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Physical Properties and Evaluation of Some Geothermal Waters in Bitlis, Van and Bingöl provinces

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Abstract

This study focused on the geothermal hot springs in the Bitlis, Van, and Bingöl provinces in the Eastern Anatolia Region of Türkiye. These geothermal hot springs are Çukur, Nemrut, Ilıcakoy (Bitlis), Erciş, Çaldıran, Gürpınar (Van), Kös, Karlıova, and Hasköy (Bingöl) which are mostly dependent on regional tectonic regime. These hot waters contains sodium, calcium, bicarbonate, and chloride and their temperature ranges from 33 °C to 80°C, which are not suitable for electricity generation. Nevertheless these hot waters are sources of healing water used balneological purposes in Turkish baths and mainly for residences heating.

Keywords: Hot water, Geothermal, Balneotherapy, Healing water, Heating.

Bitlis, Van ve Bingöl İllerindeki Bazı Jeotermal Suların Fiziksel Özellikleri ve Değerlendirilmesi

Bu çalışmanın inceleme alanı, Doğu Anadolu Bölgesi'nde yer alan Bitlis, Van ve Bingöl illerinde bulunan jeotermal kaynakları kapsamaktadır. Bu kaynaklar, Çukur, Nemrut, Ilıcakoy (Bitlis), Erciş, Çaldıran, Gürpınar (Van), Kös, Karlıova ve Hasköy (Bingöl) sıcak suları olup tektonik rejime bağlı olarak gelişmişlerdir. Genelde sodyumlu, kalsiyumlu-bikarbonatlı, klorürlü, sıcak sular sınıfına giren kaynak suların sıcaklıkları 33 °C ile 80 °C arasında değişir ve elektrik üretimi için uygun değildir. Yine de bu sıcak sulardan, kaplıca ve balneolojik amaçlı ve daha çok konutların ısıtılmasında kullanılan şifalı su kaynaklarıdır.

Anahtar Kelimeler: *Sıcak su, Jeotermal, Balneoterapi, Şifalı su, Isıtma.*

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1. Introduction

Geothermal energy is a renewable energy source from a hot fluid originating from the earth's heat (Mert & Aydın, 2017). Geothermal energy is hot water and steam formed by the heat accumulated deep in the earth's crust. It has a continuous temperature of more than 20 °C and may contain more dissolved minerals, various salts, and gases than normal groundwaters and surface waters around it (Kıranşan & Şengün, 2013). Geothermal fluid is divided into three groups according to its temperature: low (20-70 °C), medium (70-150 °C), and high temperature (>150 °C). High-temperature fluids are used to generate electricity, while low- and medium-temperature fluids are used for heating and spa tourism. Moreover, geothermal fluids are also used for different purposes, such as chemical production, aquaculture, etc (Elmastas, 2008).

Direct utilization of geothermal energy in the World has increased from 8664 MWt in 1995 to 70.885 MWt in 2015 (Lund & Boyd, 2016). Since the 1960s, 230 geothermal fields (20 °C to 287 °C) have been discovered in Türkiye (Mertoğlu et al., 2015). Hence, Türkiye ranks seventh worldwide and 1st in Europe regarding geothermal heat potential (Mert & Aydın, 2017). The geothermal wells and resources in Türkiye have a total geothermal capacity of 8000 MWt and a calculated potential of 60000 MWt (Mert & Aydın, 2017). Figure 1 shows the potential and distribution of geothermal energy utilized in Türkiye.

