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Accessible Energy Amount and the Environmental Pollution from a Clean Energy Resource: A Case Study From Güneyyolu Geothermal Area, Turkey

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ABSTRACT

Güneyyolu geothermal area is the only geothermal area in the Mediterranean region in Turkey, characterized by an abnormal terrestrial heat flow. From geological studies and the results of a drilling, the thermal energy reserve of Güneyyolu area is calculated as 1. 10^{14} kilojoules and this is equivalent to 4.2 10^{6} tonnes petroleum. Mixing of thermal water with İçmece rivulet does not create a thermal pollution but deteriorates the quality of the water. Since İçmece rivulet is very important for citrus irrigation, the use of this rivulet as a receiver for thermal discharge can not be tolerated.

1. INTRODUCTION

Turkey ranks among the top countries in the world in terms of geothermal energy potential. Balneological uses of geothermal energy are common and a very big portion of the geothermal energy potential is suitable for heating purposes. In spite of Turkey's richness in geothermal energy, Mediterranean region is quite poor in this respect. Mersin Güneyyolu geothermal area is one of the rare hot spring areas in this region and its thermal waters are utilized mainly for bathing purposes.

There are three hot springs in Güneyyolu area and these springs are located directly in İçmece rivulet and discharge into this rivulet (Fig. 1). İçmece flows through this site to the Mediterranean Sea. A well was drilled in 1999 and its water has also been discharging into İçmece. The discharge rate of the well is 40 L/s with a temperature of 39.4^{o} C.

Geothermal energy is considered as a clean energy and the environmental impact of the geothermal uses is regarded as negligible in Turkey. In the last decade, the environmental impact of geothermal energy has been sharply reduced in high enthalpy areas by reinjection of spent fluids into the ground, but such areas are very few in Turkey. In the Güneyyolu area the amount of discharge of thermal water is approximately150 tonnes/hour and creates an environmental problem downstream the İçmece rivulet.

The well was drilled not only before clarifying the geology of the area but also by using an unsuitable drilling method. Therefore it discharges into the rivulet out of control.

This paper presents results from a geological and environmental study conducted on the Güneyyolu geothermal field in Mersin..

2. THE GEOLOGY OF STUDY AREA

Güneyyolu geothermal field is located 15 km north of Mersin. The oldest geologic units are schist and marbles of Paleozoic age. The ophiolitic rocks settled in Upper Cretaceous on these units. Tertiary sedimentary rocks cover the schists and/or ophiolitic rocks. These sedimentary rocks are classified into five formations. They are Gildirli, Karaisalı, Güvenç, Kuzgun and Handere formations. Caliche and alluvium are the youngest units in the study area (Fig. 1).

The general direction of faults inclines towards to NE-SW and NW-SE directions. According to field studies, chemical analyses and drilling results, limestone blocks in the ophiolitic complex and limestone of Karaisalı formation in fault zones are characterized as reservoir rocks.

The Paleozoic metamorphic rock, including schist and marble, outcrops in the northern part of the study area. The schist shows yellowish, brown, green and grey colours, and is generally found as chlorite-muscovite-biotite schists. The marble is white, grey coloured, hard and looks crystallized.

Mersin ophiolites were emplaced on the Upper Cretaceous limestone. It is composed of rather big harzburgite leafs and isolated diabase dikes, which cut these harzburgites. 80% of the harzburgites are composed of serpentinized peridodites and contain 60-66% olivine, 25-30% orthopyroxene, 2-4% clinopyroxene and 2-4% opac minerals (Yaman and Ohnenstetter, 1991).

Gildirli formation appears as a white and greyish-white colour, and is composed of fine-to thick-layered conglomerate, sandstone and claystone. Its age is determined as Oligo-Miocene (Şenol, 1998). The Early-Middle Miocene aged Karaisalı limestone cover the Gildirli formation.Upper Miocene aged Güvenç formation consists of claystone, siltstone, tuffite and clayey-limestone. This formation is overlain by the Kuzgun formation. Kuzgun formation contains conglomerate, sandstone, tuffite and limestone series. This limestone series is mapped as an independent unit (Fig. 1). All the rocks in the study area are covered by the Handere formation, which is composed of marl, clay, sandstone, siltstone, conglomerate and limestone series and indicate a wide distribution.

