Multiple integrated use of geothermal resources in the Kebili region, southern Tunisia

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Abstract

In Tunisia, the use of geothermal energy is limited to direct utilization. Only low enthalpy resources, which are localized mainly in the southern part of the country, are available. For thousands of years, geothermal water has been used for bathing, and many of geothermal manifestations in the country have the name of ‘‘*Hammam*’’ or bath, which reflects the main use of geothermal water over the centuries. Now, the resources are utilized mostly for agricultural purposes (irrigation of oases, greenhouses). The government’s policy in the beginning of 1980’s was oriented towards the development of the oasis sector and the main aim was to supply oases with geothermal water for irrigation. Therefore, in the Kebili area, over 35 boreholes are operating mostly for the irrigation of 16,000 ha of oases after cooling the water in atmospheric cooling towers. Sixteen years ago, the State started using geothermal energy for greenhouse farming, by planting an area of one ha in the region. The results of this experiment were very encouraging, and thus the cultivated areas have today increased to 45 ha (43% of the total cultivated areas in the country).

Keywords: *geothermal resources, direct utilization, oases, greenhouses, hammams.*

1 Introduction

Commonly, geothermal utilization is divided into two categories, i.e. electricity production and direct application. Conventional electric power production is limited to fluid temperatures above 150°C, but considerably lower temperatures can be used with the application of binary fluid technology (Fridleifsson, 1996). The primary forms of direct use include swimming, bathing, space heating, agriculture, fish farming and industrial processes. In Tunisia, the low enthalpy resources limit its use of geothermal energy to direct utilization, in particular for agriculture. The resources are located mainly in the southern part of the country in the regions of Kebili, Gabes and Tozeur and utilized mostly for agricultural purposes. The government’s policy in the beginning of the 1980’s was focused on the development of the oasis’ sector and the main aim was to supply the oases with geothermal water for irrigation. Therefore, in the Kebili area, about 35 boreholes are operating mostly for irrigation of 16,000 ha of oases upon having cooled the water using atmospheric cooling towers. In 1986 the State started using geothermal energy for greenhouse farming, by planting an area of 1 ha. The results of this experiment were very encouraging, and thus the cultivated areas have today increased to 45 ha.

This report presents the main direct uses of geothermal energy in the Kebili region. The purpose is to describe this different utilization and to analyze impediments to agricultural operations. The study starts with an outline description of the geothermal resources in the region concerned. Following this, the utilization of groundwater in agriculture, bathing, washing and swimming is discussed.

2 Geothermal resources in Kebili region

The region of Kebili, having a total area of 2.2 million hectares, is located in the southwestern part of the country. Geothermal resources are present in the CI aquifer, the largest in Tunisia (the deep aquifer or CI: Continental Intercalaire). This aquifer is characterized by relatively hot water (30-75°C) at depths reaching down to 2,800 m. The resources are located in a reservoir of 600,000 km², which covers the regions of Kebili, Tozeur, Gabes and the extreme south, and extends into Algeria and Libya. The CI aquifer is one of the largest confined aquifers in the world, comparable in scale to the great artesian basin of Australia. The principal areas of recharge are in the South Atlas mountains of Algeria and Tunisia and the Dahar mountains of Tunisia. In the Kebili area, radiocarbon analysis has shown that the geothermal water is about 20-50 thousand years old and is of a sulfate-chloride type (Agoun, 2000). The salinity is some 4 g/l and the water is utilized mainly for agriculture purposes.

In the past there existed sufficient cold artesian water and the oases were limited in area, thus the geothermal resources were initially only exploited for bathing and washing. This was in the beginning of 1950 and 1960. After that, and because of the abundance of water in some of the oases and the large expansion of cultivated areas, these resources were utilized for irrigation of oases.

