien "; 2011, Bouchareb-Haouchine; 2012, 2015 Belhai et al; 2016, 2017; Bouaicha et al. 2017; Djemmal et al. 2017); Kouadra et al, 2018.
Three geothermal zones are delimited according to geological and thermal considerations: the first: the dolomites of Tlemcen in the North-West of Algeria, the second: is the carbonate formation of the North-East of Algeria and the third: the sandstone reservoir of the Albian in the Sahara in southern Algeria
The exploitation of geothermal energy remains very limited in view of the existing geothermal potential, balneology is the main use. Except some cases in the South of the country. This study aims to determine the geothermal potential and prospects of the Mila region. The study area is located in the NE of Algeria, it is characterized by the presence of numerous thermal springs known since the Roman era whose vestiges are always witnesses, the case of the source of Beni Guechat.

Geological and hydrogeogical settings

The wilaya of Mila is located in the North-East of Algeria (Figure 1), at 464m of altitude, being part of the Constantinois tell and belongs to the Kebir Rhumel watershed. It is located 370km from the capital Algiers, 100km from Jijel and 50km from Constantine.
It is bordered in the North and in the South by the parallels of 36°34'33"N to 35°53'08"N and in the East and in the West by the meridians of 5°44'41"E to 6°30'02"E. It extends on a surface of 3480.45km^2, that is to say 0.14% of the surface of Algeria.
The orographic system of the Mila region is complex; it is represented by three types of reliefs: massifs, depressions and high plains.

- A zone of high mountains limiting the wilaya in its northern part which covers 20.8% of the total area of the wilaya. These massifs of WSW-ENE orientation, constitute a rocky barrier which divides the small Kabylia of El Milia in the North and the North Constantinois in the South
- An area of foothills and hills that cover the central part of the Tellian foothills, on an area of 28.8%.
- A zone of plains in the South, covering 50.4% of the total area of the wilaya.

The region of Mila is essentially agricultural, cereals and livestock are the main activities.

Figure 2. The study area situation

The region of Mila is defined by a Mediterranean climate, sub-humid in the North and sub-arid towards the South, with an average annual precipitation of 600 mm and temperatures that are close to 40°C in summer and that fall below zero in winter (Figure 2).

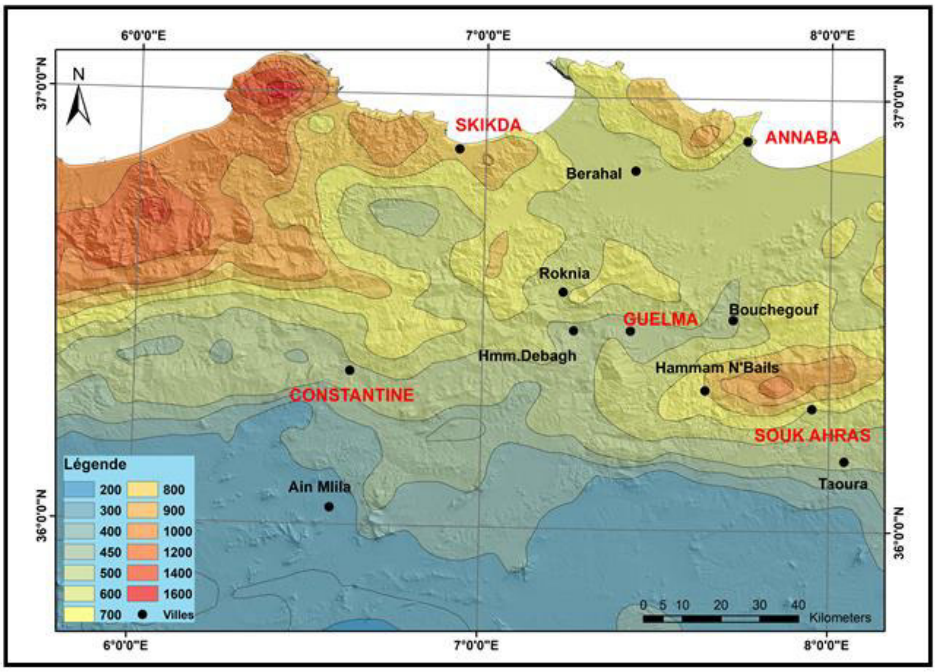


Figure 3. Rainfall average annual map in eastern algeria (ANRH,modified in Bouaicha [4])

A fairly dense hydrographic network, Oued Rhumel which merges with Oued Endja to form Oued El Kebir, Oued Cotton, Oued Seguen, Oued Bou Slah, Oued Smendou... and dams (Oued Athmania Dam, Hammam Grouz Dam and Beni Haroun Dam with a capacity of 960 million m^3 which supplies the neighboring wilayas (Constantine, Batna, Khenchela, Jijel, Mila and Oum El Bouaghi) (Figure 3)

