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GEOTHERMAL AS ENERGY SOURCE FOR REMOTE AREAS

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ABSTRACT: The modern development of a country is linked to the availability of energy, in the form of electricity and heat source. The electricity generation is mostly dependent on fossil fuels while the transport sector is controlled petroleum products which are major contributors to the pollution of the atmosphere. Wind, Solar, Biomass and geothermal are the main alternate sources, mostly available in remote areas. Geothermal energy is a non-conventional, environment-friendly energy source, available almost all round the year.

In India, geothermal energy sources are located along the Himalayan belt in the north, Son - Narmada - Tapi lineament in central India, West Coast,and Godavari valley. There are isolated hot springs reported from Gujarat, Jharkhand and North Eastern Region, mostly located in interior parts.The hot springs in India range in temperature from 30°C at Ladakh to 97°C at Tatapani, Chhattisgarh. The estimated reservoir temperature in geothermal fields in India ranges from 110°C in West Coast to >200°C at Puga, Ladakh. The geothermal resources in these areas are a potential source of energy as a substitute to electricity, as well as for direct heat uses, like spa, hot water baths, space heating, food processing, green house cultivation,and aquaculture. The measures for development of geothermal resources in India and prospects of utilization of hot springs in Gujarat are discussed here.

KEYWORDS

Geothermal energy, Tatapani, Unai, Dholera, Gujarat, Spa, Green house

Introduction

The development of modern society is directly linked with energy availability. The ample and regular supply of electricity controls the industrial and agricultural growth of the country, contributing to economic growth and employment opportunities. The energy need of India may be 3,00,000 MW by the year 2030. Presently the installed capacity of power generation is 3,31,118 MW in India, most of which is contributed by fossil fuels.The thermal power capacity in 2017 is 2,19,415 MW, Hydropower is 44,765 MW, nuclear 6780 MW and renewable energy is 60,158 MW. The notion – conventional energy is dominated by Wind and Solar energy, with partial contribution of biogas and biomass. India’s peak demand for power is expected to rise from the current level of 153000 MW to about 690000MW by 2035-36, according to the Draft National Electricity Plan prepared by the Central Electricity Authority (CEA). Such a demand puts heavy pressure on coal production and import of petroleum, ultimately contributing to green house gas emission. Thus, to meet this huge demand for energy, it is essential to switch over to non-conventional sources of energy. Besides wind, solar and biomass, geothermal is an alternate, renewable, environment-friendly source of energy.

Geological Survey of India prepared an inventory of 340 hot springs (Krishnaswamy and Ravishanker, 1982). The hot springs of India are categorized into 10 geographical provinces by Padhi & Pitale (1995). Most of these hot springs are located in remote areas along the Himalayan belt, North East India, Central India and West Coast of India, as given in the table below.

Sr. No.	Geothermal Province	Locality	Temp. Gradient	Heat Flow
I	Himalayan Geothermal Province	i. PugaIsunga Suture Zone ii. Puga Chumthang iii. Parbati Valley, Sutlej Valley, Alaknanda Valley	100°C /m 60±20°C /m 17±5°C /m	200 MW/m^2 130+30 MW/m^2
II	Naga Lusai Province	Naga Lunai Hill range bordering Burma.	Not available	70-100 MW/m^2
III	Andaman Nicobar Islands Province	Barren & Narcondam islands	Not available	100-180 MW/m^2
IV	West Coast Province	West Coast tract in Maharashtra	55±5°C /m	130±10 MW/m^2
V	Cambay Graben Province	Springs in tertiary reactivation area, oil & gas wells	25 to 55°C /m	130±10 MW/m^2
VI	Aravalli Province	Northwest ridges of Aravalli, in Rajasthan and Haryana, Neotectonic activity	41±10°C /m	100±25 MW/m^2
VII	Son Narmada Tapti Province	Tatapani, Salbardi, Anhoni - Samoni Geothermal prospects	40-120°C /m	70-300 MW/m^2
VIII & IX	Godavari and Mahanadi Province	Springs along post - Gondwana faults, e.g. Manuguru, Raigarh	39±10°C /m	80±21 MW/m^2
X	South Indian Cratonic Province	Isolated springs in shield area	30°C /m	60-90 MW/m^2