3 Geothermal utilization (results and discussion)

Major direct utilization projects exploiting geothermal energy exist in about 60 countries, and the estimated installed thermal power is 16,200 MWt. The majority of this energy use is for space heating (37%), and swimming and bathing (22%) (Lund, 2002). In the Kebili region about 1,500 l/s are exploited from geothermal resources; 96% for agricultural purposes: 77% for irrigation of oases and 19% for greenhouses. The remaider (4%) is used for bathing (hammams), tourism (hotels and pools), washing and animal husbandry. The use in greenhouses increases by about 2% compared to last year's 17% because of the increasing of cultivated areas. Figure 1 shows the different direct geothermal uses in the area.

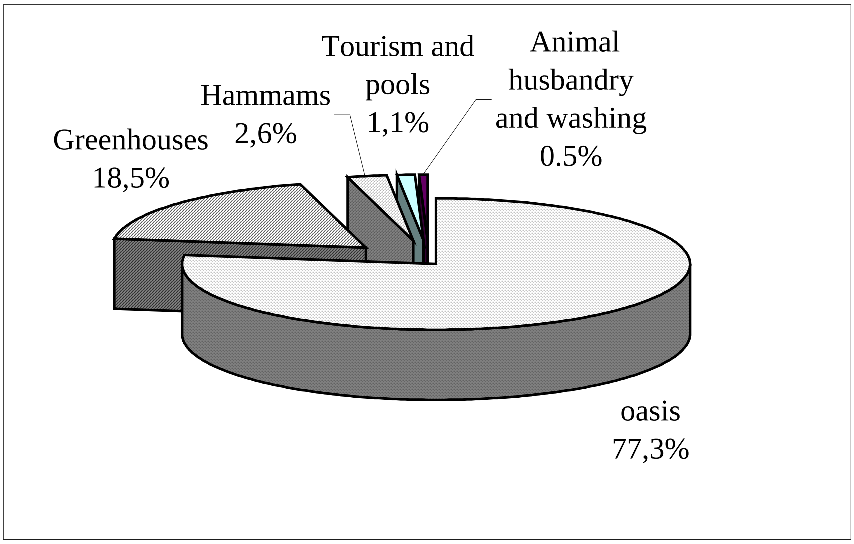

Figure 1: Geothermal direct uses in Kebili area.

3.1 Irrigation of oases

The region of Kebili, located in the southwest of the country, is characterized by desert climate (arid). The annual precipitation is irregular and generally less than 100 mm. The maximum temperature is about 55°C (July) and minimum temperature is about –7°C (December). The temperature range (the difference between maximum and minimum temperatures) is thus very high. These difficult conditions require a large quantity of water to maintain the humidity inside the oases system. The major part of the geothermal water is used for irrigating 16,000 ha of oases (77%) but all the resources taken from the Complexe Terminal aquifer (CT) are used for irrigation. The water temperatures varies from 27°C to 73°C. Generally, water less than 45°C is used directly for irrigation or cooled by means of multiple ponds or cascaded as shown in Figure 2. By this type of cooling system we can lower the temperature by 5-10°C.

Figure 2: The water-cooling system (Cascade of Oum Elfareth).

When the temperature exceeds 45°C, the water is cooled by means of atmospheric cooling towers before being used for irrigation. In normal conditions, we can in this way drop the temperature to 30-32°C.

3.2 Heating and irrigation of greenhouses

Greenhouses are one of the largest low enthalpy energy consumers in agriculture. Geothermal heating of greenhouses started in Iceland in 1924. Some glasshouses were heated by geothermal in Yugoslavia by the end of 1970. Other countries followed the experience and nowadays, around 940 ha worldwide are heated using geothermal energy, which represents 12% of the total energy use.

In Tunisia, in addition to irrigation of oasis, the geothermal water is used for heating plastic greenhouses. The utilization of geothermal energy recently started in the country as an experiment. The results were very encouraging and led to the idea of a Geothermal Utilization Project in Agriculture (PUGA-project, TUN/85/004) financed by the UNDP. In 1986 the government started to use geothermal energy in greenhouses in southern part of the country. After one year, many demonstration projects in several places had been established with the collaboration of the Energy Agency (AME) and the Rural Development Programme (PDRI). The exploitation of geothermal resources for heating greenhouses on the edge of the desert represents a promising development alternative.