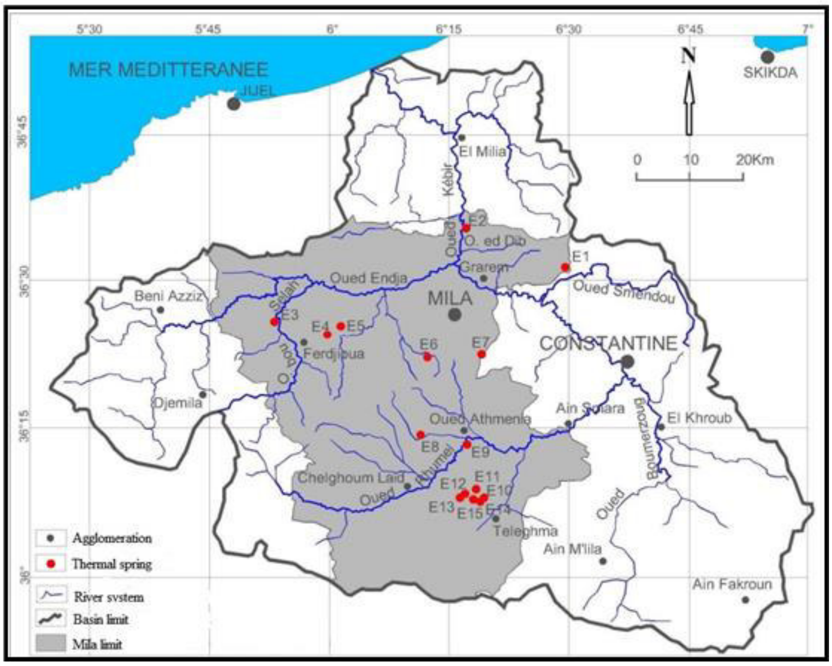


Figure 4. Hydrographical network and inventory of the thermal resources maps studied in the mila region (in Mammeri [5])

The geology of the study area is very complex; it belongs to the Tellian domain which constitutes the external zones of the alpine chain of North Eastern Algeria [3] (Figure 4). It is constituted by formations which spread out from the Trias to the Quaternary, and subjected to the various tectonic phases, in particular the neotectonic which are responsible for the current geological structures and even the emergences of the hot springs.

The lithostratigraphic analysis reveals water deposits with great hydraulic potential constituted essentially by the fissured and/or karstified carbonate formations of the Néritique Constantinois, formed by massive limestones of the Jurassic and limestones and marlstones of the Cretaceous, the nappe pénitellienne and the nappe de Djemila. The Constantine Neogene Basin is represented in the Mila area mainly by Neogene detrital and evaporitic deposits. The Triassic deposits injected along the tectonic faults or outcropping in the form of diapirs have a direct influence on the geochemical facies of most of the hot springs studied.

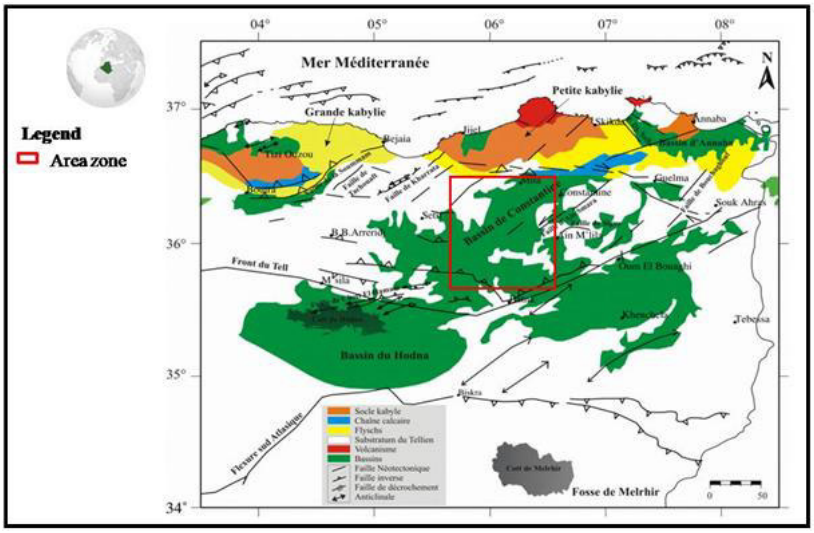


Figure 5. Geological map of study area (in Abacha, modified [6])

MATERIALS AND METHODS

Sampling and analysis

Fourteen main hot springs were inventoried in order to determine their hydrogeochemical composition, these samples were collected in different places in the province of Mila, including Hammam Beni Haroun, Source of Dar Fouini, Hammam Ouled Achour, Hammam Beni Guechat, Hammam Dar Echikh, Hammam Bouhama, Source Ain Tinn, Hammam Etouama, Hammam Grouz, Hammam Ain El Minan, Hammam Ouled Aissa, Hammam Menchar, Hammam Chaouch and Hammam Safsaf [7] (Figure 3).

Physical parameters such as temperature (T°C), electrical conductivity (EC, µS/cm), total dissolved solids (TDS), pH and dissolved oxygen are measured in-situ with a multiparameter type Water Quality Meter AZ86031. The determinations of major elements (Ca, Mg, K, HCO_3, Cl, and SO_4) were analyzed by volumetric titration.