TABLE 1. Geothermal Provinces of India (Padhi & Pitale 1995)

Geothermal Prospects in India

Puga at Ladakh, Jammu & Kashmir; Tatapani at Chhattisgarh, Tapoban & Manikaran in Himachal Pradesh, Bakreshwar in West Bengal, Anhoni Samoni in Madhya Pradesh, Jakrem in Meghalaya, Garamapani in Assam, Takshing (52°C @ 90 lps) and Chetu Maja (88°C @ 30-60 lps) in Arunachal Pradesh, Surajkund in Bihar, Manuguru in Telangana, Unai and Dholera in Gujarat, are hot springs located in remote areas useful for development geothermal resources for benefit of local population (Fig. 1).

FIGURE 1. Geothermal locations in India

Tatapani Geothermal Field, Balarampur District, Chhattisgarh State

In Central India, hot springs are reported from Salbardi area, Betul district and Amaravati district, AnhoniSamoni in Hoshangabad district, Tatapani-Jhor in Balarampur district, Unkeshwar, Nanded district and parallel to West Coast. Tatapani in Chhattisgarh is the most prominent geothermal field suitable for binary cycle power generation.

Tatapani Geothermal field, Balrampur district, Chhattisgarh State, is located along the Son-Narmada lineament. Thermal manifestations in Tatapani consists of hot springs (50°C - 97°C) in marshy ground, and hydro thermally altered clay zones covering an area of about 0.1 sqkm (Ravishanker, 1987). Tatapani Geothermal field is located 95 km NNE of Ambikapur railway station (Fig.2) and is connected by all weather tar road from Ambikapur.

