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Hydrogeochemical Study of Northern Algeria Hot Springs for Thermal Treatments

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Abstract: Thermal medicine offers an original approach to health that is not only based on treating symptoms. The major advantage of thermal medicine is based on the overall support of the disease, providing prevention, alleviation and treatment of many diseases (rheumatism, bronchitis, skin diseases, etc). In order to get the best possible results by thermal treatments, regular and accurate analysis of the thermal waters of the hot springs is often necessary. This article has a scientific objective for the development of fundamental knowledge needed to better control the hydrogeochemical hot springs in northern Algeria. This study will be addressed by conventional chemical analysis of major chemical elements found at water points (hot springs) in northern Algeria. The results are obtained in the form of semi-logarithmic graphs (Schoeller and Berkallof) and rhombic (Piper).

Key words: Hydrogeochemical, hot spring, northern Algeria, thermal medicine, water mineralization, chemical analysis.

1. Introduction

Algeria is a part of the African continent. It is bounded by the Mediterranean sea to the north, Tunisia and Morocco to the east and west, Niger and Mali to the south (Fig. 1).

According to the inventory conducted by National Agency for Hydraulic Resources—ANRH, in the northern Algeria are recorded more than 240 thermal springs that are of highest concentration in the northeastern part. The water temperature measured at the emergence is ranged from 19 ℃ in Ben Haroune (Mila) to 98 ℃ in Hammam Meskoutine (Guelma). The water mineralization is determined primarily by the chemical and mineralogical nature of the sediments it traverses. The most mineralized hot springs are in direct contact with salt deposits Gypso-Triassic so widespread in Algeria [1].

The present paper discusses the chemical analyses of north Algeria hot springs and thermals therapeutic [1].

2. Geology

North Algeria consists of structural and sedimentary assemblages showing an impression of the Alpine tectonics. It differs from North to South (Fig. 2). In the north, the Tell Atlas, varied in very complex areas. It has an inner zone and an outer zone formed of non-native land (thrust sheets). Between Tellian Atlas and Sahara, are situated the flush with the High Plains ending in the east by the Hodna chain and continue to the west by the Oran Meseta.

Tellian area: Characterized by a stack of thrust sheets with associated intra-mountain basins of sedimentary formations blankets are Mesozoic and Cenozoic age and based on a diverse base involved in the folding [2].

Saharan area: Relatively stable whose tectonics is less pronounced.

2.1 Internal Domain

Kabyle massive base cristallophylliens and metamorphic (gneiss, marble, amphibolite schists [3]. This stand exposed in the Chenoua massive (Tipaza) and Great Kabily (Fig. 3).

2.2 Domain Flyshs

Consisting of layers of Cretaceous-Paleogene flyshs.

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Fig. 1 Location map of Algeria in the world.