Slope debris is generally observed on the slopes and skirts of the mountains in the field. The alluvium consists of unconsolidated sediments composed of sand, pebbles, silt and clay, and is placed on Deliçay plain and in riverbeds and delta areas. The thickness of the alluvium is between 50-150 m. Caliche is seen around Mersin on the Tertiary sedimentary rocks. The thickness of the caliche ranges from 5 to 10 m.

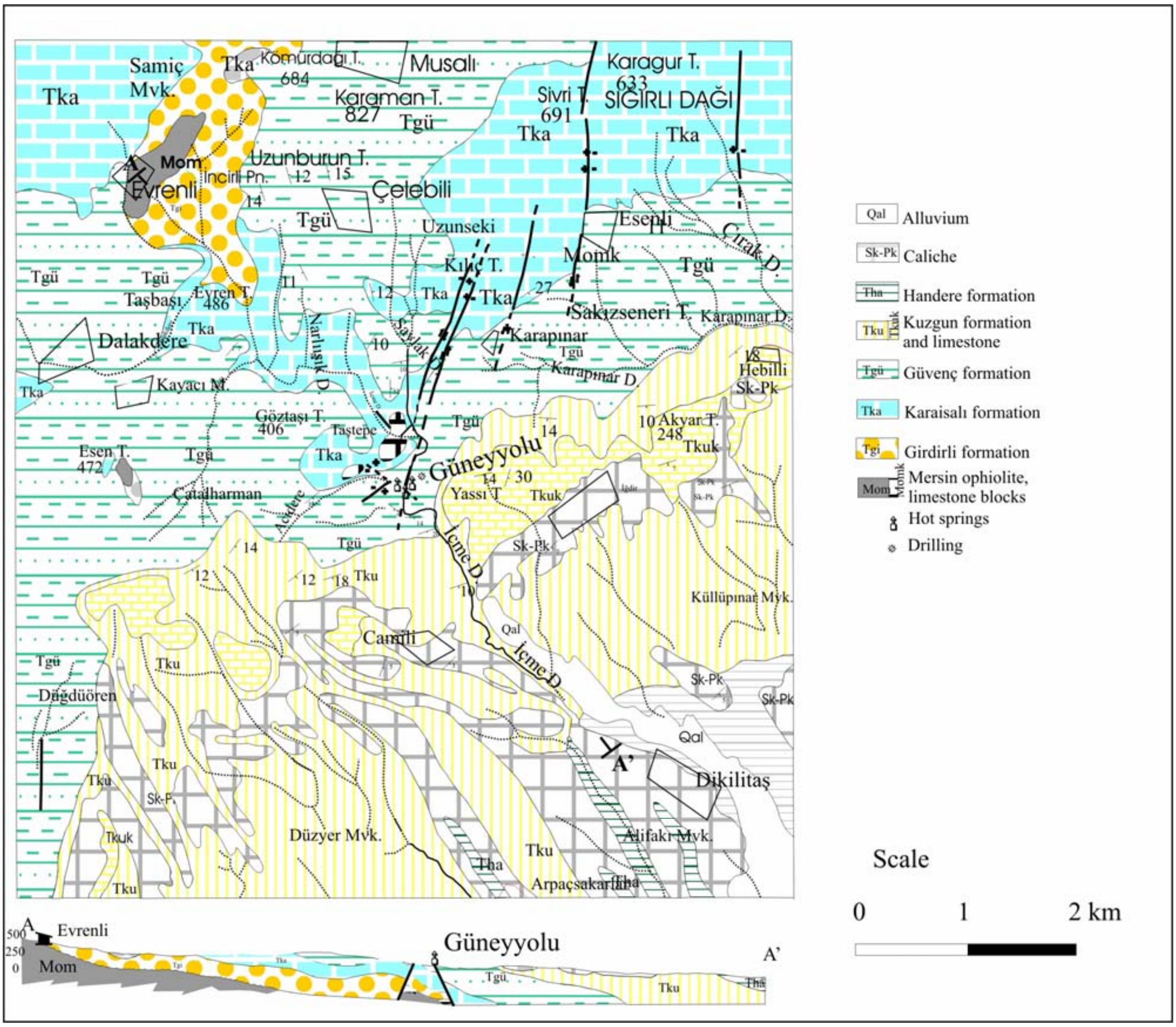


Figure 1: Geologic map of the study area.