3.2.1 Evolution of areas

Numerous commercially marketable crops have been raised in geothermally heated greenhouses in many countries. The use of geothermal energy for heating can reduce operating costs and allow operation in colder climates where greenhouses would not normally be commercial (Lienau, 1997). The leading countries using geothermal energy in greenhouse growing (Popovski, 1993) are USA (183 ha), Hungary (130 ha), China-Taiwan (60 ha), Macedonia (51 ha) and former USSR (25 ha). In 1993, Tunisia occupied the third position with 71 ha, after the USA and Hungary. But, based on papers for WGC2000 (Lund, 2002), Tunisia occupied the first place in the world with 102 ha. Starting with one ha as an experiment in 1986, the total area of geo-thermally heated greenhouses in Tunisia has increased considerably. Indeed, the greenhouse covered area reached 21 ha in 1988 of which 51% were in the region of Kebili. In 1998, the total area covered was 80 ha (40% in the region). Today, the total area is 102 ha, of which 43% are located in the Kebili area. Figure 3 shows the evolution of the greenhouse area in the country and in the region.

In the beginning plastic covered greenhouses were used by small farmers having typically two greenhouse units. The first experience was in the Limagues zone where 1 ha was planned in 1986 and subsequently expanded to 18 ha in 1989. Since 1990 this sector has stagnated at at a level of about 28 ha, but started increasing again in 2000 and has now reached about 45 ha. The development of the greenhouse sector was very fast, at least for some farmers starting with only two houses, having now 5-6 greenhouses and sometimes 10 greenhouses. The utilization of the geothermal resources will, without a doubt, increase in the near future by the application of the remaining part of the greenhouse strategy. Some 13 ha will have been added by the end of 2003, bringing the total in the region to 58 ha , which represents an increase of 29% relative to the total area and 58% of the regional geothermal goal (100 ha).

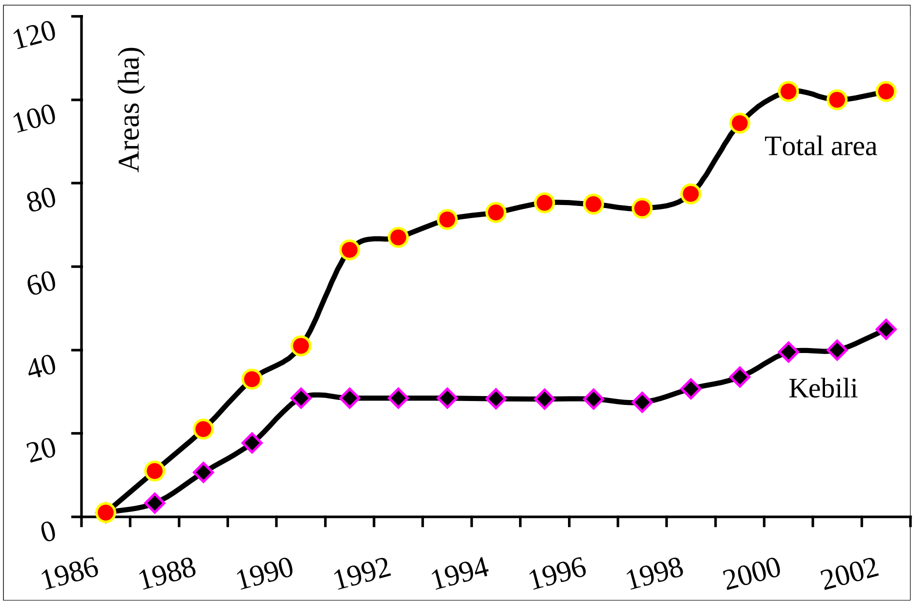

Figure 3: The evolution of the greenhouse area.