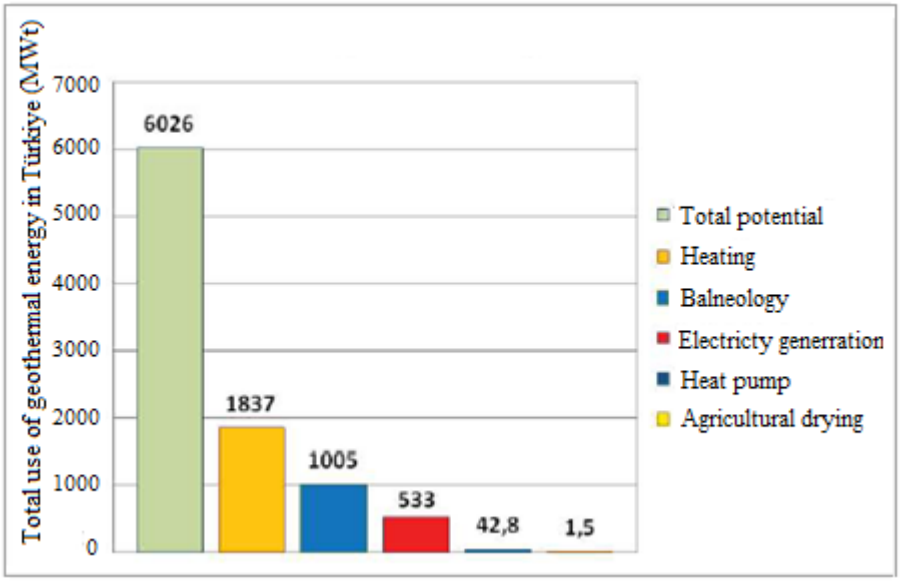

Fig. 1 Total use of geothermal energy in Türkiye (Düzen, 2016; Akkuç & Alan, 2015)

Türkiye has 410 geothermal water resources with different flow rates, temperatures, radioactivities, molten mineral ratios, and accessibility (Lund&Toth, 2021), Doğanay, 1999; Doğaner, 2001; Sayılı et al., 2007; Akbulut, 2010). The Eastern Anatolia Region ranks third with 64 geothermal water resources (Özşahin & Kaymaz, 2013).

The geothermal water resources in Eastern Anatolia are located on fault lines or in volcanic zones. These geothermal resources are unsuitable for electric power generation due to their low-to-medium-temperature. They contain different minerals (sodium, bicarbonate, sulfur, sulfate, chloride, etc.). They are mostly used for heating and spa tourism. Geothermal water resources are high in demand because they have therapeutic physical and chemical properties (Elmastas, 2008).

Erzurum, Erzincan, Ağrı, Bingöl, Bitlis, Van, and Elazığ provinces in the Eastern Anatolia region are rich in thermal resources. This study investigated the chemical and physical properties of some geothermal waters in Bitlis, Van, and Bingöl.

2. Geothermal Regions

This study focused on the Çukur, Nemrut, Ilıcakoy (Bitlis), Erciş, Çaldıran, Gürpınar (Van), Kös, Karlıova, and Hasköy (Bingöl) geothermal spring waters. Table 1 shows their chemical properties.

Table 1. Chemical properties of spring waters (mg/l), (Elmastas, 2008; Düzen, 2016; Celebi, 1994)

Component	Bitlis			Van			Bingöl		
	Çukur	Nemrut	Ilıcaköy	Erciş	Çaldıran	Gürpınar	Kös	Karlıova	Hasköy
Na	429.17	350	200.29	838	610	24	167.1	686	114
Ca	143.93	38	7.0	135	165	164	144.2	77.1	180
K	54.68	38	3.24	99	150	0.3	20.3	104	9.9
Mg	85.89	4	22.08	14	22.2	110	58.3	39.5	19.8
Fe	5.22	-	3.60	-	-	-	0.12	0.12	0.05
Al	0.09	-	0.25	-	-	-	4.23	-	0.01
NH_4	12.20	-	12.20	0.31	3.6	0.1	-	-	0.01
Zn	0.52	-	0.01	-	-	-	-	-	-
Cu	0.02	-	-	-	-	-	-	-	-
Li	731.76	-	-	2	2.3	-	-	-	-

2.1. Geothermal Fields in Bitlis

Bitlis is located in the Upper Murat-Van part of the Eastern Anatolia Region. The northern part of the Bitlis has several volcanic cones formed as a result of volcanic activities between Neogene to Quaternary. The most significant one volcanic cones in the Bitlis area is, Nemrut stratovolcano, which has erupted volcanic material in several phases (Elmastas, 2008). It consists of volcanic rocks, such as andesite and basalt, while the volcanic material formed a dike to the west, in the northern parts of

Lake Van. Bitlis has three geothermal areas (Çukur (Güroymak), Nemrut (Ilıgöl), and Ilıcaköy (Taggermav)] with water temperatures between 38 ºC and 60 ºC (Fig. 2), (Elmastas, 2008).