STATISTICAL ANALYSIS AND GRAPHICAL PRESENTATION

Table 1. Values of the parameters of each sample (in Mammeri) [5]

ID	Sample	T (°C)	pH	EC (µS/cm)	TDS	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	So_4 (mg/l)
E1	S Dar Fouini	32	6.8	1593.90	1020.09	252.50	40.98	19.40	414.80	106.50	340.00
E2	H. B Haroun	40	7.08	5229.00	3346.56	180.36	36.26	151.70	252.54	340.80	235.00
E3	H. O Achour	39	6.7	4312.68	2760.12	200.40	52.56	180.80	581.94	344.35	145.00
E4	H. Beni Guechat	56.1	6.19	21700	13888	781.56	117.60	5870.29	888.16	10171.87	1155.00
E5	H. Dar Echikh	35	7.47	1338.66	856.74	72.95	33.51	127.69	207.40	223.87	110.00
E6	H. O Bouhama	43.5	6.8	3706.29	2372.06	513.83	70.90	247.83	237.90	276.90	1410.00
E7	S. Ain Tinn	32	7.35	819.18	524.28	92.18	32.05	2.86	355.02	31.95	125.00
E8	H. Etouama	37	7.28	1700.00	1088	189.98	27.13	119.97	390.40	213.00	247.50
E9	H. Grouz	45	6.65	2151.36	1376.87	236.47	52.04	124.31	272.06	259.15	377.50
E10	H. Ain El Minan	45	7.66	1155.36	739.43	84.97	32.06	87.55	274.50	163.30	80.00
E11	H.O Aissa	50	7.11	1156.36	752.20	80.16	46.46	71.07	268.40	166.30	85.00
E12	H. Menchar	48	7.08	1175.28	752.18	88.98	31.09	89.49	278.16	170.40	75.50
E13	H.Chaouch	51	7.06	1165.32	745.80	84.17	32.06	87.70	269.62	166.85	75.50
E14	H. Safsaf	44	7.05	1349.12	863.44	109.82	36.35	80.96	279.38	163.30	137.50

RESULTS AND DISCUSSION

The temperatures of the thermal waters vary according to the geological conditions and the geographical situation, in Algeria the hottest waters are those of Hammam Debagh with 96°C. In the region of Mila the source of Beni Guechat is the hottest with 56.1°C, on the other hand the lowest corresponds to the source of Ain Tinn with 32°C.

Water is said to be thermal when its temperature exceeds the average annual air temperature by 4°C. The classification of waters according to (Verdeil; 1976) [8] is given as follows:

- Hyperthermal water T > 45°C
- Orthothermal waters 37°C < T < 45°C
- Mesothermal waters 22°C < 37°C
- Cold water T <22°C.

In our study area, the temperature values oscillate between 32 and 56.1°C, out of 14 samples, six are classified as hyperthermal (T > 45°C), five are classified as orthothermal (37°C < T < 45°C) and three are classified as mesothermal (22°C < T< 37°C) (table.1and Fig.5). For the conductivity of water depends, this parameter depends mainly on the presence and concentration of major elements and its temperature.

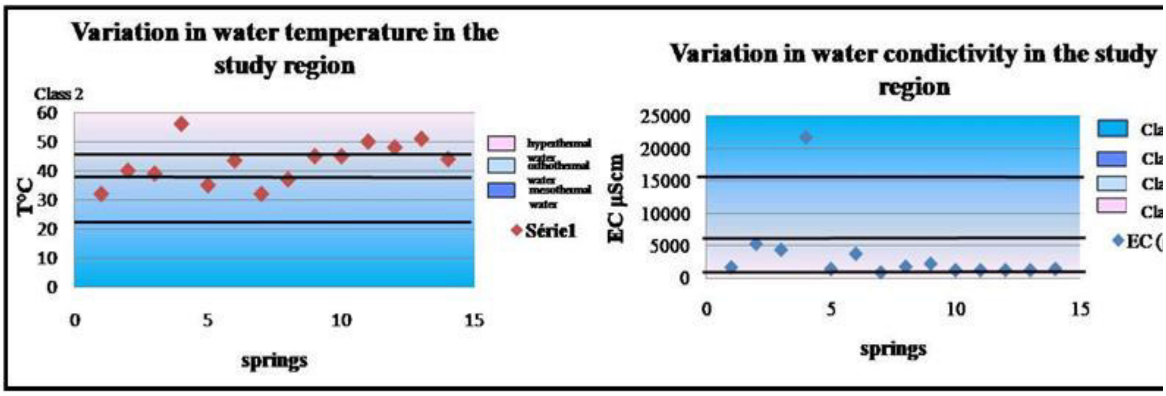


Figure 6. Spatial variation of chemical elements in the study area

In 1992, A. Issaadi [9] grouped mineral and thermal springs into four classes:

- Class 1: EC < 2000 µS/cm;
- Class 2: 2000 < EC < 7500 µS/cm;
- Class 3: 7500 < EC < 15000 µS/cm;
- Class 4: EC > 15000 µS/cm.