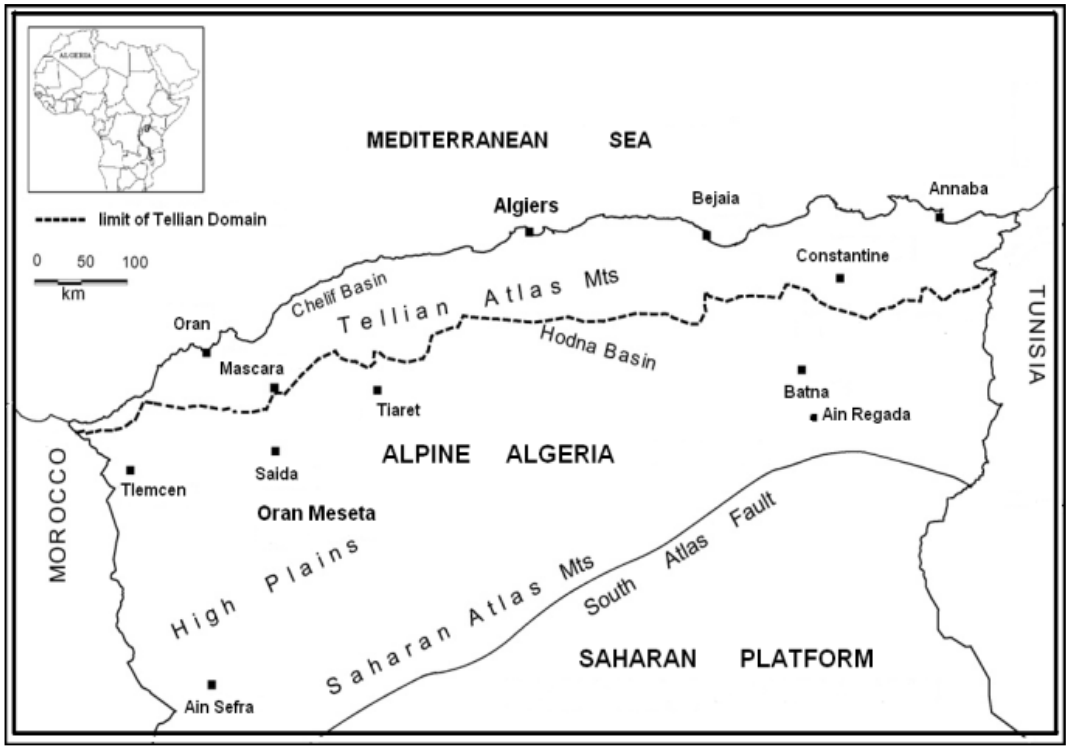

Fig. 2 Geological units of Northern Algeria.

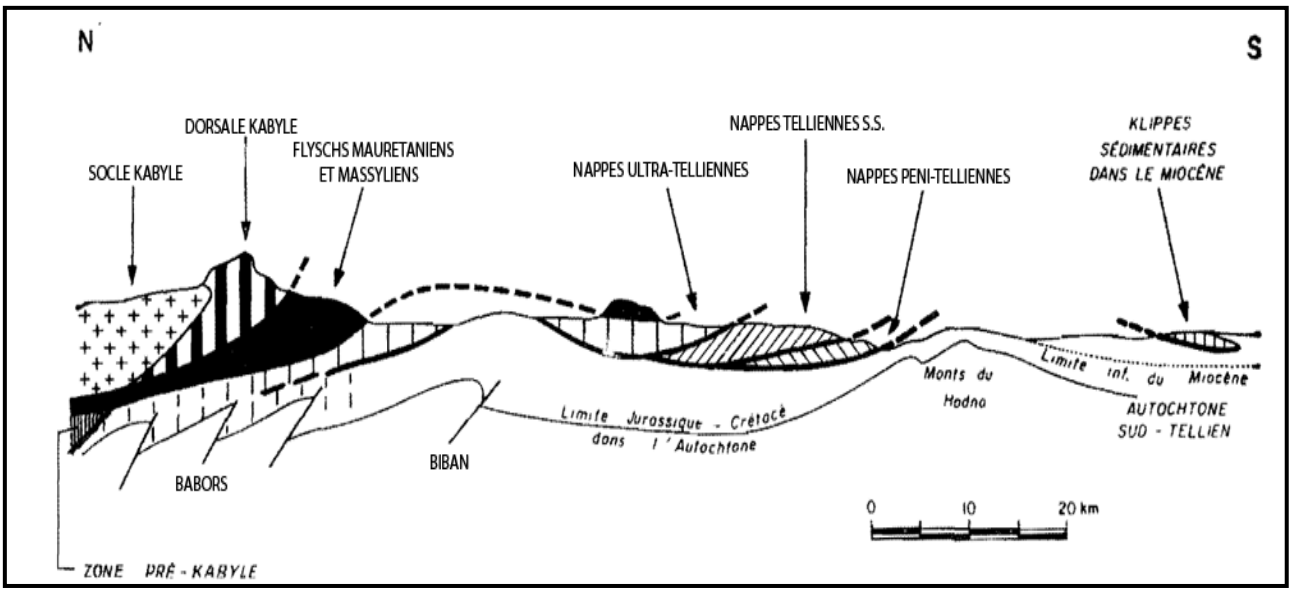

Fig 3 Relationship between the different structural units of the Maghrebides chain of (modified from Durand-Delga [3]).

2.3 External Domain

Tellian domain consists of a set of non-native groundwater, characterized by a marly facies of Middle Cretaceous age has Neogene.