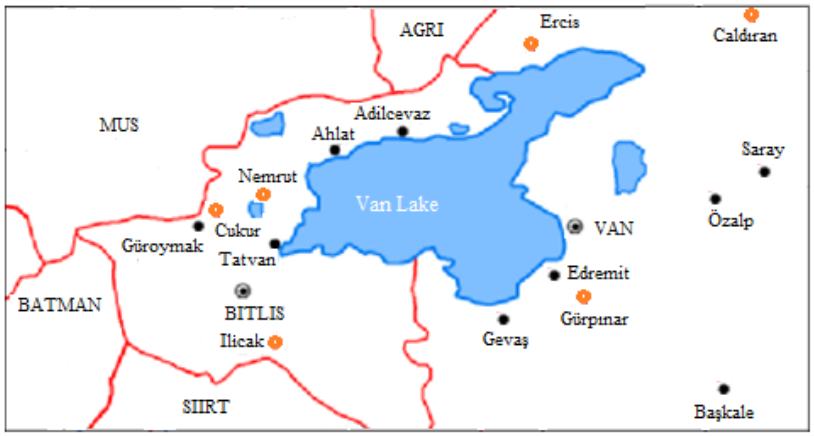

Fig. 2 Geothermal resources locations in Bitlis and Van (Elmastas, 2008)

2.1.1. Çukur (Güroymak) Geothermal Field

Çukur (Güroymak) geothermal field is located 10 km from the Güroymak district center and north of Bitlis province (Fig. 2). It is located at the west of the Nemrut stratovolcano and at the intersection of the Mount Nemrut stratovolcano and the Muş plain. The spring waters are accumulated on the exit points of the springs and form a pond with a diameter of 40-50 meters. Located on the fault line running east-west, Çukur (Güroymak) geothermal field has 13 springs with flow rates of 10 to 12 l/sec. It is the largest geothermal field in the province in terms of flow rate. The temperatures of the springs are between 37.5 °C and 39 °C. Hence, these springs could be are considered as low-temperature waters. The springs have suitable temperature and flow characteristics for hot spring tourism and fish production (Elmastaş, 2008). Therefore, local people use the springs not only for touristic purposes but also for treating diseases (rheumatism, skin diseases, etc.). Nevertheless, this geothermal potential may also have potential for domestic heating and greenhouse purposes due to their temperatures.

2.1.2. Nemrut (Ilıgöl) Geothermal Field

Nemrut (Ilıgöl) geothermal field is located within the Nemrut caldera formed on the Nemrut sratovolcano and it is 15 km from Tatvan and 25 km from Ahlat. Thus, it is easy to access, except in winter period, for touristic purposes. Nemrut caldera covers an area of approximately 48 km^2. It is 8.4 km long in the east-west direction and 7.2 km in the north-south direction. Lake Nemrut is located

in its western part of Nemrut sratovolcano, while Lake Ilıgöl is in its northeast part (Güner, 1984), (Fig. 2).

Geothermal springs are on the fault line extending in the E-W direction north of Lake Ilıgöl. There are two hot springs on this fault zone. The temperatures of Nemrut hot springs are between 46 °C and 60 °C and this spring discharges into Lake Ilıgöl. Furthermore, Nemrut hot springs are bicarbonate and sodium waters. This spring could also use for treatment of various diseases (rheumatism and dermatological disorders) (Erişen et al., 1996).

2.1.3. Ilıcaköy (Taggermav) Geothermal Field

Ilıcaköy (Taggermav) geothermal field is located in Ilıcaköy in the Bölükyazı sub-district of the central district of Bitlis (Fig. 2). The spring waters are located on the metamorphic Bitlis Massif and are on the right side of the Seyhcıman stream valley. The springs are located on a probable fault zone, which is approximately in the E-W direction of the valley (Elmastas, 2008).

Ilıcaköy geothermal spring waters are hyperthermal mineral waters in terms of physical classification. They are sodium, bicarbonate, and chloride waters regarding chemical classification and their flow rate is 1.3 l/s (Table 2). They are using for rheumatism and dermatological disorders treatments and they have usages as baths (Elmastas, 2008).

2.2. Geothermal Fields in Van

2.2.1. Ercis-Zilan

Zilan geothermal field is located at 30 km north of Erciş and Lake Van and is between the villages of Hasanaptal-Şorköy Gergili in the Zilan valley, which are between 1850 and 3500 meters above sea-level (Fig. 2). The thermal springs in Erciş geothermal field have temperatures of 34 to 80 °C, flow rates of 9 to 18 l/sec, and pH values of 6.0 to 8.5 (Düzen, 2016). These features allow to them use for spa facilities, and greenhouses. In addition, they could use for rheumatism and dermatological disorders treatments.

