



Estimating Minimum Heat output from a geothermal field using simple chemical parameters

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Abstract

An estimation of minimum heat output from the geothermal area is one of the vital information required for initiation of the geothermal exploration process. Geothermal prospects along the west coast of Maharashtra are promising power generation sites in India. In the present study, minimum heat output from the hot springs of Tural and Rajwadi have been calculated using their discharge rate and average chloride concentration. The estimate of heat output from the system is 2.35×10^6 Cal/sec which is in good agreement with the results obtained from convective heat discharge model in the area which indicates heat output as 2.1×10^6 Cal/sec. This study was carried out to explore the feasibility of operating a geothermal power plant.

Keywords: Deccan traps, geothermal, heat output, discharge rate, chloride flux.

Introduction

Ever growing demand of energy and expected scarcity of fossil fuels in near future has put impetus on exploring renewable energy resources in India. Geothermal source is an important renewable energy resource for producing energy. Estimation of natural heat output from the geothermal field is crucial for decision of setting up as well as operating a power plant. All the geothermal springs in India are classified on the basis of their geo-tectonic set up and they are broadly distributed into seven provinces- The Himalayas, Cambay, Sohona, west coast, Son-Narmada-Tapi rift Zone (SONATA), Mahanadi and Godavari. Western margin of volcanic Deccan trap known as Western Ghats is one of the potential geothermal fields due to the presence of a group of 18 such areas with 60 hot springs^{1,2}. These hot springs are spread over a linear stretch of nearly 300 km and width of 20 to 30 km, trending NNW-SSE, parallel to west coast³. Detailed geological, hydrogeological, chemical, geophysical and isotopic investigations had been carried out in this region by GSI and also by NGRI^{2,3,4,5}. Recently there have been many studies on the physico-chemical parameters of the hot springs and its effect on the microorganisms and human lives living around that area^{6,7,8,9,10,11,12}. GSI had conservatively estimated about 5.66 MWatt (t) as total heat loss from the hot springs in the whole west coast area⁴. The aim of the present study is to demonstrate that the heat loss from the hot springs can be computed using chemical parameters which can be compared with model estimated value.

Study Area: Tural and Rajwadi geothermal fields are located near the Tural and Rajwadi villages of Chiplun taluka in the Ratnagiri District of Maharashtra, India shown in Figure-1. Geothermal activity in this area is manifested by the cluster of

thermal springs (50-62^oC) scattered over an area ~1km². The fracture zones trending in N20^oW-S20^oE within trap flow III control the thermal springs at Tural-Rajwadi⁴. It falls in Deccan Traps terrain of India. About 65 million years ago (at the end of the Cretaceous period) due to series of volcanic eruptions the Deccan Traps were formed. Geomorphologically, the area consists of chains of small hills and undulating plateaus with altitude ranging from 25 to 250 m above mean sea level (amsl). The elevation of the hot springs is less than 35m amsl.

Material and Methods

The use of chloride fluxes to estimate geothermal heat output is a well-developed technique^{13,14,15}. Chloride ion mostly behaves conservatively in the flow path of geothermal fluids. In this method the rate of addition of chloride to the rivers draining any geothermal field is equated to the total chloride flux coming from the depth to the up-flow zone of the geothermal field. Hence, if we know the ratio of enthalpy to chloride concentration of the deep geothermal fluid then the chloride flux can be used to estimate the rate of energy transport from depth¹⁵. Due to the absence of suitable gauging site monitoring the total chloride flux of Tural and Rajwadi geothermal fields in some common drainage system, we had measured the discharge rates of each hot spring sprout at their discharging points in April, 2013. Figure-2 shows the sampling locations. The respective values of discharge rate of all the hot springs individually are given in Table-1. The values match with the previously reported value which remains constant over the years³. Total discharge rate turns out to be 16.84 l/s. The average chloride concentration of the thermal springs of this area can be taken as 370 mg/l^{2,4}. From previous

study it is established that thermal waters in this area does not undergo significant mixing with either shallow ground water or with sea water². So it can be concluded that all the chloride must be coming from the reservoir. The temperature of the sub-surface reservoir is estimated 170⁰C using silica-enthalpy mixing model which matches closely to the Na-K geothermometry value (unpublished report). Average ambient temperature of the study area at the time of sampling was 32⁰C. Using these values the total heat loss by the springs can be calculated:

The total chloride flux is
 $16.84 \text{ l/s} \times 370 \text{ mg/l} = 6230.8 \text{ mg/s Cl}$

Each 0.37 mg chloride is associated with 172 calories (the enthalpy of liquid water in equilibrium with steam at 170⁰C) of heat. Therefore total convective heat flux above the average temperature (32⁰C) is:
 $\{(6230.8 \text{ mg Cl /sec}) (172 \text{ Cal} - 32 \text{ Cal})\}/(0.37 \text{ mg Cl}) = 2.35 \times 10^6 \text{ Cal/sec}$