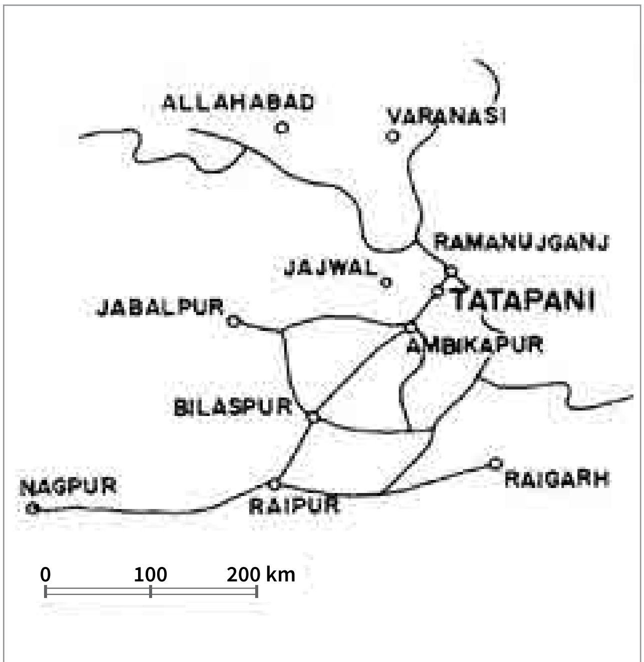

FIGURE 2. Location map of Tatapani

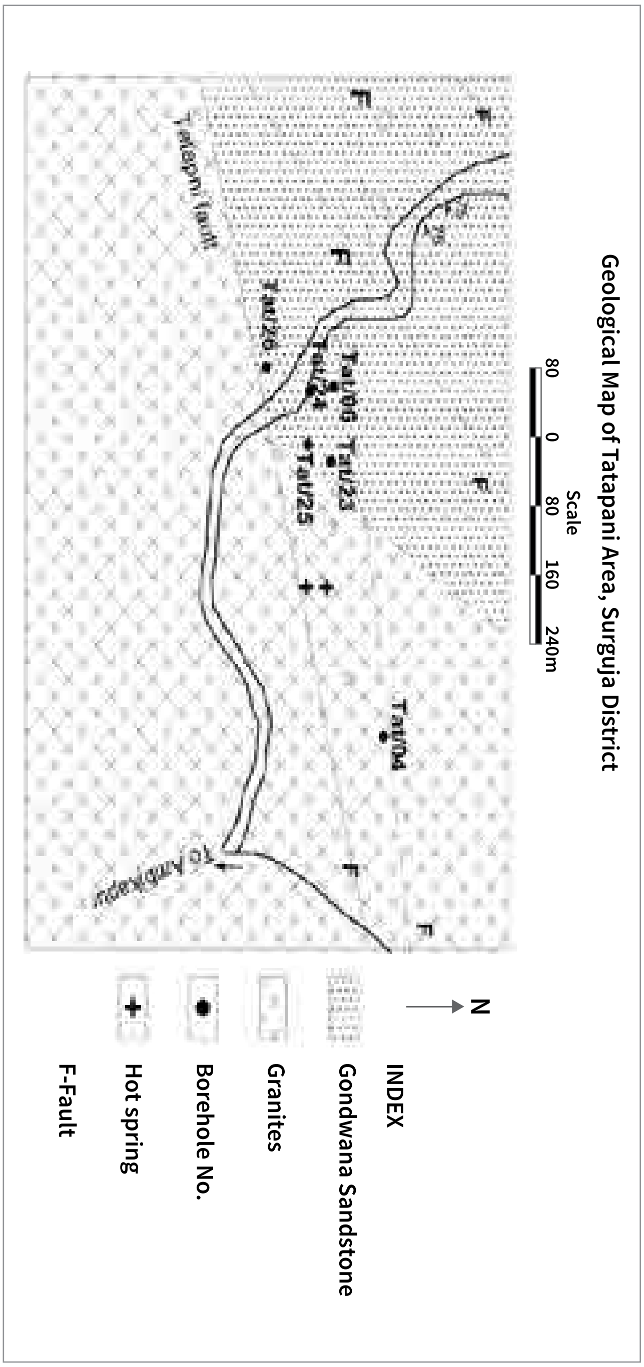

FIGURE 3. Geological map of Tatapani Geothermal Field, Chhattisgarh

Location

Archaean rocks comprising biotite-chlorite schist, biotite gneiss, and few calc-granulite bands cover the area. Precambrian pink porphyritic granite with biotite is exposed south of Tatapani. The pink granite shows the effect of shearing causing alignment of biotite. The fault zone is marked by injections of a quartz vein. The area north-west of Tatapani exposes green shale and siltstone of Talchir Formation, basal conglomerate and feldspathic, coal-bearing Barakar sandstone of Gondwana Supergroup (Fig. 3).

Structure

A fault trending ENE - WSW with sub-vertical dips is noticed near Tatapani village, separating sandstone of Gondwana Supergroup and Archaean/ Precambrian rocks (Patbhaje 2014). The fault is marked by a thick shear zone comprising hard brecciated pink granite and quartz veins. Cross faults trending NE -SW directions are found near village Newadih and Tatapani (Fig 3). The hot springs are mostly confined to this fault system.

Discharge

The hot springs and boreholes at Tatapani were monitored since 1991. The hot springs show temperature varying from 52°C to 97°C. Twenty-six boreholes were drilled, out of which five boreholes GW/tat/6, 23, 24, 25 and 26 discharge water of 104°C (in Tat/25) to 109°C (in Tat/23) on the surface. The discharge of borewells varied from 270 lpm in Tat/6 to 460 lpm in Tat/24. The initial discharge of five bore wells was 1800 lpm, which has reduced to 1125 lpm due to caving and blockage in Tat /24. At Tatapani, the fact that the flow rate is high, that they emerge at near boiling point of water at atmospheric pressure but in association with a gas phase of clear meteoric signature, suggests the presence of a very well developed convective circuit (Misissale and others, 2000).

Chemical analysis

The chemical analysis of water at Chemical Laboratory, GSI Nagpur indicates that thermal water is mostly bicarbonate sodium type with rather high HCO_3 and moderate Cl and SO_4 content. The pH of thermal water ranges from 7.7 to 9.0, chloride content varies from 68 to 140 ppm, TDS from 491 to 545 ppm, SO_4 ranges from 52 to 76 ppm, HCO_3 28 to 169 ppm, sodium varies from 100 to 146 ppm, magnesium, calcium and potassium content is low; SiO_2 varies from 131 to 161 ppm, Boron <1 ppm and fluorine content varies from 10 to 20 ppm (Sarolkar & Mukhopadyay, 1998). The thermal water contains low arsenic and high fluorine.