2.2.2. Çaldıran

Çaldıran geothermal field is in the Çaldıran plain northeast of Lake Van (Fig. 2). Many hot, mineral and cold-water springs are discharging along the Çaldıran fault zone. Ayrancılar (25-36 ºC) and Buğulu (36 ºC) are the most important hot water springs in this area (Mutlu & Aydın, 2010). According to the General Directorate of Mineral Research and Exploration (MTA), the hot and

mineralized waters in the Çaldıran geothermal field have temperatures between 14.0 and 60.8 ºC their flow rates range from 1 to 8 l/sec, and a pH value is 6.72 (Akkuş et al., 2005). The hot springs in this area are using for touristic and therapeutic purposes (rheumatic and skin diseases). Besides these purpose, they could also be used for heating greenhouses in Çaldıran, which is one of the coldest districts in Türkiye (-45 °C).

2.2.3. Gürpınar

Gürpınar geothermal springs are located in approximately 24 km south of Van, and they have igneous origin. These springs are located along the Gürpınar fault. They have a temperature of 37 °C, a flow rate of 6.7 l/sec, and a pH value of 6.1, (Düzen, 2016). Hence, they could have potential for touristic purposes and as greenhouse heating.

2.3. Geothermal Fields in Bingöl

Bingöl hosts the most important geothermal potentian in the Eastern Anatolia (Fig. 3). These geothermal resources are mainly located on the East Anatolian Fault Zone. The main geothermal resources in Bingöl province are Kös Hot Spring, Göynük Hacılar Hot Springs, and Yayladere Hasköy Hot Springs (Kıransan & Sengün, 2013).

2.3.1. Kös Hot Springs

Bingöl Kös Hot Springs is located in Kös village of Ilıcalar town, 20 km northeast of the Bingöl-Erzurum highway (Fig. 3). The region has important hot springs and spa culture. The hot springs are located on the west bank of the Kös Stream valley, which runs north-south, or on the valley floor on the right bank. The hot spring waters are carbon-dioxide and carbon-gas waters (Bulut & Girgin, 2001).

Bingöl Kös hot Springs are hyperthermaI waters (36-45 ºC), which are rich in minerals and have a flow rate of 35 l/sec (Çomak & Güncegörü, 2012). They might increase gastric and intestinal motility and urination. Furthermore, they could improve digestion and partially empty the gall bladder. Even though they are drinkable on site, they cannot be bottled due to sediment proportion (Bulut & Girgin, 2001). They are good for osteoporosis, tooth decay, diabetes, rheumatism, sciatica neuritis, and bone, gastrointestinal, urinary tract, nervous, cardiovascular, and gynecological diseases (Kıransan & Sengün, 2013).

Fig. 3 Bingöl spring waters

Table 2 Physical properties of spring waters (Elmastas, 2008; Mert&Aydın, 2017; Kıranşan&Şengün, 2013)

Properties	Bitlis			Van			Bingöl		
	Çukur	Nemrut	Ilıcaköy	Erciş	Çaldıran	Gürpınar	Kös	Karlıova	Hasköy
Temperature, (°C)	37.5-39	46-60	44	34-80	14-61	37	36-47	62	33
pH	6.72	6.2	9.1	6.3	6.72	6.1	6.7	7.1	6.1
Flow rate, (l/s)	10-12	1	1.3	27	10.5	6.7	35	35	8

2.3.2. Hasköy Hot Springs

Hasköy thermal springs are located about 5 km south of Yayladere, Bingöl. It is sodium water containing bicarbonate. The local people either drink or swim in it because they believe it has therapeutic properties. Hasköy thermal springs also soothing and wound healing properties. The water heals wounds and is good for malnutrition, urinary, kidney diseases, and rheumatism. Hasköy thermal springs are also known as fault thermal springs. They have a temperature of 33 °C and a pH value of 6.10 (Celebi, 1994).

2.3.3. Karlıova Hacılar Geothermal Borehole

Karlıova Hacılar Geothermal Borehole is 30 km south-east of the Hacılar village in the Karlıova district of Bingöl. It is located on the banks of the Hubus stream. It is about 45-50 kilometers from Bingöl. It has a water temperature of 62 °C, a pH value of 7.1 and a flow rate of 35 l/sec (Şahan, 2011).

3. Results and Discussion

There is a positive correlation between the distribution of thermal water resources and fault lines in Türkiye. In other words, the main fault zones have numerous thermal springs (Fig.4).