This is the estimation of heat loss by the hot springs flowing in Tural and Rajwadi region. This amount of heat loss can also be computed from the temperature difference between the reservoir and average air temperature as proposed by Sorey and Lewis¹⁶. From the isotopic study it is established that the geothermal waters of Tural and Rajwadi are primarily of meteoric origin^{2,17}. This water must be heated from average air temperature (32⁰C) to the reservoir temperature by conduction from the surrounding rocks as it moves through the system. The gain in heat content of the water can be calculated as:

$$C = d_{170} \times (h_{170} - h_{32})$$

$$= 897.51 \text{ kg/m}^3 \times (172 - 32) \text{ cal/gm}$$

$$= 1.25 \times 10^8 \text{ Cal/m}^3$$

Where C= gain in heat content per unit volume, d_{170} = Fluid density at 170⁰C, h_{170} , h_{32} = Fluid enthalpy at 170⁰ and 32⁰C respectively. As this water moves upward toward the discharge areas, heat is removed from the thermal reservoir at a rate given by CQ, where Q is the volumetric flow of the hot water. From table-1, Q turns out to be 16.84 l/sec. Thus the estimate of convective heat discharge from our system is $2.1 \times 10^6 \text{ Cal/sec}$.

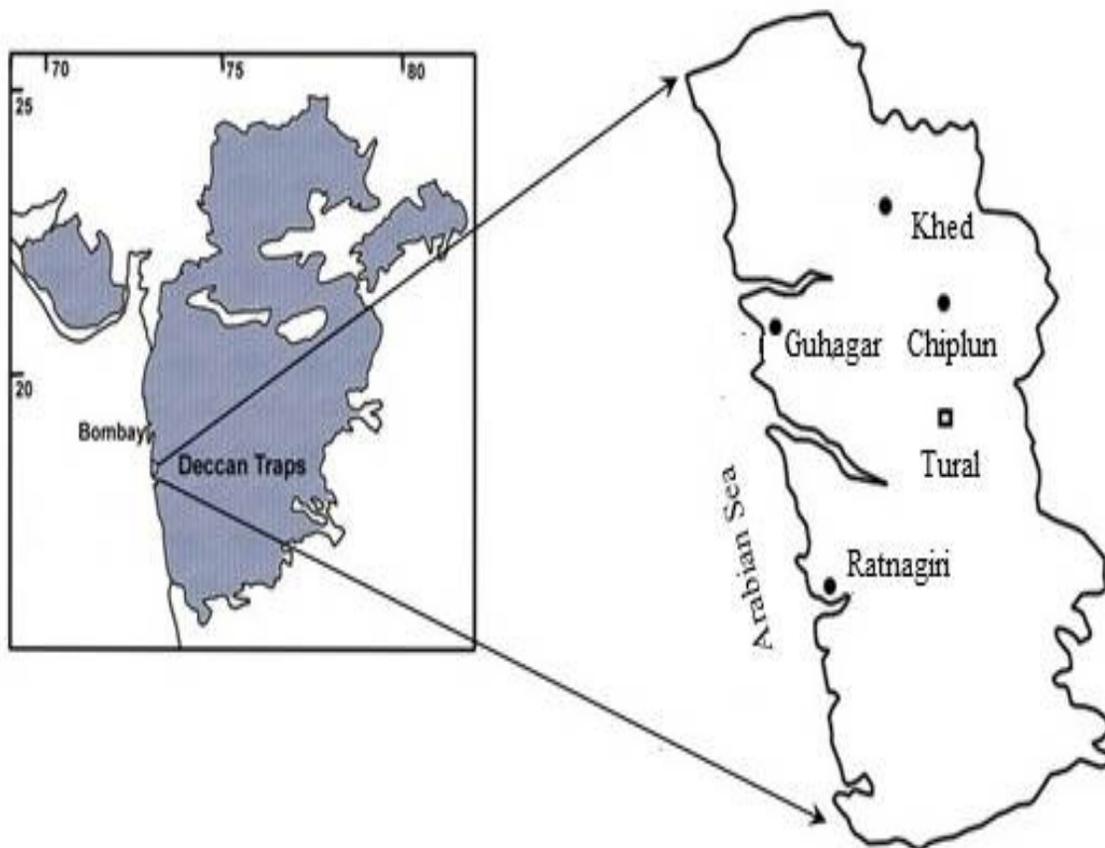


Figure-1
 Location map of the study area

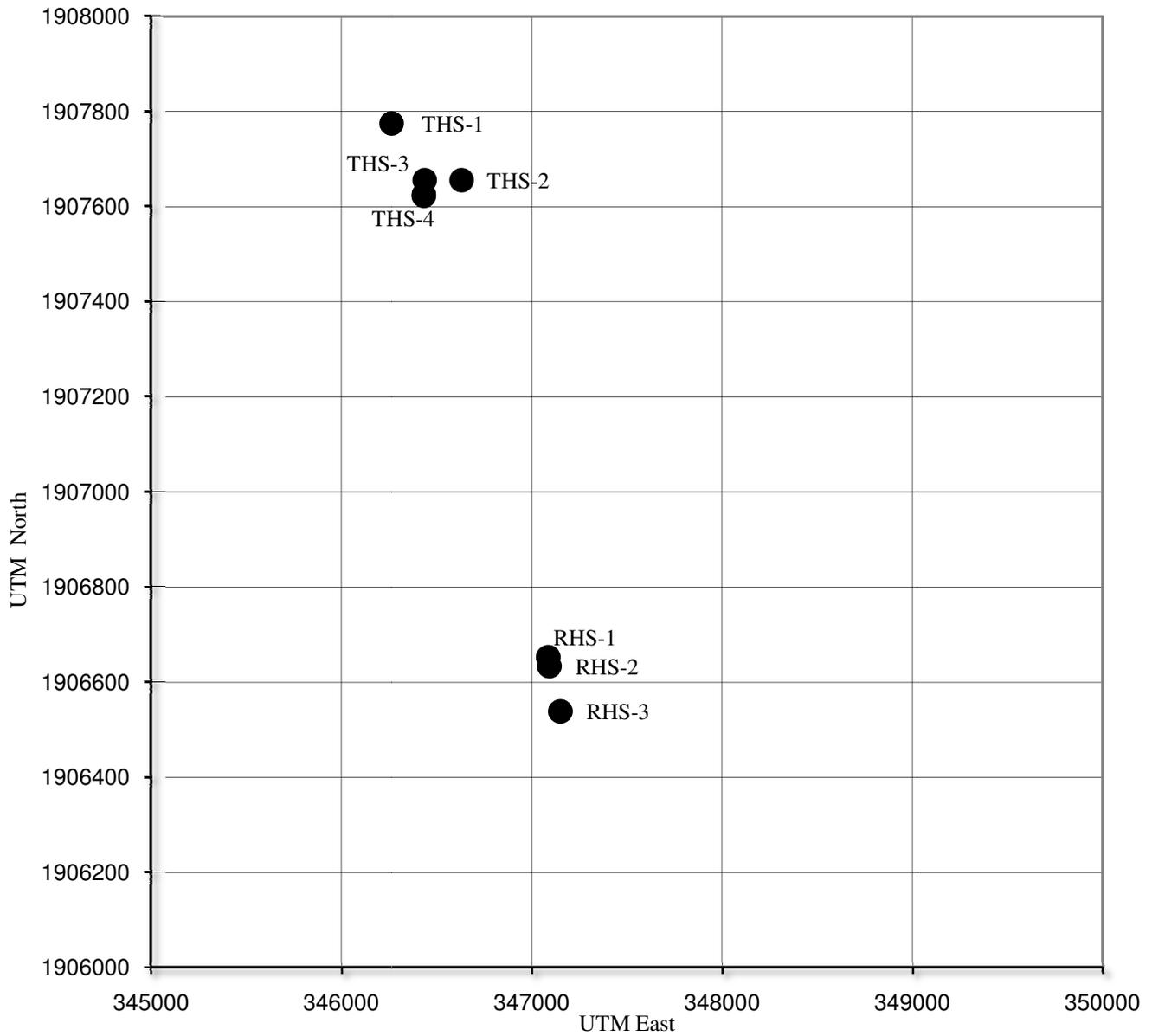


Figure-2
 Sample Prospect map showing sampling locations

