Chapter

The Hot Springs of Central Northern Algeria Hydro Geochemical and Therapeutic Aspects: Direct Applications and Therapeutic Value

Mébrouk Benziada

Abstract

This Science article summarizes the preliminary work carried out by the Renewable Energy Development Centre under the National Research Project in the Central North of Algeria from 2013 to 2016 to explore for geothermal resources and hydrogeology and hydrogeochemical and therapeutic aspects. The geology is very complex in this region and it determines the thermal water reservoirs. The value and importance of the thermal springs in Algeria is very significant. This study will be addressed by means of conventional chemical analyzes of the main hot springs major elements in the north central region of Algeria. Hydrogeochemical prospecting was carried out in detail is briefly exposed and the main results are described in particular regarding the hot springs of the Centre North of Algeria. The existing geothermal potential in Algeria is operated primarily for the balneotherapy and some applications for aquaculture. In this study, we will apply the hydrogeochemical techniques to the hot springs of the Centre North of Algeria. To promote this energy source which will certainly have a socio-economic interest, it is important to know the geothermal gradient in this region and the hydrogeological and physico - chemical characteristics of the main hot springs particularly temperature, flow rate and the elements major chemical. The thermal springs of north central Algeria belong to the Tellian domain, characterized by a complex geological structure and active tectonics. The thermal spring of Hammam Bouira is strongly mineralized, it presents a sodium chloride chemical facies. These facies are generally linked to Triassic evaporites. The thermal waters of the study area are characterized by a hyper mineralized facies (4 to 20 mS/cm at 25° C), sodium chloride type source Hammam Melouane and source Hammam Bouira. The mineralization of these thermal springs is acquired from contact with the evaporite formations of the Triassic, mainly by the dissolution of halite and gypsum. Known for its geological, structural and tectonic complexity, the northwestern region of Algeria has very important thermal manifestations. The presence of thermal springs in this region are linked to the existence of faults. Ten sources of spas were analyzed in the laboratory of the National Tourist Company in 1984. The chemical analysis of the major element concentrations (Ca2 +, Mg2 +, Na +, K +, Cl-, SO4 2-, HCO3 - and NO3 -) and the physico-chemical variables (temperature, electrical conductivity, dry residue and pH). The physico-chemical composition of warm waters in this region shows a very

varied chemical facies due to the complexity of geology. The geothermal applications are very diverse: - The balneology, aquaculture, heating greenhouses, air conditioning habitat and production of electricity. The use of geothermal energy helps to preserve natural resources while reducing CO2 emissions related to energy production and to cure certain diseases. Direct use of geothermal energy in agriculture, spas and domestic heating is possible.

Keywords: Hydrogeology, Hydrogeochemistry, Geothermal gradient, Therapeutic aspects, geothermal potential, low-energy, direct applications, health

1. Introduction

Algeria belongs to the Mediterranean basin; the Sahara occupies the major part of the country.

Algeria is located between Morocco and Tunisia forming the Maghreb (**Figure 1**).

This scientific article shows an overview of the geology, geothermal resources; chemical analyzes of water thermals therapeutic applications in Algeria.

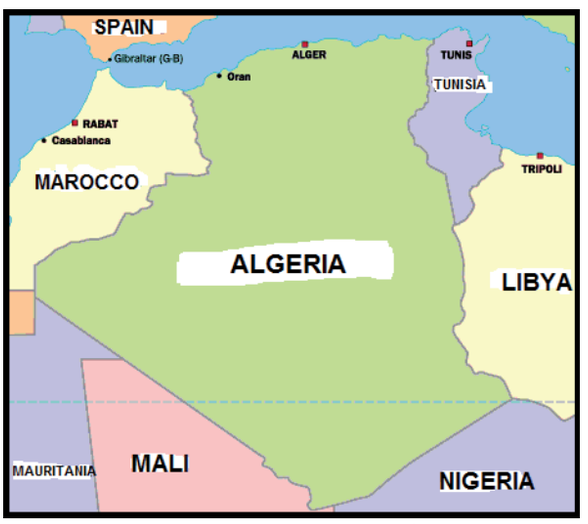

Figure 1.
Location map of Algeria in the world.