3. TECTONICS

The tectonics of Anatolia are directly related to the formation of geothermal fields in Turkey. The geothermal springs are placed within the intersection areas of the faults. A very large strike slip fault, striking NNE-SSW forms the main tectonic structure in the study area. In addition, there are several subfaults and cracks mainly in the same direction. Güneyyolu thermal springs are placed within the intersection area of this fault with a normal fault, which strikes in NW-SE direction (Fig. 1).

4. GEOTHERMAL MODEL

The heat source of geothermal water is the abnormal terrestrial heat flow. The formation of the geothermal system is completed with the deep circulation of meteoric waters, which leak into porous and reservoir rocks around the faults. Both reservoir rocks, the limestone blocks within ophiolite and Karaisalı limestone are surrounded by impermeable cover rocks. Heated fluid uses cracks, faults and fractures as channels to reach the surface. The temperature of the natural hot springs in this area is in the range of 36^o C and 37.5^o C and total the flow rate is about 0.5 L/s. The production rate of the well is 40 L/s and temperature of its water is 39.4^o C. This well reached Karaisalı limestone in the depth of 150 m (Fig. 2).

The two reservoirs are separated from each other by the Gildirli formation. The clay and siltstone of the Gildirli and Güvenç formations form the cover rocks of the geothermal system. The faults and fractures disturbed the isolation, causing a hydraulic contact between the reservoirs.

4.2 Water chemistry

The chemical analyses of thermal waters of the Güneyyolu area are given in Table 1. The pH values of the samples ranged from 7.0 to 7.6. The pH of a cold spring in the same area is 7.4. The thermal water samples are Na-Cl types. The chemical characteristic of the cold spring water is Ca-Na-Cl-HCO_3 type. The Piper diagram indicates that all thermal waters have the same origin (Fig. 3). The cold-water sample is at a different place in the Piper diagram and is therefore of different origin.

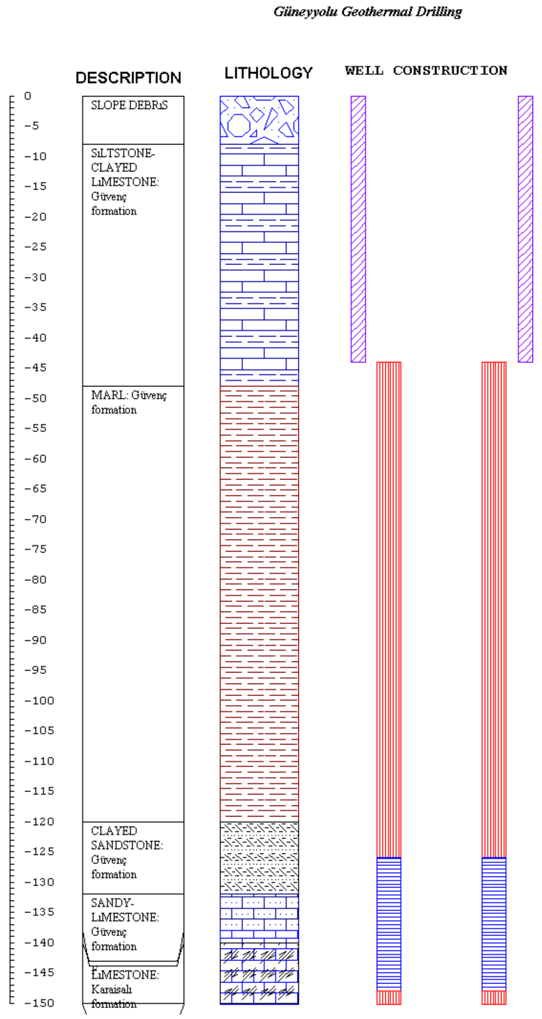


Figure 2: Geology and casing plan of the geothermal drilling.