3. Materials and Methods

We selected ten most important thermal springs which were the subject of several measurement campaigns [4]. Direct measurements of pH, conductivity and temperature of thermal water samples are made in order to define the physicochemical characteristics of the selected hot springs. The results are given in tables 1.

4. Results

4.1 Hydrogeochemical Analysis

They show that emergency temperatures are ranged between 41 ℃ and 96 ℃. These values characterize Hydrotherapy of low enthalpy. pH values of these waters are broadly neutral; they vary from 6.4 to 7.98. The termal water has a slightly higher TDS value that ranged from 0.398 g/L to 3.9 g/L [5]. The thermal water mineralization is determined by the mineralogical and chemical nature of the terrain they cross. The strong mineralization of hot water is due to the presence of salt deposits Gypso-Triassic widespread in Algeria (Hammam Mélouane 2.9 g/L and Hammam Guergour 3.9 g/L).

4.1 Graphical Representation

4.1.1 Diagram Schoeller-Berkaloff

The chart analysis (Fig. 4) facilitates graphical representation of several samples at a time and defines the chemical characteristics of hot springs.

To the west: Hammam Boughrara hot spring (Magnesium chlorinated water); Hammam Bouhadjar hot spring (sodium chlorinated water); Hammam Bouhanifia hot spring (sodium bicarbonate water). To the Center: Hammam Melouane hot spring (calcium bicarbonate water); Hammam Righa (sulfated lime water).

To the east: Hammam Chellala hot spring (calcium bicarbonate water); Hammam Salhine hot spring (sulfated lime water).

To the South: Hammam Essalhine hot spring (calcium sulphate water); Hammam Zelfana hot spring (sodium sulphate water).

4.1.2 Piper Diagram

From the piper diagram, the selected hot springs are classified as following:

(1) Hammam Salhine hot spring belongs to the family of calcium hyper chlorinated water;

Table 1 Chemical analysis (mg/L) and temperature of thermal spring in the northern Algeria [4].

Hot spring	TC	pH	RS	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3
1.H Boughrara	43	7.98	398	36	58	46	3.9	244	97.98	19.33	-
2.H Bouhadjar	66.5	6.36	3,210	196	107	874	32.2	549	1,469	68	-
3.H.Bouhanifia		6.64	1,400	172	48.6	253	19.55	823.5	355	110.4	
4. H. Chellala	96	-	-	224	19	40	05	397	-	300	42
5. H. Essalhine	43	-	3,251	375.7	92	347.53	10.3	167.4	482.8	1,682	-
6. H. Guergour	44	6.9	3,600	580	80	250	-	200	480	1,600	-
7. H. Melouane	41	-	2,900	36	21	18	4	140	35	40	-
8. H.ammam Righa	68	-	2,173	310	14	198	13	301	320	425	2
9. Hammam Salhine	70	-	2,082	106	43	565	29	274	775	300	3
10. Hammam Zelfana	41	6.5	1,810	163	61	508	22	165	497	518	15