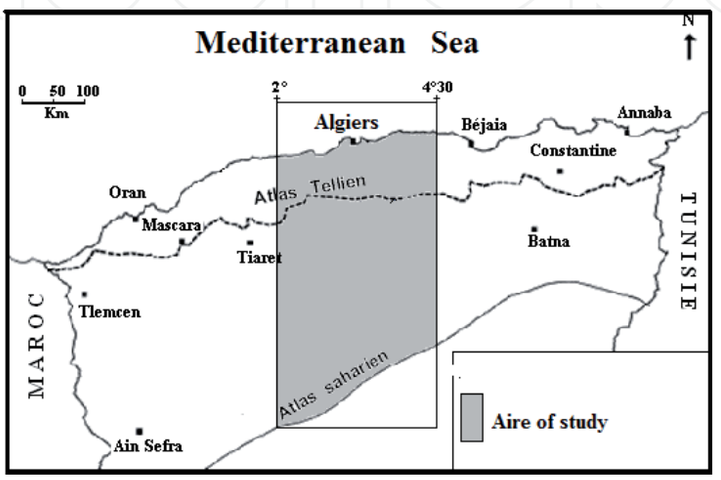

Figure 2.
Geographical location of the study area.

In Algeria, balneotherapy is practically the only direct use of geothermal energy. Yet the country has more than two hundred hot springs distributed throughout the northern region of Algeria. About one-third (33%) have temperatures above 45° C. There are even sources at high temperatures of the order of 98° C in Guelma. Algeria is determined to diversify its economy, to free itself from its heavy dependence on oil revenues, by turning to the development of renewable energies. The study area is located north central Algeria between longitudes 2° and 5°. It is limited to the north by the Mediterranean Sea, the South by flexure south Atlas The geology of hydro-thermal sites Hammam Melouane, Hammam Righa, Hammam Médéa and Hammam Bouira (a) (b) and is described in our field trips to determine the hydrogeological and hydrogeochemical characteristics of the underground environment (**Figure 2**).

2. Geology of the north of Algeria centre

Region consists of structural and sedimentary units showing an imprint of the Alpine tectonics. From north to south there are: the Tell Atlas, varied and complex area. It includes an internal zone and an outer zone formed of non-native land (thrust sheets). Between the two Atlas (Tellian and Sahara) are flush with the High Plains ending to the east by the chain of Hodna and continue to the west by the Oran Meseta (**Figure 3**). The sedimentary formations covers are of Mesozoic and Cenozoic age and based on a diverse base involved in the fold [1].

The warm and sulfurous waters of Hammam Ksana emerge from the bowels of the geological layers of the Triassic and Jurassic of the rocky peaks of the Bibans. The source it self is located at 500 m altitude on a slope of Wadi Tazdart, douar of El Mehir.

Tellian area:
Characterized by a stack of thrust sheets with associated intra-mountain basins Sedimentary formations blankets are Mesozoic and Cenozoic age and based on a diverse base involved in the folding.
Saharan area:
Relatively stable or tectonics is less pronounced (**Figure 4**).