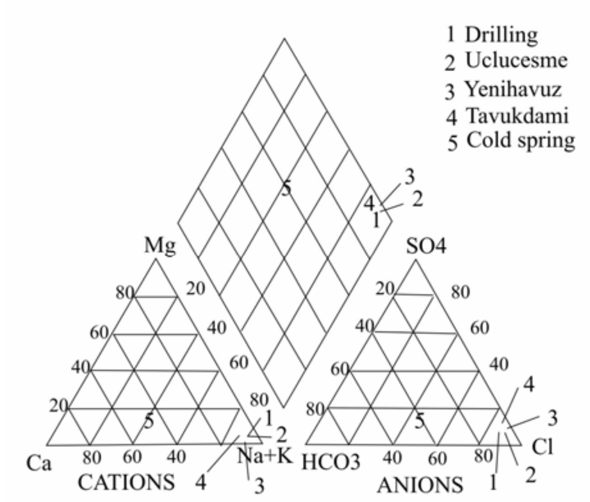


Figure 3: Classification of the waters of the Güneyyolu geothermal area (Piper diagram)

4.3 Geothermic resource estimation

As mentioned above, there are two reservoirs in Güneyyolu geothermal area. The volumes of the first and second reservoirs are calculated as 0.75 10^9 m^3 and 3.7 10^9 m^3, respectively according to field works (Demirel, 2002). Porosity was assumed as 0.2 because both limestone reservoirs are intensively fractured and have karstic holes. By using these values, the amount of the stored thermal waters is determined as 9 10^8 m^3. The results of common chemical geothermometers applied to the thermal waters of the Güneyyolu area give temperatures in the range of 74°C and 156° C. The K-Mg geothermometer of Giggenbach (1988) yields a maximum temperature of 97° C. The accessible energy amount of the Güneyyolu geothermal area is calculated as 10^{15} Joule (Demirel, 2002). Demirel (2002) gives the thermal energy reserve as 2 10^{14} kilojoules and this value is equivalent to 4.2 10^6 tonnes of petroleum.

5. ENVIRONMENTAL CONTAMINATION FROM GÜNEYYOLU GEOTHERMAL AREA

There are three thermal springs in Güneyyolu geothermal area, which are located in the İçmece rivulet (Fig. 1). The low discharges of these springs do not have an important impact on the environment. The well with higher discharge is expected to create an environmental pollution in the rivulet.

The temperature of the rivulet water before mixing with thermal discharge of 39.4° C is 16° C. The balance of the temperatures after the mixing is established in a very short time and distance mainly because of the turbulent flow of rivulet. So it can be easily said that there is no thermal pollution.

The chemical composition of the geothermal brines from the three hot springs and drilling and İçmece rivulet are given in Tables 1 and 2, respectively. The locations of the sample points are shown in Figure 4. The chemical character of the rivulet water being Mg-Ca-HCO_3 type becomes Ca-Mg-Na-HCO_3-Cl type after mixing with Na-Cl type of well water (Fig. 5). At the sample point 44, which is approximately 5 km down from the mixing place, the chemical character of the rivulet water is changed to a new type, Na-Ca-Mg-Cl-HCO_3. This change may be due to agricultural land use and/or wastewater discharges from the settlings along its flow path.