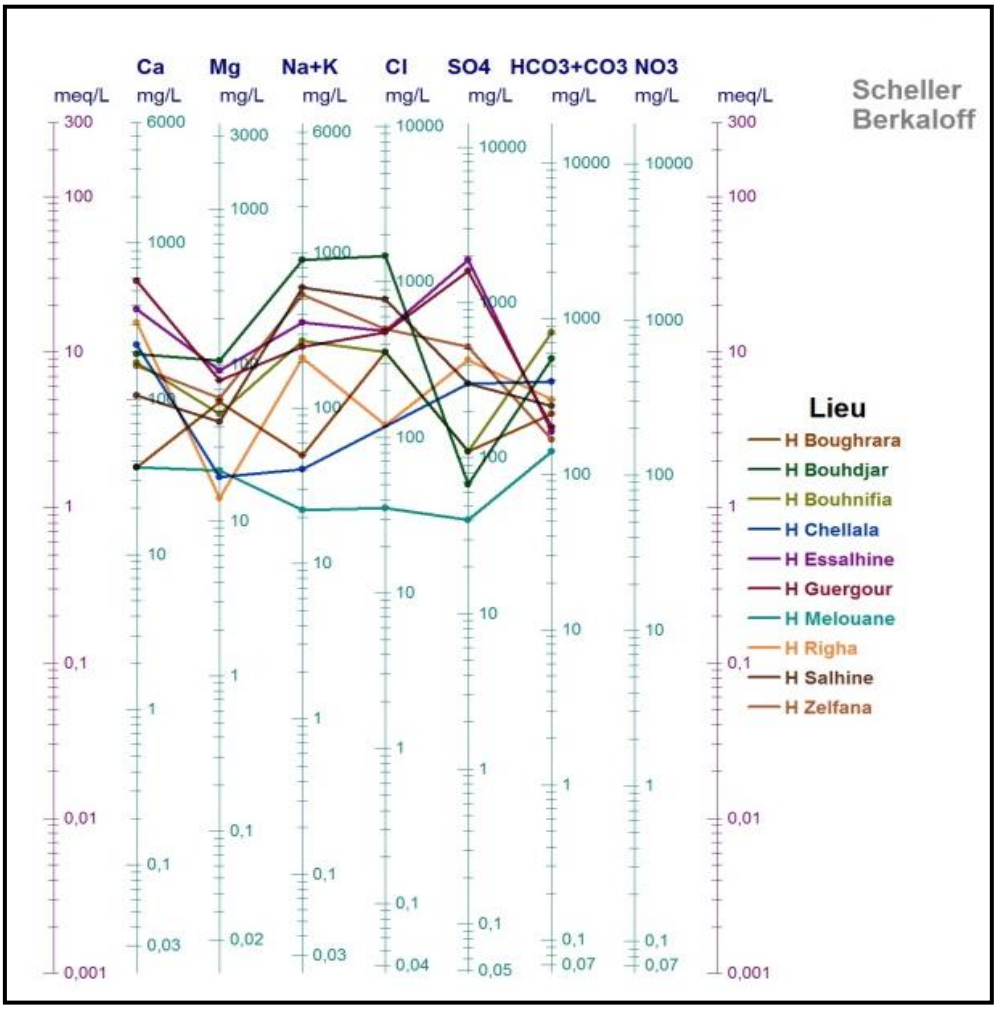

Fig. 4 Scholler Berkaloff diagram of thermal springs of northern Algeria.

(2) Hammam Khenchla, Hammam Chellala, Hammam Righa and Hammam Boughrara hot springs are part of the chlorinated and sulfated calcium family;

(3) Hammam Melouane and Hammam Bouhnifia hot springs are classified as calcium and magnesium bicarbonate waters;

(4) Hammam Sokhna, Hammam Bouhdjar and Hammam Zelfana hot springs are classified as sodium and potassium chloride waters.

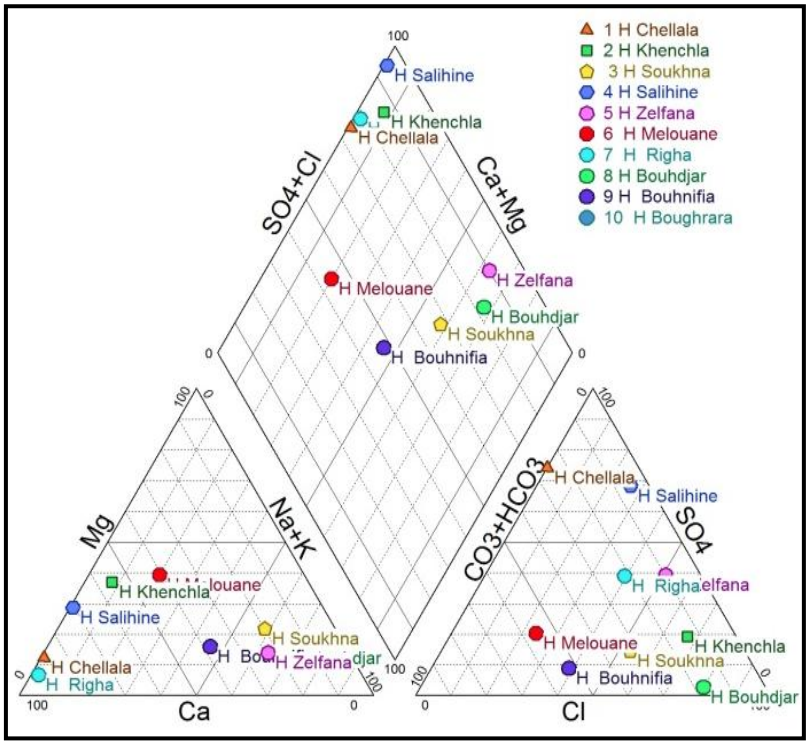

Fig. 5 Piper diagram of thermal springs of northern Algeria.