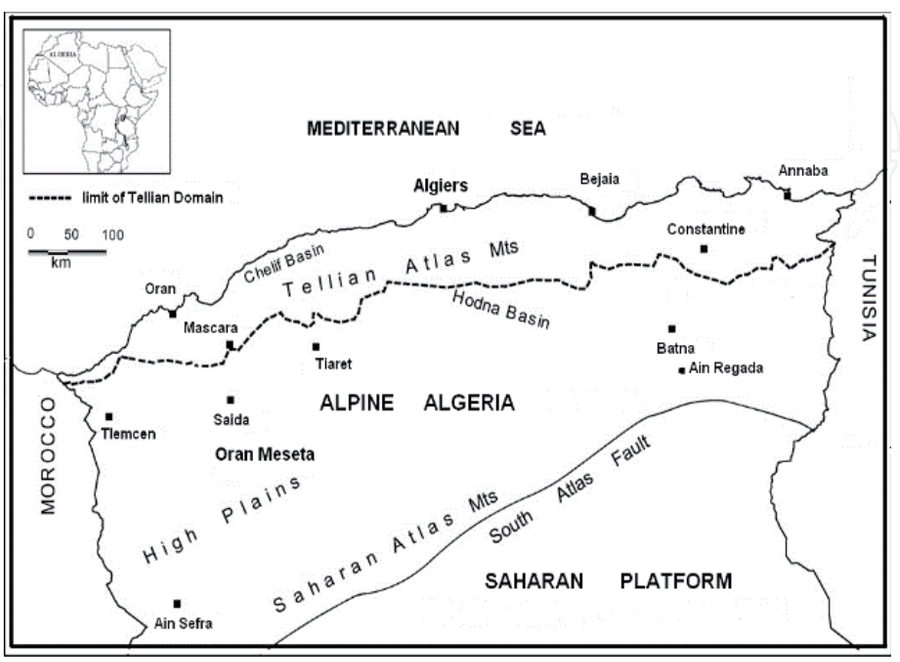

Figure 3.
Geological units of the northern Algeria.

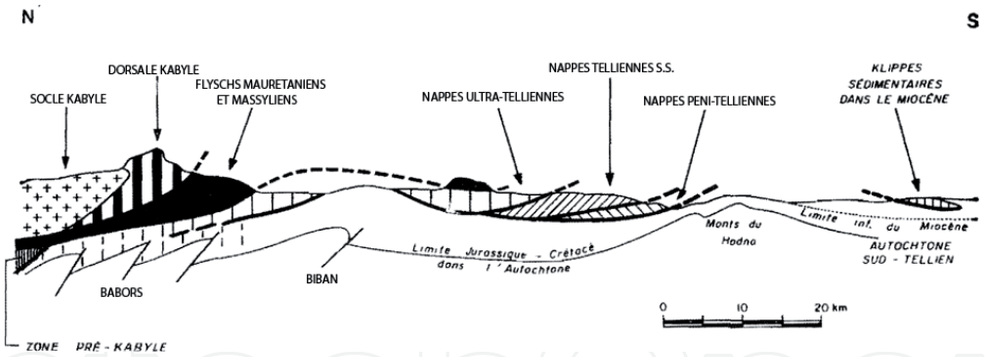

Figure 4.
Relationship between the different structural units of the chain of Maghrebides (modified from Durand-Delga, 1969 Bibans and Babors who were considered the aboriginal also include tablecloths Tellian).

2.1 Internal domain

Kabyle massive base cristallophylliens metamorphic (gneiss, marble, amphibolite schists and mécaschistes) [2]. This stand exposed in the massive Chenoua (Tipaza) and Great Kabylia (**Figure 3**).

2.2 Domain flyshs

Consisting of layers of Cretaceous-Paleogene flyshs.

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. Methodology and materials

3.1 Work in the office

Make an inventory of oil drilling reconnaissance work. The counting of polls reporting was used to select thirty boreholes with their BHT (Bottom Hole Temperature) measured at different depth logging operations to establish a geothermal gradient map. A geological and hydrogeological survey of the thermal springs of writing is based on previous geological research studies.

3.2 Fieldwork

In our scientific research work in the field, we made direct measurements of the Ph, conductivity and temperature of the thermal water and take samples of the water samples of the hot springs of four sites (H. Melouane, H. Righa, H.Médéa and H.Ksénna) to analyze in the laboratory of the National Agency of Water Resources in Algiers to determine their physicochemical characteristics. The results are shown in **Table 1**. We selected four most important thermal springs which were the subject of several measurement campaigns (2014–2015). Work performed and results obtained.

	pH	Cond μmho/cm	Rs g/l	T°C	Flow l/s	Facies Chemical
H. Melouan	6.4	20000		40	—	Chloride- sodium
H.Righa	7.53	4000	3.4	64	20	Sulfate- calcium
H.Médéa	7	2800	1.4	38	—	Bicarbonat-sodium
H.Bouira (a)	6.5	17200	5.9	63	20	Chloride- sodium
H.Bouira (b)	—	—	—	80	1.2	Chloride- sodium

Table 1.
Physical and chemical characteristics of the thermal source in the study region (2014–2015).