The measured values vary from 819.18µS/cm of Ain Tinn, low mineralized water, and 21700 µS/cm of H Beni Guechat water extremely charged in salts testifies of the leaching of the triassic evaporite levels. This variation of values allows us to have an idea on the origin of the waters and the state of mineralization of the studied mineral and thermal springs (Figure 4). 65% of the waters have conductivity lower than 2000µS/cm, which [8] qualifies as weakly mineralized; the majority of the springs that fall into this class are strictly related to carbonate reservoirs. Thus, the mineralization of the waters of this class can be enriched by limited leaching of evaporites or by condensation of waters in karst cavities. 28% of the springs are classified in class 2 where the electrical conductivity is between 2000 and 7000 µS/cm whose mineralization is affected to various degrees by the evaporite formations. For Hammam Beni Guechat (class 4) which is considered as extremely charged water directly linked to the triassic formations. The pH values measured at the springs revealed that 65% have a slightly alkaline pH; the maximum value is recorded at H. Ain El Minan 7.66. The remaining 35% have an acidic pH, the lowest value of pH is 6.19 characterizes the waters of the source of Beni Guechat. According to A. [9]"it is obvious that these pH measurements are influenced by the presence of gas, especially carbon dioxide.

In aquifer systems, the mineralization of water is related to the origin of chemical elements (cations, anions) they contain, the content of the latter depends on two factors: the type of reservoir and the speed of chemical reactions that are directly related to the time of water-rock contact.

According to the work of M. Mammeri [5]

- Calcium (Ca^{2+}) its presence is mainly related either to the dissolution of carbonate formations, or the dissolution of gypsum formations. The low values of Ca^{++} indicate that these waters are less influenced by the dissolution of carbonate and gypsum formations. The higher values are related to the existence of dissolution of these formations. The values of calcium vary between 72.95 mg/l (Hammam Dar Echikh) and 781.56mg/l (Hammam Béni Guechat).

- Magnesium (Mg^{2+}): its origins are comparable to that of calcium because it comes from the dissolution of carbonate formations. The values obtained are between 32.06 mg/l (Hammam Chaouch) and 117.6 mg/l (Hammam Béni Guechat).
- Chlorides (Cl^-) and sodium (Na^+): the origin of these elements is mainly related to the dissolution of salt formations. For chlorides, the values obtained by chemical analysis vary between 31.95 mg/l (Source of Ain Tinn) and 10171.87mg/l (Hammam Béni Guechat). Concerning sodium, the values are between 2.86 mg/l (Source Ain Tinn) and 5870.29 mg/l (Hammam Béni Guechat).
- The presence of sulphate elements in water is linked to several origins, either to the solubility of gypsum in clay sediments, calcium sulphates and magnesium sulphates, or it is linked to the oxidation of sulphur or the oxidation of sulphide minerals. The concentrations of sulfates in the analyzed waters vary from 75.50 mg/l (Hammam Chaouch) and 1410mg/l (Hammam Béni Guechat).
- The presence of bicarbonates in water is due to the dissolution of carbonate formations by water loaded with carbon dioxide. The values of bicarbonates in the analyzed hot waters are between 20740 mg/l (Hammam Dar Echikh) and 888.16 mg/l (Hammam Béni Guechat).

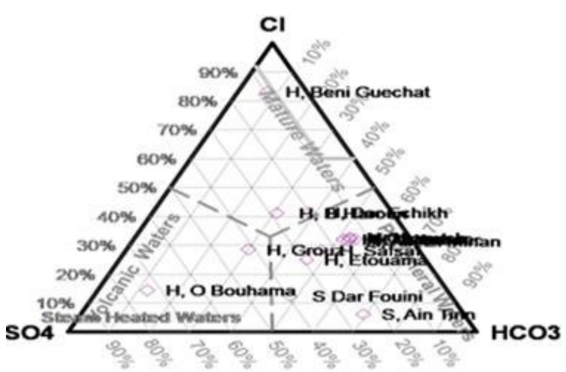
CHEMICAL FACIES

For the classification of waters, the Piper diagram was used, it allows visualizing the spatial geochemical evolution (several water samples from the same aquifer) or temporal (several water samples from an aquifer in different climatic seasons). The representation of the physico-chemical data on the piper diagram shows several chemical facies that depend on the geological nature of the aquifers. The transfer of 14 samples taken at the level of thermal springs and Hammams on the piper diagram (Figure 6) shows a variability of the chemical facies of the waters. These are divided into two poles:

- The saliferous pole: which is characterized by a sodium chloride facies and is represented by H. Béni Guechat and H. Dar Echikh, this is explained by a leaching of evaporite formations of the Triassic which outcrop along the deep tectonic accidents N-S and E-W at the level of Djebels Oukissène, Bou Charef and El Hadid;
- The gypsum pole, characterized by calcic sulphate waters, they are represented by the emergences: Dar El Fouini and H. Ouled Bouhama springs and the calcic sulphate waters of Ain Tinn spring, rich in bicarbonates and weakly concentrated in sodium chloride.

The triangle of cations allowed us to distinguish the calcic sulphate facies with a percentage of calcium exceeding 70% for the Dar El Fouini spring and 60% for H. Bouhama and H. Grouz. The diagram of anions allowed us to separate the sodium chloride facies (Cl superior to 90%) and the calcium sulphate facies rich in bicarbonates (HCO^{3-} superior to 50%). The water points that are grouped between these two poles represent a zone of mixtures; this is the case of the hot waters of Hammams Teleghma (from 10 to 15).

The Cl-SO_4-HCO_3 ternary diagram confirms the existence of a saliferous contribution of evaporitic origin represented by the Triassic formations that outcrop in the region.