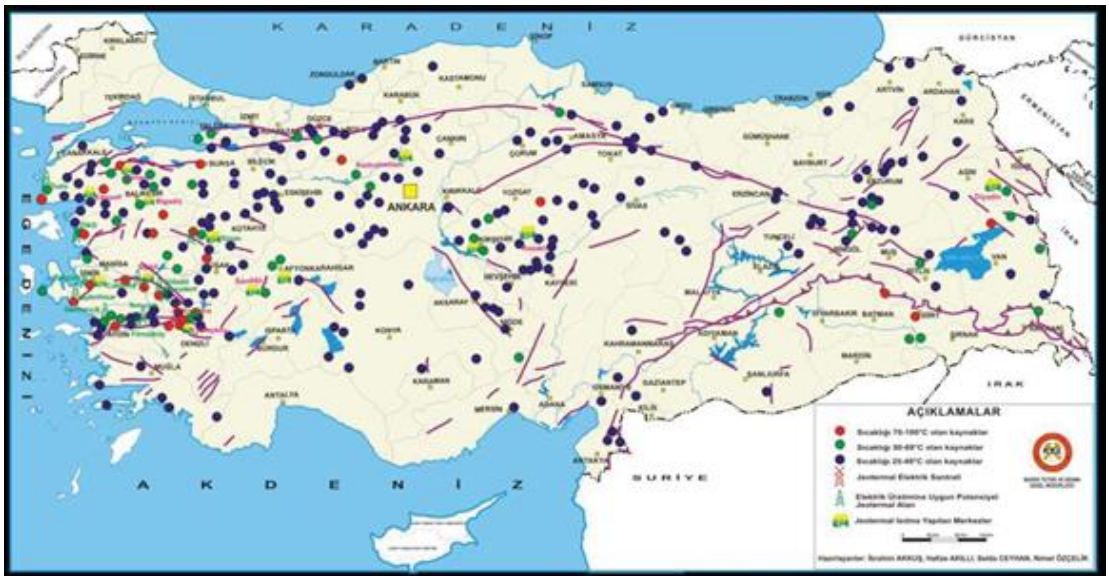

Fig.4 Thermal water resources and fault lines distribution relationship map in Türkiye (Düzen, 2016)

For power generation, the temperature must be higher than 150 °C. Hence, Nemrut, Ilıcaköy, Erciş, Çaldıran, Kös, and Karlıova geothermal waters do not have any power generation potential since their temperatures lower than 150 °C. Nevertheless, their temperatures are suitable for heating houses and greenhouses and for tourist purposes. Çukur, Gürpınar, and Hasköy geothermal waters have a temperature below 40 °C, which make them for tourist or aquacultural purposes (Fig 5).

We should first turn ılıcas into hot springs to put them to public use. In this way, they will attract more attention and contribute to the protection of public health. They should be made available not only to local people but to tourists as well. These waters can be used for greenhouse purposes. They can also be bottled and sold as mineral water, contributing to the local economy.