4. Results and discussions

4.1 Map preliminary geothermal gradient Northern Algeria centre

The geothermal gradient map sets from the temperature data stored in oil drilling during logging operations. It shows a geothermal anomaly of about 4° C/100 m in the Djelfa region (**Figure 5**). It serves as a support base for future projects in the applications of geothermal energy [3].

4.2 Hydrogeochemistry of hot springs

The study area is characterized by the emergence of numerous hot springs area linked to major geological accident (faults) [4–6]. The temperature of these sources usually varies from 20 to 64° C. The chemical composition dominant is sodium chloride-sulfated.

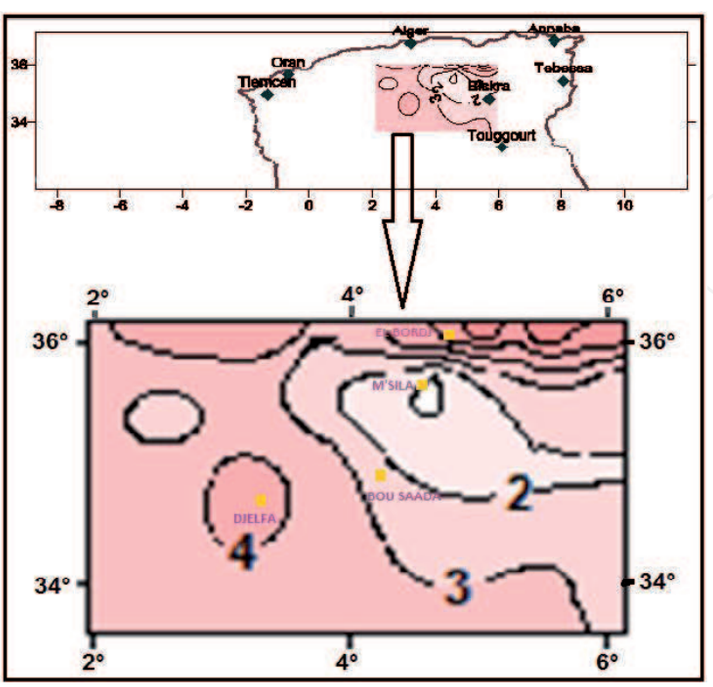

Figure 5.
Map preliminary geothermal gradient northern Algeria Centre.

4.3 Results hydrogeochemical hot springs centre Northen of Algeria (2013–2015)

The Jurassic limestones of the Algerian North, which constitute important geothermal.

reservoirs, give rise to more than five hot springs located mostly in the north-east and northwest regions of the country [7]. These sources have temperatures above 40° C. That of Hammam Bouira (b) (80° C) is the most important. These natural emergences are generally the losses of existing reservoirs, with a flow rate of the order of 2 m^3/s. The temperature of the hot springs in the study area varies from 38° C to 80° C which corresponds to a low energy enthalpy. The pH of the thermal waters ranges from 6.4 to 7.53 and generally neutral rate is between 3 and 20 l/s (**Table 1**). The conductivity of the largest thermal water is the source of Hammam-Melouane with a value of 20000 μmhoS/cm and the lowest is that of Hammam-Righa with 4000 μmhoS/cm. The highest-dry residue is that of Hammam-Bouira-b source with 5.8 g/l.Sources H.Melouane and H; Bouira-b have the same chemical profile of a chloride-sodium kind while that the source of H.Righa has a sulfated lime facies and source H.Médéa a sodium bicarbonate-facies (**Figures 6** and 7).

4.4 Hydrogeological hot springs central northern of Algeria

4.4.1 Hammam-Melouane

Griffins are aligned along a major geological accident oriented E-W, by contacting the Cretaceous and Lower.

4.4.2 Hammam-Righa

The hydrogeological study reveals the existence of two aquifers, the most important is represented in Zaccar Chergui by cracked limestone of the Upper Jurassic, strongly mineralized and intensely karstified. These limestones are based on the schist-quartzite waterproof primary series and are an important reservoir whose static level is close to the coast 700 m.