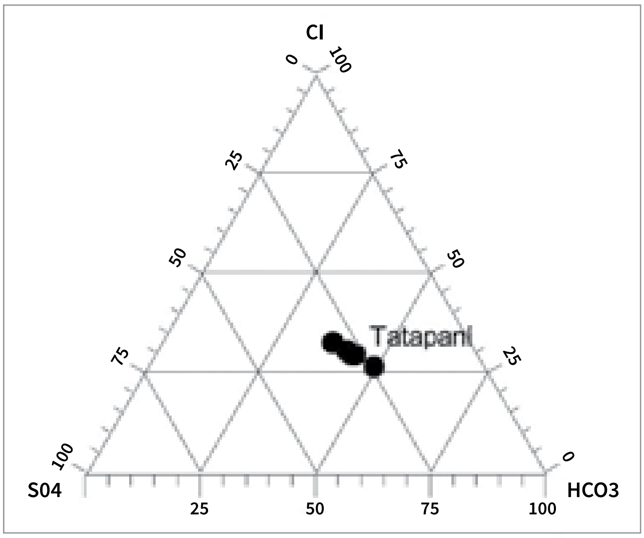

FIGURE 4. Cl-HCO_3-SO_4 ternary diagram, Tatapani

The ternary Cl- SO_4 -HCO_3 diagram (Fig.4) shows that Tatapani thermal water is the mixed chloride-bicarbonate type (Sarolkar 2005). The thermal water falls in the HCO3 field with minor sulphate content. The above observation is supported by Na-K-Mg ternary plot, which shows that the thermal water samples from Tatapani plot in Mg field (Fig.5) suggesting that the thermal water is immature, and may not represent the geothermal water from the deep reservoir (Giggenbach, 1997).

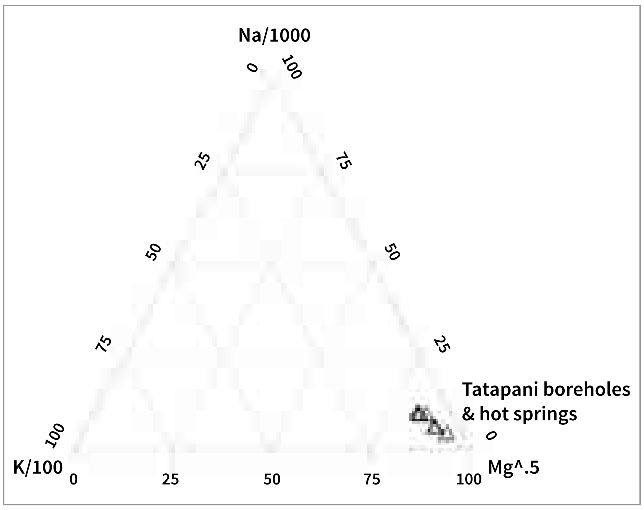

FIGURE 5. Na-K-Mg ternary diagram, Tatapani

This suggests that the Tatapani thermal water is mostly meteoric water heated during percolation to the shallow reservoir and mixed with ground water during ascending to the surface. The deep reservoir geothermal water is still not encountered in the bore wells. Uniform boron content points to the common source of water (Wright 1991).

Isotope Study

The oxygen and deuterium isotope study of Tatapani is depicted in Fig.6. The oxygen isotope study of Tatapani thermal water indicates that the thermal water is mostly meteoric in origin. (Misissale et al., 2000). The thermal water from the bore well Tat/26 shows enrichment in ^{18}O content as compared to the other water samples.