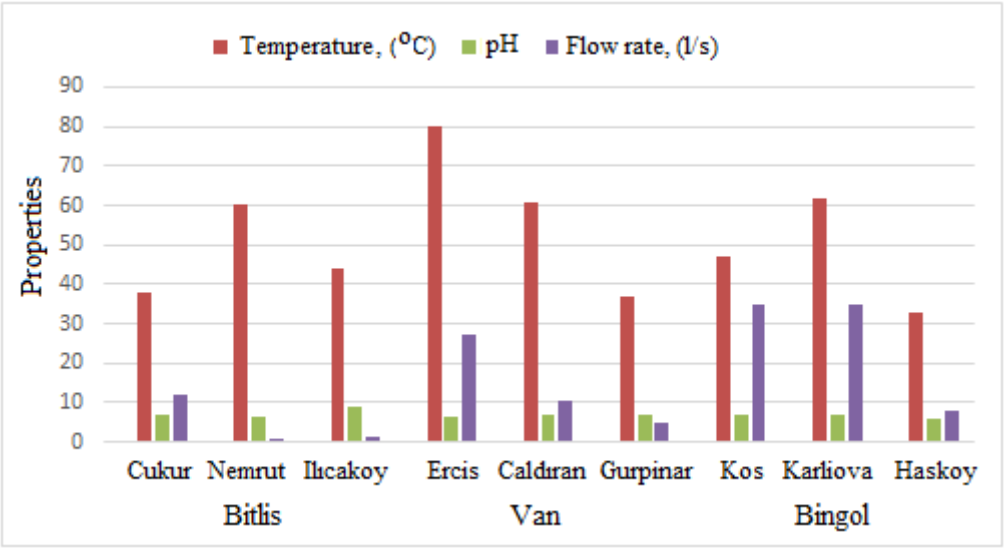

Fig. 5 Physical properties of spring waters

3.1. Geothermal Fields in Bitlis

Bitlis is rich in geothermal water springs. The touristic geothermal waters of Nemrut (Ilıgöl) have a temperature of 46 to 59.5 °C. There are no facilities on Nemrut geothermal springs. Permanent facilities may pollute the waters of Nemrut and Ilıgöl, which do not have a surface outflow. Therefore, precaution should be taken from anthropogenical related pollution in this area. Ilıcaköy geothermal area is located in the Seyhcuman valley, covered with forests in the Southeastern Taurus Mountains.

Çukur geothermal field has 13 hot springs (flow rates of 10 to 12 l/sec) on the same line. It is the largest geothermal area in Bitlis. We need to analyze these hot springs chemically, physically, and biologically to determine what kind of diseases they are good for health. Therefore, this field should be utilized within the framework of health tourism.

The hot waters drilled around the Çukur geothermal springs have a reservoir temperature of 200 °C (Elmastas, 2008). This indicates the existence of uncooled pockets underground and the geothermal energy generation potential in the basin. This potential can also be utilized residence heatings in Güroymak. Overall, the geothermal hot springs in Bitlis have potential for therapeutic, greenhouse, and fishery purposes. Hence they can provide contributions into the province's economic development.

3.2. Geothermal Fields in Van

Van provinces has a continental climate and easy to do greenhouse farming in and around it. Because, it has geothermal energy at its disposal and it receives long hours of sunlight throughout the year. Vegetables are cultivated in greenhouses and tunnels in and around Van. However, farmers can extend the vegetation period and grow warm climate vegetables even in winter by heating greenhouses through hot springs.

Van is located in a tectonically compressional zone. Moreover, a new geothermal activity will likely occur there because the 2011 earthquake led to new fault systems. Therefore, Van has tectonic activities and fault systems. All in all, we should use the region's geothermal potential.

3.3. Geothermal Fields in Bingöl

Bingöl is one of the richest provinces in the Eastern Anatolia Region in terms of geothermal water resources. Therefore, geothermal fields in this province have the potential to contribute to the local economy.

Kös Hot Springs have great potential regarding their geographical location, water temperature, and chemical composition. The locals have been using them for recreational and therapeutic purposes since the first facilities were built. Facilities should be both therapeutic centers and holiday resorts. Therefore, we need to build more service units. People use Kös Hot Springs for hygiene and therapeutic purposes (tooth decay, fluorine deficiency, bone, gastrointestinal, urinary tract, nervous, gout, cardiovascular, diabetes, and gynecological diseases).

Hot water from hot springs and boreholes in the Karlıova district can be used for heating of residences and greenhouses. Furthermore, the recent facilities in this district should be renovated in order to improve touristic activities.

Research studies show that Hasköy hot springs treat many diseases (nutritional disorders, kidney diseases, rheumatism, etc. (Kıranşan & Şengün, 2013). As like in Karliova district, the facilities (e.g., baths) in this area should also be modernized in order to make them attractive for health tourism, and improvements for bottling hot spring water as mineral water could also have additional economic potential. Furthermore, springs in this area have potential greenhouse heating.

4. Conclusions

This study focused on the geothermal hot springs in Bitlis, Van, and Bingöl in the Eastern Anatolia Region. The following are the results:

1- The geothermal hot springs in Bitlis, Van, and Bingöl have low temperatures and medium flow rates. Therefore, they are not suitable for geothermal power generation. However, researchers should investigate whether we can install mixed systems (solar energy, natural gas, etc.) to generate power.

2- The local people of Bitlis, Van, and Bingöl use the hot springs in spas, baths, and fish farms. They make use of them for balneological purposes (thermal tourism). They also use them for heating (residential, thermal plant, and greenhouse) and wet food drying. Nevertheless, further studies should done in order to find out additional usages of these springs.

3- The hot springs should be made available not only for local tourism but for regional tourism as well. Therefore, the recent facilities should be modernized in order to make them more attractive for regional tourists.

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