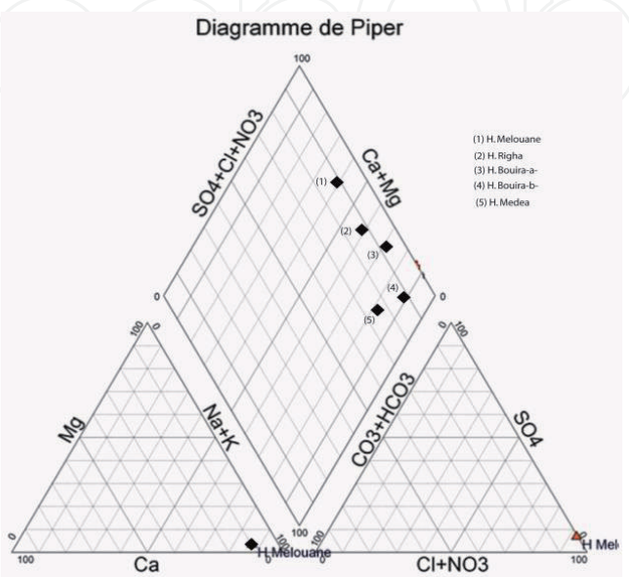

Figure 6.
Classification of the thermal springs (piper diagram).

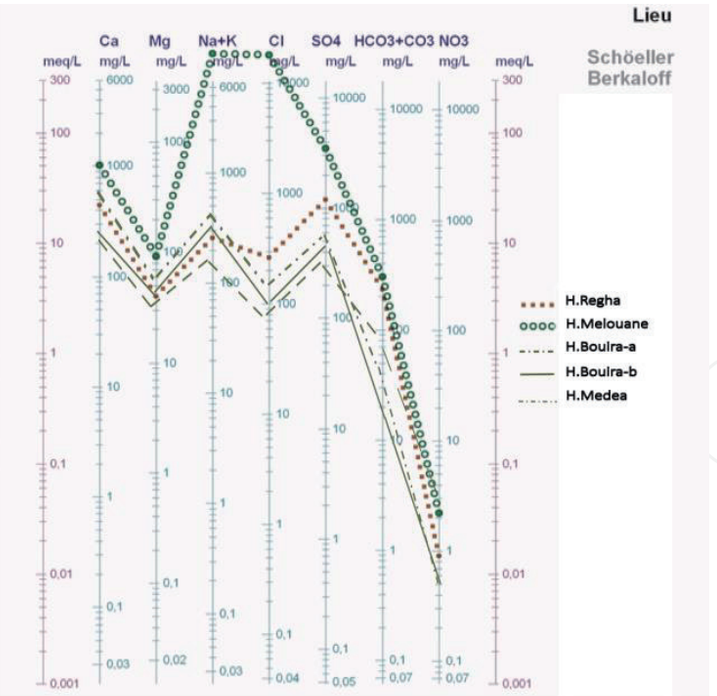

Figure 7.
Classification of the thermal springs (diagram Schoeller-Berkaloff).

4.4.3 Hammam-Medea

A thermal spring with a flow rate of 3 liters/second. The waters of Hammam Medea emerge the feet of the northern flank of Jebel El Gharbi Souebah. They are very rich in mineral and weakly conductive. The most dominant ion correspond bicarbonate and sodium. The mineralization of these waters is acquired by the leaching of geological formations during their ascent. The Cretaceous formations, limestone of the Turonian and Vraconian are the only aquifer can supply the hot spring.

4.4.4 Hammam-Bouira (a) (b)

The waters of Hammam Ksana (Bouira) emerging south of the plain of El-Asnam. They are loaded with minerals and highly conductive. The most dominant ions are chloride and sodium. The mineralization of these waters is acquired by alteration lithologies traversed during circulations of underground fluids. The aquifer can match the Cenomanian limestone.

5. Geothermal resource in Algeria

Geothermal resources are various low temperatures. They are located in northern Algeria and northern Sahara [8].

In the north, the reservoirs are complex and discontinuous. They consist of facies (limestone, sandy limestone and sandstone) of the Mesozoic and south, a continuous tank is composed mainly of sandstone [9].

He was appointed tableclot Albian [10].