3.2.2 Heating of greenhouses

Continuous low temperatures at 10-12°C during two successive days disturb the physiological behavior of plants. Paradoxically, temperatures higher than 30-38°C can also cause irreversible damage to crops. Normally, temperature variation should not exceed 5-7°C. In the south this is difficult to ensure, as the risk of frequent temperature variation is high. The use of geothermal water is a good solution to this problem since it improves the climate inside greenhouses principally during the night.

The heating is effected via pipes lying on the ground between the plants (see Figure 4).

Figure 4: A typical greenhouse heating system.

Several types of pipes have been tried and polypropylene pipes were selected (Mougou et al., 1987). Generally, an average of 8-10 loops are used per house and they are connected with the system by an easily operated valve. For heating greenhouses in the Kebili region, 13 wells are operating and they supply 22 different sites. An area of 45 ha is heated using water at temperature varying from 45 to 73°C. The need for greenhouse heating is only six months, mostly during the night. Farmers start heating in November-December and stop it in April. The heating period is 14 hours per day. This means that they open the heating system in the afternoon when they cease working and close it the next morning when they reach the farm (Ben Mohamed, 1995).

3.2.3 Irrigation of greenhouses

After the thermal water has been used for heating it is collected in concrete ponds for subsequent use for irrigation. These ponds need to be large to store all the cooled water until it is used for irrigation. In some projects, farmers utilize very small and simple ponds with plastic linings, which are cheaper and very practical. Their capacities vary from 40 to 80 m^3. Generally, these ponds are used for the irrigation of an open field area close to the greenhouses. The need for water irrigation during the growing period is very low (0.6 l/s/ha or 5,500 m^3/ha) compared to heating. In that way, farmers utilize a local system. Water circulates inside a perforate pipeline lying on the ground. The chemical composition of the geothermal water used in irrigation must be monitored carefully to avoid adverse effects on plants because of the high salinity in the region (from 2 to 4 g/l).

3.3 Soil disinfections

Crops grown under greenhouses can become infected by nematodes such as *Meloidogyne*, which are parasites on the roots of vegetables. Several methods are used to resolve this problem and they are classified as agronomical, chemical, physical and biological treatments. Resolving this problem chemically has negative aspects:

- Environment (percolation of chemical products),
- Residues of chemical products in fruits.

Some farmers in the Kebili area utilize the physical method. The geothermal water is combined with solar radiation (solarisation) and used to disinfect the soil. The idea is to irrigate the total area of the greenhouse in summer time. The techniques consist of three different steps. The first is to divide the greenhouse area into several small basins to be submerged by hot water. The second is to cover the area irrigated by geothermal water by plastic films. The third is to add a solution of the chemical formol 1‰.

3.4 Bathing (hammams)

People have used geothermal and mineral waters for bathing and health enhancement for many thousands of years. Balneology, the practice of using natural mineral water for the treatment and cure disease, also has a long history (Lund, 2000). For thousands of years, geothermal water has been used for bathing in Tunisia and many of geothermal manifestations in the country have the name of ‘‘Hammam’’ or bath, which reflects the main use of geothermal resources in the centuries.

In the north, people go to hammams not only for bathing and having curative treatments, but also for fun, recreation, exercise, mud baths and other many reasons. These hammams have also the name of thermal stations (Spas in other countries). The hammam’s activity is very well known and hammams are spread over the country, especially in the south. In Arabic speaking, the world ‘‘*Hami*’’ means hot. In the south, two areas are called hamma (Gabes and Tozeur regions) because of the hot water in these areas. In Kebili area, there are 10 traditional baths using about 3% of the total volume of geothermal water. Generally, they are small baths with a similar design with two small covered pools. The Steftimi bath, for example, has a different design, with four covered pools 3 x 6 m and 5 x 6 m (two for ladies and two for gentlemen), two sitting rooms, two dressing rooms, and one prayer-room.

Thermal waters have a similar chemical composition from place to place. Table 1 shows some analyses of the major constituents of water from wells in several locations. There are high concentrations of chloride and sulphate. Sulphate could be used in treating diseases such as syphilis, scrofula and rheumatism. Whereas chloride could be used in the treatment of eczema, acne, stomach ailments and rheumatism (Lund, 1993).