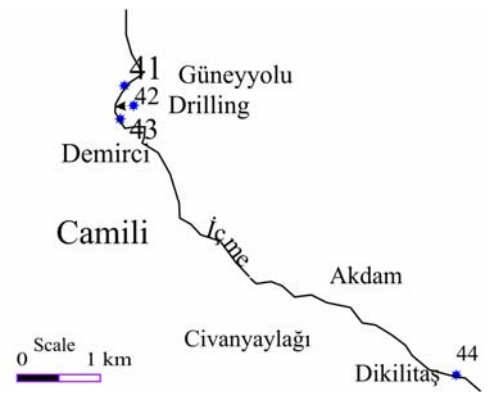


Figure 4: Locations of the rivulet samples

Deep geothermal fluid from the well is rich in major ions and Li. The Li concentration, which is less than 0.1 mg/L in unpolluted rivulet water, increases to 0.16 mg/L after mixing with thermal water. The concentrations of almost all major ions are higher than those of unpolluted rivulet water. Furthermore, the rivulet water exhibits high values of SO_4 and Cl concentrations, which are mainly caused not only by the thermal water but also by the anthropogenic activities along its flow. Figure 6 exhibits that the Na, Cl and SO_4 concentrations increase in the direction of downstream and the trend of the increase is very sharp between the mixing point and Dikilitaş village.

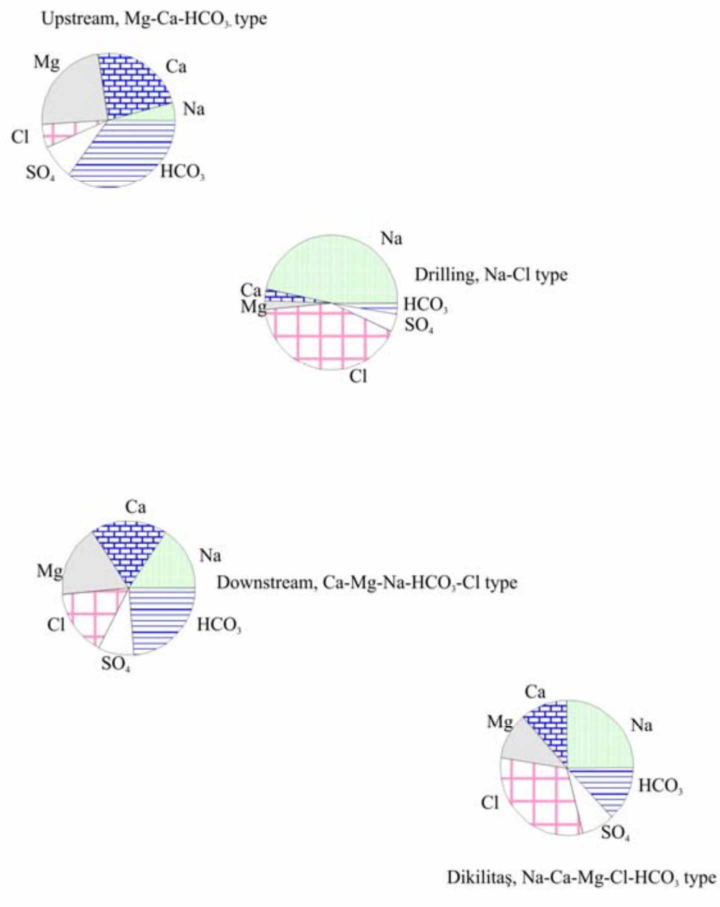
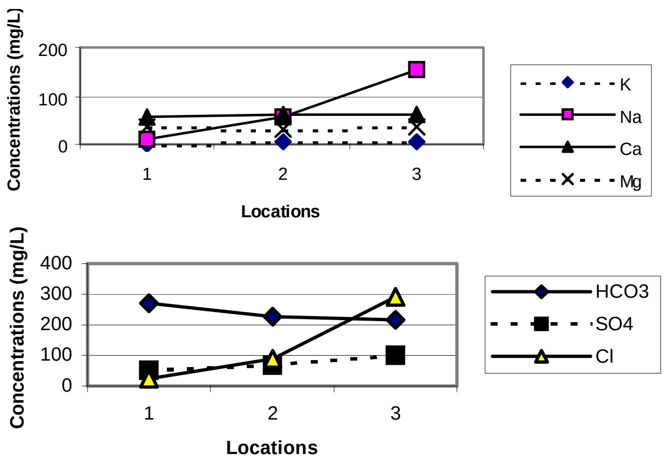