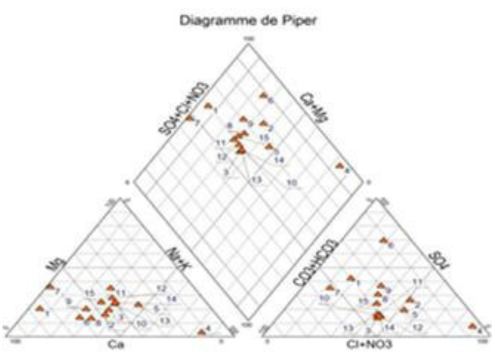


Figure 7. ternary plot and Piper diagram

Principal components analysis (PCA)

PCA is a descriptive statistical method, its objective is to represent in graphic form the essential information contained in a table of quantitative data, in this table of data with 9 variables (T, pH, EC, Ca, Mg, Na, HCO3, SO4, Cl), the individuals (the 14 emergences studied) are in a 14-dimensional space.

The correlation matrix (Table 2) allows us to distinguish a very good positive correlation between conductivity, which expresses mineralization, with Cl and Na and to a lesser degree Mg, HCO3 and Ca. Cl is well related to Na, but less so to Mg and Ca. HCO3 is bound with Mg and Na and to a lesser degree with Ca. SO4 correlates well with Ca and less well with Mg. These various correlations between the chemical elements constituting the mineralization of waters allow the following mineral associations: CaSO4, NaCl, and $CaCl_2$. These associations indicate that the mineralization of the majority of the waters takes place in contact with gypsum and saline formations.

The principal component analysis allows us to extract three main factors that express 93.33% of the total variance of the data table. 75.92% for the first factor, 10.30% for the second and 7.11% for the third. The factorial axis F1 is strongly correlated to the variable pH in positive value, and CE, HCO3, Cl, Ca, Mg, Na and to a lesser extent SO4 in negative value. The proximity of (Na, Cl) and (Mg, HCO3) shows strong correlation between these variables, while the correlation between temperature T and SO4 is almost null. The factorial axis F2 is correlated with the variable T. According to the factorial plane F1-F2 (table 3) we observe that the majority of the statistical units are arranged on the right of the factorial axis F2, they are waters with pH values higher than 7. We can distinguish four groups: The first group includes the boreholes of Teleghma which are characterized by very high temperatures (over 45°C). The second group is made up of statistical units located near the intersection of two axes; this group is characterized by waters rich in Ca, HCO3, and Mg with temperatures below 40°C. The third group is represented by the sulphated waters of Hammam Bouhama (E6) and the spring of Dar El Fouini (E1). The fourth group is characterized by hyperthermal waters very rich in chlorides and sodium, corresponding to Hammam Béni Guechat (E4). On the F2-F3 factorial plane, all the variables are centered at the intersection of the two axes, which helps us to understand the poor correlation between the F3 factor and the different variables, with the exception of SO4 and T, which have some correlation with this axis.

Table 2. Correlation between physico-chemical parameters of water (in Mammeri) [5]

	T°C	pH	CE	Ca	Mg	Na	HCO_3	Cl	SO_4
T°C	1,0000								
pH	-0.3285	1,0000							
CE	0.4147	-0.7109	1,0000						
Ca	0.2961	-0.7888	0,8712	1,0000					
Mg	0.4562	-0.8056	0.9057	0.9392	1,0000				
Na	0.4686	-0.6384	0.9682	0.8251	0.8804	1,0000			
HCO_3	0.3069	-0.8119	0.8778	0.8102	0.8525	0.8528	1,0000		
Cl	0.4665	-0.6385	0.9684	0.8190	0.8761	0.9998	0.8544	1,0000	
SO_4	0.2300	-0.6432	0.6464	0.9196	0.8175	0.5902	0.5428	0.5788	1,0000

On this plan we observe a distribution of emergences in two orthogonal directions according to temperature, SO_4, HCO_3, Cl and Na where we have distinguished: Waters with high temperatures and high chloride contents and relatively low concentrations of sulfates. Orthothermic to mesothermic waters with bicarbonate or chloride character rich in bicarbonates and calcium. According to the F1-F3 plan, a good negative correlation appears between the F1 axis and the majority of the variables (Cond, HCO_3, Cl, Ca, Mg, and Na), the strong link between conductivity and chlorides, sodium and bicarbonates is explained by the richness of the thermal waters studied in these ions. The good correlation noticed between Ca and Mg is explained by the same carbonate origin of these ions. The axis F3 groups in negative value the variables SO_4 and T quite well correlated to F3. The first set of emergences concentrated at the intersection of two axes is characterized by orthothermic to mesothermic waters rich in Cl and HCO_3 concentrations with high Ca concentrations. The second set constitutes the springs outside the first set characterized by waters richer in sulfates, with an acid pH. The hyperthermal and very charged waters of Beni Guechat represent the third set characterized by very high concentrations of Cl, Na and a conductivity reaching 20.000 µS/cm.