4. The Northern Algeria Spa and Their Heating Powers

More than 240 thermal springs have been inventoried across the country. Each source includes therapeutic advantages. In order to benefit from the thermal waters of the northern Algeria, thermal establishment have been built in many thermal areas. Over 80 spas are operated across the country, including 10 major national: Hammam Bouhanifia (Mascara), Hammam Bou Hadjar (Ain Temouchent), Hammam Boughrara (Tlemcen), Hammam Rabbi (Saida), Hammam Righa (Ain Defla), Hammam Guergour (Setif), Hammam Salhine (Biskra), Hammam Meskoutine (Guelma), Hammam Salhine (Khenchla), Hammam Zelfana (Ghardaia). These spas are managed by the Algerian Society of Spa and are under agreement with the various social security funds (CNAS, CASNOS, military chest) [5]. The thermal establishments have modern facilities with highly qualified medical and paramedical staff trained to provide care based on scientific methods for spa therapy. Other spas are especially sought by spa guests for traditional thermal baths. The spas are mostly requested by the Algerian population for various therapeutic treatments (rheumatism, dermatology, gynecology etc.). Indeed, thermal medicine offers an original health approach which is not based only on the treatment of symptoms. The major advantage of the spa medicine is based on the overall pathology support. Some treatments, such as jetted tubs will act as a leg massage to stimulate blood circulation, add more oxygen to the muscles and reduce pain experienced. Due to the quality of its waters, for several decades there has been a craze for spa tourism in Algeria. Depending on the conditions being treated, customers opt for a stay in spas waters renowned for their healing qualities.

5. Discussions

The classification of these useful mineral water hydrotherapy is therefore based on the predominant anion: bicarbonate, sulfate, chloride. Calcium bicarbonate waters may be used in gastrointestinal disorders. As sulfated waters containing calcium and

magnesium sulphates are useful in the disorders of kidney, liver and biliary tract. As for sodium chloride-rich waters sodium chloride that can reach neighboring considerable levels of solubility limit their therapeutic indications of interest to children's diseases (hypotrophy, respiratory diseases), diseases of the central and peripheral nervous system and the gynecology. They are also used for physical rehabilitation. Based on the results obtained and the therapeutic indications for the ten selected spas are as follow:

(1) Hammam Boughrara (Tlemcen)

It is located at 282 m above sea level in the extreme western Algeria; on the banks of the river near the town of Tafna in Maghnia. The thermal water is chlorinated magnesium with a temperature of 45 ℃. Therapeutic indications: rheumatology, dermatology, gynecology and respiratory problems.

Thermal techniques: simple bathroom, carbon dioxide baths, local baths, jet showers.

Additional care: thermotherapy (infrared applications and paraffin), electrotherapy, dry massages.

(2) Hammam Bou Hadjar (Ain Temouchent)

It lies 65 km to 21 km from Oran and Ain-Témouchent, at 153 m of altitude. It counts forty sources, hot in majority. Water is rich in sulfur, particularly alkaline bicarbonate sources, sodium, iron-rich, low-level radioactive. The temperature is of about 72 ℃.

The main indications: steam baths, rheumatology, dermatology, gynecology and treatment of respiratory tract.

The thermal treatments: simple and local baths, general and local showers, underwater massage and kinebalneotherapy pool. They are additional care such as massages dry thermotherapy (infrared applications and paraffin), electrotherapy.

(3) Hammam Bou-Hanifia (Mascara)

It is located at 100 km south of Oran and Mascara 25 km, at 600 m altitude. Alongside a group of hot springs, sodium bicarbonate, calcium chloride, carbo-gaseous highly radioactive (40 ℃ to 70 ℃).

Indications: rheumatology, neurology, digestive and metabolic disorders.

Thermal practices: drinking cure to general and local bathing, the steam baths, the general and local showers, underwater massages. They are thermotherapy (infrared applications and paraffin), electrotherapy, and functional rehabilitation.