The distribution of thermo-mineral waters, in Algeria, is very irregular. These sources are increasing in number gradually as one approaches from the east. This distribution seems to follow that of the ore deposits. Thus it has about twenty mineral springs in the region of Oran, about 40 in the Algiers and 150 in the region of Constantine.

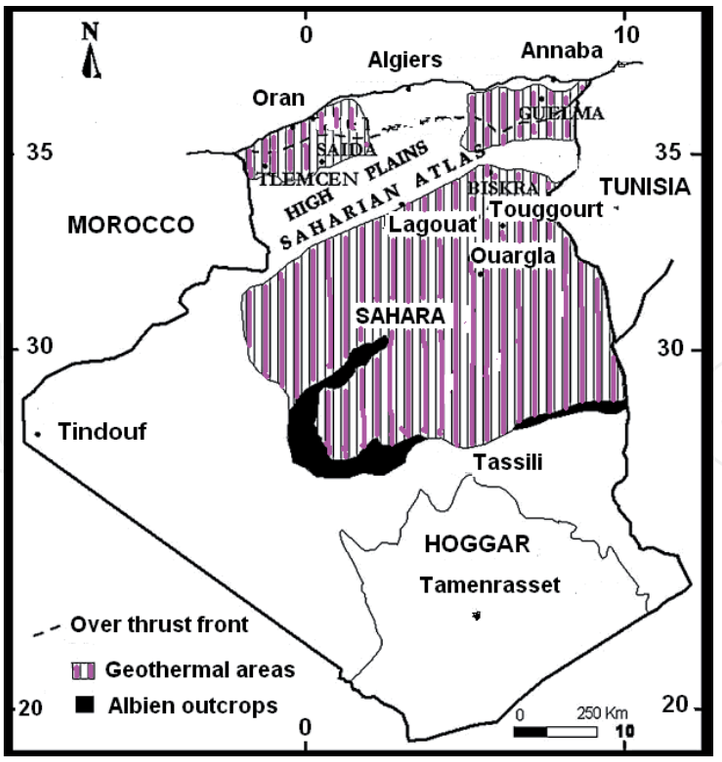

Figure 8.
Main geothermal area [11].

In the North, in part including the Saharan Atlas to the sea, emerging more than 200 hot springs. The water temperature varies between 22 and 98° C and mineralization total dissolved salt varies between 4 and 10 g/l. The reservoirs are typically at depths between 1500 and 2500 m.

South, the water Albian covers an area of 600,000 km^2. It is semi-free in the western and captive and warm only in the eastern part (**Figure 5**) [11]. The roof of the aquifer to the east is located between 1000 m and 2600 m, the average temperature of water is 60° C and an operating rate of 4 m^3/s, the water Salinity is 3 g/approx.

The geothermal potential to dewatering, by summing the total flow of the hot springs flow from operating Albian aquifer is over 700 MW (**Figure 8**).

6. Use of geothermal energy

6.1 Agriculture and geothermal energy

The agricultural field is compatible with the use of geothermal energy [12]. The heating of greenhouses, for example vegetable farms, can be carried out by heat from the ground and deep boreholes to collect geothermal hot water. The two main applications of geothermal energy in agriculture are fish farming and agricultural greenhouses. For fish farming, an increase in temperature by a few degrees and above all its maintenance at a constant level produces an increase in metabolism in fish and crustaceans.

6.2 Geothermal energy for health

Geothermal energy is good for health! As a natural energy source, geothermal energy is not harmful to humans and their environment, unlike some fossil fuels [13]. Geothermal water is also known for its benefits and is particularly used in spas

to treat rheumatism. Hydrotherapy was one of the first applications of geothermal energy during antiquity, recognized for its health qualities. Today, it remains an excellent natural remedy for thermal cures.

7. Spas in Algeria and their healing powers

Over 80 spas are operated across the country, including five major national. 200 thermal springs inventoried across the country. Each source including therapeutic advantages. Spas most requested by the Algerian population for various therapeutic treatments (rheumatism, dermatology, gynecology etc. ...). Thermal establishments in Algeria have SPE and modern facilities with highly qualified medical and para-medical to the contribution of patient care and hydrotherapy. Thermal medicine offers an original approach health is not based only on the treatment of symptoms. The major advantage of the spa medicine is based on the overall pathology support, providing prevention as an important place that relief. Some treatments, such as jetted tubs will act as a leg massage to stimulate blood circulation, 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.