Table 3. Correlation between variables and factors

Variables	F1	F2	F3
T°	-0.467206	0.771155	-0.426295
pH	0.822241	0.174011	0.127374
CE	-0.959200	-0.072913	0.195335
Ca	-0.946845	-0.261353	-0.135990
Mg	-0.974378	0.180664	-0.103469
HCO_3	-0.903741	-0.030145	0.269299
Cl	-0.936063	0.185709	0.241059
SO_4	-0.773307	-0.397115	-0.437071

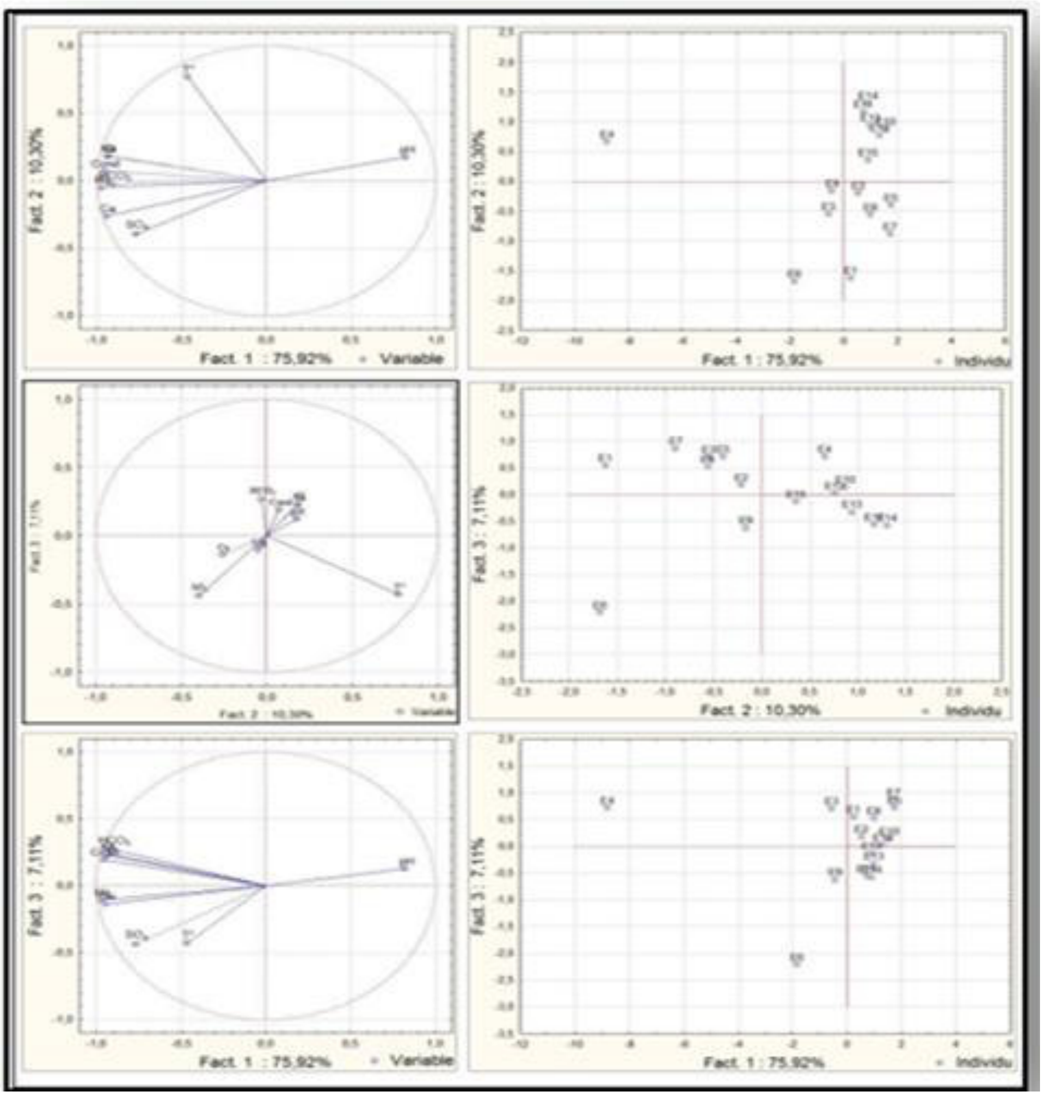


Figure 8. Principal component analysis of the thermal waters of the Mila region

CHEMICAL GEOTHERMOMETRY

Chemical geothermometry is an important tool to estimate reservoir temperatures of hydrothermal systems. We will use the approach of (Giggenbach 1988) [10] to evaluate the temperature of the reservoirs and identify waters that have reached equilibrium with the host lithologies.
All the samples analyzed from the thermal springs of the Mila basin were represented on the Giggenbach diagram (Figure 7). This geothermal technique suggested by (Giggenbach 1988) [10] separates between immature and fully equilibrated waters in deep reservoirs.
Thermal water represents a mixture of notably warm waters with surface or near-surface seepage waters with Jurassic-Cretaceous dolomitic and limestone formations that contain high concentrations of Mg, except for the case of H Beni Guechat which is in the partially balanced water domain. This is located near the mature water zone