(4) Hammam-Melouane (Blida)

Located at 37 km south of Algiers at an altitude of 105 m—The nature of water is ferrugineous and chloride, with sodium, very little limestone. The temperature is about 29 ℃ to 41 ℃. Indications: Rheumatology, Dermatology.

(5) Hammam Righa (Ain Defla)

Located 100 km south-west of Algiers, at 520 m altitude. It is located in a green and forested region appreciated for its unpredictable weather. Thermal water is rich in minerals, salinas, sulfated, calcium 39 ℃ to 67 ℃. Hammam Righa spa is very popular and very solicited by patients and visitors for full health, adapted to different therapeutic orientations. However, some sources have disappeared during the earthquake of 1980.

Therapeutic indications: arthritis, rheumatic diseases, nervous disorders, injuries and trauma, anemia, hepato-renal insufficiency, chlorosis, embarrassment digestive functions, in general all diseases know because the loss of blood.

The curing techniques: general and local bathing, jet showers and ablutions, underwater massages. Dry massage, electrotherapy, rehabilitation and paraffin wraps.

(6) Hammam Guergour (Setif)

It is located at 60 km northwest of Setif and at 115 km from Bedjaia, at 650 m altitude. Characterized by sulphated waters very radioactive with average temperature of 43 ℃, it is considered as one of the most radioactive sources placed third in the world.

Therapeutic indications: rheumatism, dermatology and blood circulation disease.

Thermal practices: bathroom tub, pool or walking corridor, local baths, underwater massage and complementary treatments (electrotherapy, ultrasound, infrared).

(7) Hammam Chellala (Guelma)

It is located at 110 km from Constantine and at 20 km from Guelma, at 546 m altitude. There are new sources of hyperthermal water, the temperature ranges from 74 ℃ to 96 ℃, calcium bicarbonate, chloride sodium, ferruginous, arsenic, radioactive in with evolution of hydrogen sulfide.

Therapeutic indications: these waters have valuable properties, especially effective in the treatment of rheumatic and arthritis.

Thermal practices: bathroom tub, pool or walking corridor, local baths, underwater massage and complementary treatments (electrotherapy, ultrasound, infrared and poultices paraffin). Bathing and showers to ORL techniques (inhalations, aerosols, sprays ...).

Additional care is using physiotherapy techniques and protocols for functional rehabilitation.

(8) Hammam Salhine (Khenchla)

Ex-Hot-Fontaine is a Roman bath that has existed for 2,000 years. It is located in the town of El Hamma, tourism and therapeutic site is about 7 km from the capital of the province of Khenchela. The temperature of its waters is around 70 ℃, its chemical composition gives it the therapeutic properties indicated for rheumatic diseases, neurological; respiratory and skin.

(9) Hammam Essalihine (Biskra)

Located just outside Biskra, at 400 km south-eastern of Algiers and 115 km from Batna, at 519 m altitude. The water is chlorinated and sulfated sodium, mesothermal (46 ℃), highly mineralized.

Therapeutic indications: rheumatism, respiratory disorders, ENT, dermatology, gynecology.

Thermal practices: bathing, showers, humages and inhalations. There adjoin physiotherapy techniques and masso physiotherapy.

(10) Hammam Zelfana (Ghardaia)

It is in the center of the touristic city of Zelfana, the remote agglomeration is at 65 km east of the capital of the province of Ghardaia. The Zelfana spa is exploited for hydrotherapy. Indeed, Zelfana waters occur many health benefits.

Essential conditions: Neuro-Respiratory.

Secondary conditions: Rheumatic, gynecological, dermatological.

Main mineralization: Sodium Chloride.

6. Conclusions

Spas in Algeria can be exploited for touristic purposes and present a great therapeutic solutions. The therapeutic thermal waters are strongly recommended for the treatment of multiple diseases.

The numerous hot springs of Algeria, could have a better exploitation if the conditions are assured.

The existing geothermal potential in Algeria is mainly used for Balneology, thermal applications are very limited. Geochemistry helps to know the possibilities of using this resources in many and varied applications. They will direct applications (fish, space heating and agricultural greenhouses, cooling and power generation).

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