7.1 Therapeutic hot springs North Centre of Algeria

7.1.1 Hammam-Melouane (Blida)

Located 37 km south of Algiers at an altitude of 105 m - Nature and Thermality water: ferrugineous and chloride, with sodium, very little limestone, 29° to 41°C. Indications: Rheumatology, Dermatology.

7.1.2 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 [14, 15]. Thermal water rich in minerals, Salinas, sulfated, calcium 39° to 67°C. Spa hammam Righa is a mecca for full health, adapted to different therapeutic orientations. 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.

7.1.3 Hammam-Médéa

He warm and therapeutic waters are excellent and strongly recommended for the treatment of gynecological, epidermal, neurological diseases as well as rheumatism.

7.1.4 Hammam Bouira (a) (b)

A thermal water with its important hydrothermal emergence with proven therapeutic virtues.

Rheumatism, neuropathy, myopathy, and certain affections ENT, intestinal, dermatosis, sequel of burns, arteriopathy, varicose veins, asthma, paralysis, chronic bronchitis. Certains pathologies are treated by the thermal water of Hammam Bouira (a): herpes, mycoses, rheumatism, low back pain, certain arthroses, affections uro-genitales etc. ...

7.2 Habitat heating

In the case of a district heating network of large, deep aquifer Albian can be exploited by a geothermal doublet. Depending on the type of installation, geothermal covers 50–100% of the heat demand. After using the hot springs for heating, reclaimed water can ensure the supply of thermal pools complex Zelfana which falls within the field of health and recreation.

7.3 Agriculture

7.3.1 Aquaculture is a growth area in Algeria

The two main applications of geothermal energy in agriculture are the fish and greenhouses [16]. Greenhouse crops are an attractive option because the energy requirements are high.

As regards fish farming, an increase in temperature of a few degrees above and keeping it at a constant level produces an increased metabolism of fish and crustaceans. In the field of food manufacturing, temperatures between 40° C and 100°C is used for dehydrating fruits and vegetables. From 60° C, the heated air can be used for drying agricultural products, fish and timber.

7.4 Industry

The frost of large industrial buildings can be achieved by a moderate temperature geothermal resource, but most hot water needs or steam industry is between 100° C and 200° C. If the geothermal resource is less than 100° C, it will be used to preheat iron water, whose temperature will be increased by means of a heat pump. Many processes require large amounts of hot water, such as pulp and paper, textile washing, extraction of chemicals or evaporation of concentrated solutions [17].

Thus it is easy to see, Algeria contains an abundance of thermo-mineral sources of various compositions and meet all the needs of modern therapeutics. It is highly probable that most of these radioactive sources are: education, barely sketched, can believe it. It is therefore obvious that most inhabitants of Algeria could find, there, in the colony, mineral waters they need [18].

8. Conclusions

The center-north of Algeria is characterized by an abundance of springs and by high heat flow values [19]. Hot waters, seem essentially controlled by tectonics, because most thermals springs are located on faults or abnormal contacts. The heat flow study shows one important anomaly:

An anomaly situated in the region of Djelfa. The geophysical study highlights the Djelfa region is most favorable to the future exploitation of geothermal energy with a gradient of 4° C/100 m. The numerous thermal springs northern central Algeria, where better exploitation of these natural resources is an opportunity for a good investment in the housing niche, agriculture (greenhouses), aquaculture and

tourism health. Hot springs and hammam righa Hammam Bouira (a) (b) Ksénna have a significant amount of geothermal energy with temperatures respectively of 64° C and 63° C and a flow rate of 20 l/s each. The use of this renewable energy would achieve energy savings of sizes in addition to contributing to the reduction of greenhouse gases.

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Author details

Mébrouk Benziada
CDER Centre de Développement des Energies Renouvelables, Algiers, Algeria

*Address all correspondence to: mbenziada2011@gmail.com

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