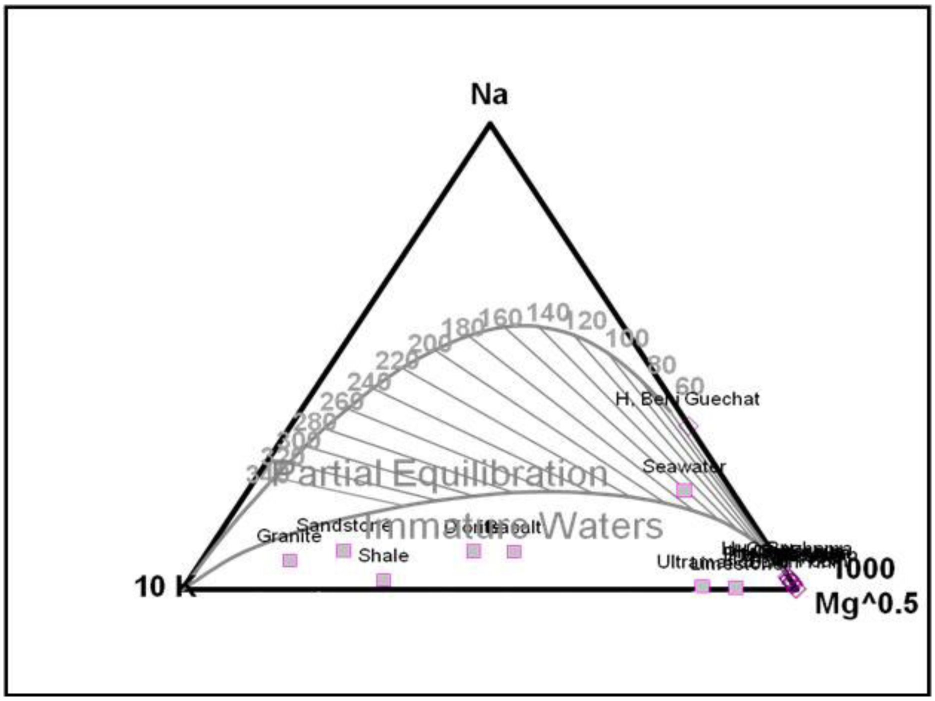


Figure 9. Giggenbach diagram for Mila geothermal waters

For the geothermometers used (Giggenbach and Mg/K) the results are close
For Giggenbah: Hammam Beni Guechat is individualized with a temperature close to 100 ° C, for the other sources the temperature of the reservoir varies between 40 ° C and 60 ° C.
For the geothermometer Mg/K gives the following results:
Beni Guechat (80°C), Bouhama and Dar Fouini enter (70°-75°C), Beni Haroun and H Grouz and O Achourla temperature varies between (70°-60°C), and the rest the reservoir temperature between 50°-40° C) it seems therefore. It seems that the waters of Ouled Achour, Ouled Bouhama are in the reservoir of the albo-cenomanian limestones. The waters of Beni Guechat can circulate in a deeper reservoir; it would be the neritic limestones of Constantine. The variations of temperatures at the emergence as well as the mineral load make it possible to suggest a contribution of the higher aquifers (penile-tellian) and a contamination of the waters by the Triassic evaporites.

POTENTIAL AND PERSPECTIVE

Renewable energy is becoming a major issue in many countries around the world. The direct use of hot water has existed for a long time and continues to grow in various different fields of application. The first geothermal district heating system was inaugurated in the 14th century in Chaudes-Aigues, France, and the first geothermal well was drilled near Reykjavik, Iceland, in 1755 [11].

Geothermal systems are located in areas with a normal or slightly above normal geothermal gradient, creating low to medium enthalpy geothermal reservoirs (less than 150°C).
Mila has a non-negligible geothermal potential. It has about twenty springs and Hammam, 11 Hammam are located in Mechta Smara (Teleghma) with a flow Q = 20 l/s, can create more than 100 direct jobs, as well as indirect employment (depending on the season).
Some cases of use: we can quote the fish farm of Saida (a drilling provides 60l/s of hot water 30°C), Ouargla (drillings provide 44l/s of water at 21°C) and Ghardaia (150l/s of water at 28°C) in the Sahara (in the south). Saïda is the first site in Algeria, which uses a geothermal heat pump. This 34KW reversible heat pump is used to heat and cool 12 classrooms, the library and the restaurant of an elementary school. The hot water (46 °C) first passes through the heat pump before being used for swimming. The water comes out at 39 °C. This system allows comfortable temperatures of about 30°C during the cold period and 15°C in summer [12] Currently, balneology (crenology) is the main use; it can be used to treat a variety of diseases. The most serious diseases that use balneotherapy to relieve symptoms include cardiovascular disease, fibromyalgia, chronic fatigue syndrome, depression, anxiety, insomnia, osteoarthritis, rheumatoid arthritis, psoriatic arthritis, ankylosing spondylitis, spinal cord injury, spasticity, stroke, acne, dermatitis, psoriasis, eczema, lichen and scleroderma. Other benefits of balneotherapy treatments include pain reduction, increased collateral blood flow, elevation of cellular fluids, muscle relaxation as well as many curative benefits from the absorption of minerals and botanical substances. Many spas in the Mila region base their treatments on balneotherapy, which offers an additional health benefit due to their mineral-rich compositions.
The wastewater of these thermal centers are directly rejected in the nature without preliminary treatments, these hydrothermal effluents are waters very rich in mineral salts, active tension products and organic matters, which constitutes a threat for the environment whether it is on the human health or on the fauna and the flora. The purpose of this approach is to make a quantitative and qualitative evaluation physico - chemical of the level of contamination of the surface and ground water by the hydrothermal effluents; a durable management (economic, social and environmental) of the hydrothermal water discharges. A valorization of these effluents by building a heating system for the thermal stations of the Mechtat Smara area.
As an example (Table 4): a capacity of reception of curist of a minimum 100 rooms of water, all the rooms of water can be used on average ten (10 times/day) and each time, the basin must be filled and emptied after use, this bathtub has a capacity of 1600 liters without counting the water used directly of the tap, we arrive at quantities of notable annual water charged of tensio-active [13]