Figure 5: Chemical characters of the rivulet water samples



Locations: 1; Upstream, 2; Mixing point, 3; Dikilitaş village

Figure 6: Change of major ions concentrations along İçmece rivulet

6. CONCLUSION

Although Turkey is fairly rich in terms of its geothermal energy potential, Güneyyolu geothermal area is unique area in southeastern Mediterranean region. There are two reservoirs in the area and they are separated with an impermeable rock from each other. There is not any volcanic activity in this region and the heat source of the geothermal system is the abnormal terrestrial heat flow. The value of the stored thermal water in the reservoirs and the accessible energy amount are determined as 9 10^8 m^3 and 1 10^{15} joule, respectively. The energy reserve of 2 10^{14} kilojoules of Güneyyolu area is equivalent to 4.2 10^6 tonnes petroleum (Demirel, 2002).

Geothermal energy is considered as a clean energy, but thermal water discharge into İçmece rivulet creates an environmental impact. While a thermal pollution in the rivulet water is negligible, the quality change due to thermal water discharge makes the rivulet water unsuitable for irrigation. The water of İçmece rivulet is affected by increased concentrations of major elements such as Na, SO4, and Cl. The concentrations of these elements are greater than the Turkish water standards (Table 1). The contamination of the rivulet is very critical because of the transporting the geothermal load towards urban areas outside of the geothermal field. The indirect affect of the geothermal spills is that the use of the contaminated rivulet water for consumption and irrigation could arise a long-term health risk for the urban population as well as for the citrus.

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Table 1: Chemical analyses of the hot springs

PARAMETER	ÜÇLÜÇEŞME SPRING	YENIHAVUZ SPRING	TAVUKDAMI SPRING	DRILLING	COLD SPRING	TÜRKISH WATER STANDARDS
Discharge (L/s)	0.16	0.36	0.55	40.0	5.0	
Temperature (^{o} C)	37.5	37.0	36.0	39.4	16.0	25-30
pH	7.6	7.6	7.4	7.0	7.4	
K (mg/L)	75.0	72.0	61.5	62.3	4.7	
Na (mg/L)	2064	2050	1751	2150	92	125-250
Ca (mg/L)	130	136	130	111	97.3	
Mg (mg/L)	51.0	42.5	40.0	52.1	17.3	
B_{TOTAL} (mg/L)	2.7	2.7	2.6	0.2	-	1
HCO_3 (mg/L)	176	181	198	341	296	
SO_4 (mg/L)	445	483	399	409	64.6	200-400
Cl (mg/L)	3234	3350	2800	2933	182	25-400
SiO_2 (mg/L)	16.3	16.8	17.0	20.3	16.0	
Chemical Character	Na-Cl type	Na-Cl type	Na-Cl type	Na-Cl type	Ca-Na-Cl-HCO_3 type	

Table 2: Chemical analyses of the rivulet water

No	pH	EC µmho/cm	K^+ mg/L	Na^+ mg/L	NH_4^+ mg/L	Ca^{+2} mg/L	Mg^{+2} mg/L	$Fe_{(T)}$ mg/L	Li^+ mg/L	$Mn_{(T)}$ mg/L	SiO_2 mg/L	HCO_3^- mg/L	SO_4^{-2} mg/L	Cl^- mg/L	F^- mg/L	Br^- mg/L	NO_2^- mg/L	NO_3^- mg/L
41	7.8	648	1.5	12.5	<0.1	58.1	35.9	0.05	<0.1	<0.03	14.6	269.0	50.4	24.6	0.2	<0.1	<0.1	12.1
42	7.0	10570	62.3	2150	4.2	111	52.1	<0.03	1.8	<0.03	20.3	341.0	409.0	2933.0	<0.1	<0.1	<0.1	<0.1
43	7.7	890	3.1	55.8	<0.1	59.7	33.1	0.05	<0.1	<0.03	17.1	227.0	66.6	90.2	0.21	<0.1	<0.1	13.5
44	7.8	1400	6.5	152.0	<0.1	61.0	36.7	<0.03	0.16	<0.03	13.6	215.0	101.3	292.0	0.21	<0.1	<0.1	16.1