Table 1: Composition of water (August 4, 1995) (mg/l) (Source: CRDA, 2001).

Wells	Ca	Mg	Na	K	SO_4	Cl	HCO_3	pH
Steftimi 2	336.6	107	558.6	31.2	**869.3**	**673.6**	122	8.1
Menchia	340	112	690	22	**1200**	**1242**	90	7.03
Menchia CI.6	232	164	310	36	**816**	**781**	102	8.1
Z.Chorfa CI.4	148	135	230	10	**672**	**497**	112	7.72
Bechri CI.2	220	112	265	24	**912**	**639**	115	7.74
Mansoura CI.3	384	82	519	35	**1143**	**886**	219	8
Kebili CI.10	328	26	358	23	**744**	**687**	158	8
Jemna CI.11	250	72	597	41	**792**	**875**	256	8.2
Douz CI.12	288	80	1064	60	**898**	**1524**	122	8.1
Faouar CI.19	180	77	413	37	**730**	**602**	134	8.1

A survey carried out shows that visitors have mainly six reasons for going to the hammam:

1. To cure diseases,
2. To prevent diseases,
3. To relax,
4. To reduce stress,
5. To clean,
6. To spend time (mostly in Ramadan).

But, never:

1. To be in solitude,
2. To reduce weight,
3. To quit smoking,
4. To meet people.

3.5 Swimming pools and tourism

Three pools in three different hotels located in Kebili and Douz are supplied by hot water for tourist purposes. There is another pool at Kebili-Ras-Elaïn (see Figure 5), the water that flows through it is later used to supply the surrounding oasis. It is a small public pool with a temperature of 42°C and is located inside the oasis 200 m from the water cascade. It was renovated by the municipality in 1998 and needs now more maintenance and a special protection. People visit the pool every season of the year in early morning and late afternoon. The main purpose is curative. A questionnaire presented to visitors shows that one visit lasts from thirty minutes to two hours but most of the visitors stay for an average of one hour. More than 40,000 citizens visit the pool per year. Four other hotels and a cafeteria at the edge of the Sahara in the Ksar Ghilane area are also supplied with geothermal water. About 1% of the total amount of water is used for hotels and swimming pools.

Figure 5: The swimming pool at Ras-Elaîn locality.

3.6 Washing

The geothermal resources were initially exploited for bathing and washing. This was in the beginning of 1950 and 1960 in the Menchia and Steftimi areas. Generally, ladies wash the clothes, wool and heavy things such as winter covers. It is estimated that more than 1% of the total amount of water is used directly for washing but it is difficult to estimate. Thermal water is transported via furrow to parcels of land for irrigation and an amount of the water is taken off for washing. In the region, 55 places for washing were counted in 17 localities. The use of hot water in washing is very practical and developed for many reasons: washing easy, warm water in winter time, with no cost (water saving), large space and washing together (spending time).

3.7 Animal husbandry

A small amount of water is used for animal husbandry especially for camels, sheep and goats. Two wells having a total flow rate of 6 l/s are used for this purpose. It is important to indicate that animals, especially camels prefer warm water to cold water. In addition, warm water is so demanded in wintertime because of the salty taste and it increases animals' appetite. Camels travel many kilometers to reach hot sources (see Figure 6) such as the case of Bazma source (well CI.16).

Figure 6: Animal husbandry.

4 Conclusion

In southern Tunisia, geothermal water is used for bathing, tourism, washing, and animal husbandry and for agricultural purposes. Its main use is for irrigation of oases and heating of greenhouses (96%). For water saving purposes, its cascaded use has recently started in the region. For the new projects, there is good relation between the users, and water from greenhouses goes directly to oases for irrigation. The need for heating and irrigating a greenhouse is estimated at 0.3 and 0.03 l/s respectively. The return water representing 90% (0.27 l/s) should supply the oases surrounding the area, but this is often difficult to achieve. It is important to note that the location of a greenhouse project near the oasis is preferred and the greenhouse-oasis combination must be considered in the future.

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