Table-1
 Summary of hot water discharge data

Sample ID	Location	Type	Latitude	Longitude	Discharge rate (l/sec)
THS-1	Tural	Hot Spring	17 ⁰ 14'55.5''N	73 ⁰ 33'26.5''E	6.2
THS-2	Tural	Hot Spring	17 ⁰ 14'54.7''N	73 ⁰ 33'19.8''E	0.3
THS-3	Tural	Hot Spring	17 ⁰ 14'55.8''N	73 ⁰ 33'19.9''E	0.3
THS-4	Tural	Hot Spring	17 ⁰ 14'44.7''N	73 ⁰ 33'19.6''E	0.38
RHS-1	Rajwadi	Hot Spring	17 ⁰ 14'23.3''N	73 ⁰ 33'42.2''E	4.45
RHS-2	Rajwadi	Hot Spring	17 ⁰ 14'22.7''N	73 ⁰ 33'42.4''E	4.45
RHS-3	Rajwadi	Hot Spring	17 ⁰ 14'19.6''N	73 ⁰ 33'44.4''E	0.76
Total	-	-	-	-	16.84

Conclusion

The above study gives the minimum estimate of heat output because the effects of conductive cooling, mixing with cooler non-thermal waters and subsurface boiling on the heat content of the up flowing water were not taken into account. The computed value matches well with the value provided by the model. This exercise provides an easy way to primarily access the potential of geothermal field using simple chemical parameters. Similar kind of estimation can be made by measuring the discharge rate of boron. The heat output from Tural and Rajwadi region (~10 MWatt) exceeds to that of the estimate given by GSI in whole west coast area. This finding signifies the importance of fresh estimation of heat output in the whole west coast area.

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