Table 4. Volume of discharged water loaded with Tensio-active

designation	amount of water discharged per day (m^3/d)	amount of water discharged per month (m^3/month)	amount of water discharged per year (m3/year)
volume of water discharged by the thermal centers $1.6m^3 \times 10$times/d×100 rooms	1600	48000	576000

We would like to point out that these thermal-therapeutic centers work more than 15 hours a day (2 x 8 hours), and that the authorized duration of the bath is 3/4 hours (45 minutes), which allows a use up to (20) twenty times a day and that, and that therefore the volume of water discharged with surfactant currently exceeds 1152000 m³/year, or more than 8064000 m^3 over the fourteen years of operation without any prior treatment.

CONCLUSIONS AND RECOMMENDATIONS

In this present work, we have studied the hydrothermal potential of the region of Mila, located in the NE of Algeria, a very complex geology made up of formations that range from the Triassic to the

Quaternary, and subjected to various recent tectonic phases that are responsible for the current geological structures and even the emergence of hot springs.
The thermal waters have a more or less important mineralization; it is lower than 1g/l in the boreholes of Teleghma, the hot spring of Ain Tinn, and Dar Echikh. It is between between 1 and 2g/l in the springs of Dar El Fouini, Béni Haroun, Ouled Achour, Etouama, Hammam Grouz, it is between 2 and 3g/l for the hot waters of Ouled Bouhama and it exceeded 20g/l with a conductivity higher than 20000µmhos/cm for the source of Béni Guechat spring.
The pH values are generally close to neutral, ranging from 6.19 to 7.66. The low values of pH values are related to the very important release of carbon dioxide of deep origin.
The chemical classification of the waters according to the Piper diagram, has given three dominant facies: calcic and sodic chlorinated waters, calcic sulfated waters and calcic bicarbonate waters.
The study of the limits of the thermality of the waters and the measurements on the ground of the temperatures of 9 springs and 6 boreholes allow us to classify the hot waters as mesothermal, orthothermal to hyperthermal waters with temperatures between 31.5 at Ain Tinn and 56.1°C at Beni Guechat.
The multidimensional analysis by the A.C.P. method leads to the interpretation of the mineralization as probably coming from a gypsum and saliferous environment which often hides the original chemical composition of the saliferous environment which often masks the original chemical composition of the waters.
The thermalism in Mila is a real vein offering real investment opportunities with undeniable economic producers, as long as it is rationally exploited, either in the framework of crenotherapy either in the tourist field and respecting the context environmental.

REFERENCES

[1] Kedaid, F Z (2006) Développement de la base de données géothermiques de l'Algérie par un système d'information géographique. Revue des Energies Renouvelables Vol. 9 N°4, p. 253 – 258.

[3] Vila JM (1980) La chaine alpine d'Algérie orientale et des confins Algéro-tunisiens. Thèse de Doctorat, Université Paris VI (in French).

[4] Bouaicha F (2018) Le géothermalisme de la région de Guelma. Thèse de Doctorat en sciences, Université de Constantine, Algérie (in french).

[5] Mammeri Madiha (2015) Le thermalisme de la région de Mila. Magistère, Université de Constantine, Algérie (In french).

[6] Abacha I (2015) Etude de la sismicité de la région Nord-Est de l'Algérie. Thèse de Doctorat en sciences, Université de Sétif, Algérie (in french).

[7] Dib Adjoul H (2008) Guide pratique des sources thermales de l'Est Algérien. Mémoires du Service Géologique National, no 15, p 106 (in French).

[8] Verdeil P (1982) Algerian thermalism in its geostructural setting— how hydrogeology has helped in the elucidation of Algeria's deep-seated structure. J Hydrol 56:107–117.

[9] Issaadi A (1992) Le thermalisme dans son cadre géostructurale, apports a` la connaissance de la structure profonde de l'Algérie et de ses ressources géothermales. Thèse de Doctorat d'état, IST, USTHB, Alger (in French).

[10] Giggenbach WF (1988) Geothermal solute equilibria, derivation of Na–K–Mg–Ca geoindicators.

[11] Saibi, H, Finsterle, S, Bertani, R. & Nishijima, J., 2013. Geothermal Energy. In: Kauffman, J. & Lee, K.-M. (eds): Handbook of Sustainable Engineering. Springer Netherlands (Dordrecht): 1019–1042.

[12] Fekraoui.A (2010) Geothermal Activity in Algeria. Proceedings World Geothermal Congress.Bali, Indonesia, 25-29.

[13] Belhadj M.Z (2017) Qualité des eaux de surface et leur impact sur l'environnement dan la wilaya de Skikda. These Doctorat en Sciences, Université de Biskra, Algérie (in french).