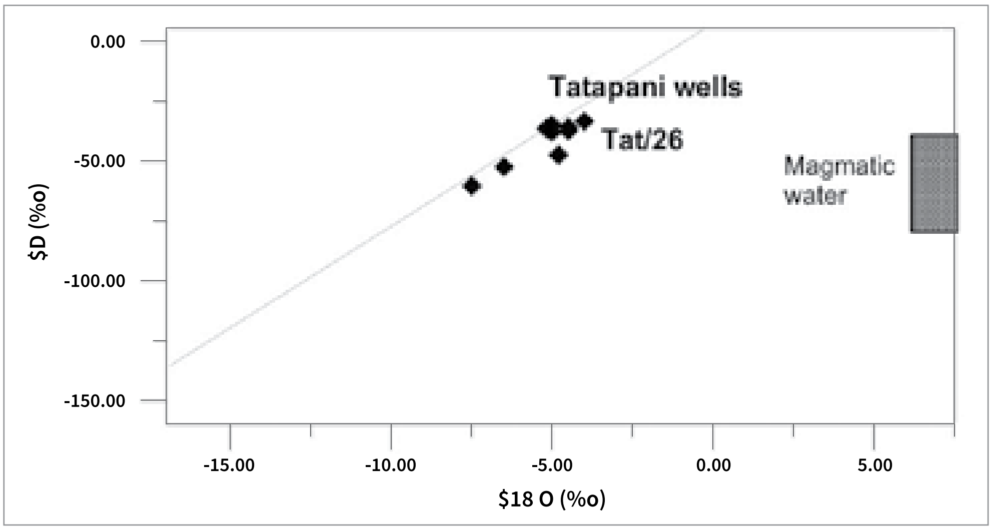

FIGURE 6. Plot of isotope content of thermal water

The bore well Tat/26 has a maximum ^{18}O shift, which may be due to some water-rock interaction (Sharma 1996). The isotope analysis has confirmed the meteoric origin of thermal water at Tatapani. Tritium content in Tatapani water indicates residency period of 30-40 years (Thussu et al. 1987).

Reservoir Temperatures

The indicated reservoir temperatures were calculated by silica and Na/K geothermometers (Table 2). The silica geothermometer shows 137°C to 166°C, while Na/K geothermometer indicates reservoir temperature of 168°C to 237°C. The quartz (Fournier, 1979, 1981) and K-Mg thermometer tends to respond more quickly to sharp cooling gradients and subsequent re-equilibrium (Simmons et al. 1994), which may explain the discrepancy in reservoir temperatures indicated by quartz solubility and Na-K method. The hot water shows mixing at a shallow level, suggesting that temperatures by Na/K method may be more appropriate. Thus, the indicated reservoir temperature at Tatapani is probably > 180°C.

Sl no.	Method	Min. Temp	Max. Temp
1.	Silica, max steam loss	137°C	152°C
2.	Silica, no steam loss	128°C	166°C
3.	Na/ K(F)	168°C	217°C
4.	Na / K(G)	177°C	232°C

TABLE 2. Reservoir temperatures indicated by aqueous geo thermometers

Geophysical Survey

Deep resistivity surveys at Tatapani show the presence of low resistivity zone at the depths of 300 m and 600 m, respectively. The AMT surveys have indicated the zone in the sub surface, close to the hot springs, which may correspond to the hot water formation (Joga Rao et al. 1987). AMT survey at Tatapani has depicted an elongated E-W trending telluric low, suggesting the presence of a conductive zone in this direction. (Harynarayan, 1998). The Tatapani MT anomaly is associated with a narrow conductive fault /fracture zone extending to deeper levels in addition to shallow aquifer with a width of about 3 km (Harinarayan, 1998).

Fluid Inclusion

Fluid inclusion studies on primary and secondary inclusions in quartz vein and calcite / zeolite, in cavity fillings, show Th of 139° to 258°C, during the heating cycle. Nearly 47% fluid inclusions measure Th of >200°C and 38% measure Th of 150°C to 200°C. Rest of the inclusions measure Th of <150°C. Thus, fluid inclusions suggest reservoir temperature around 200°C. The temperature of melting (Tm) of fluid inclusions ranges from -0.3°C to –21.5°C, corresponding to salinities ranging from 0.5‰ to 23.3‰ with an average of 8.9‰, NaCl equivalent. The low salinity of most of the fluid inclusions suggests a meteoric origin for the geothermal waters.

Hydrothermal alteration

Hydrothermal alteration is controlled by temperature, permeability and pressure conditions in a geothermal reservoir. The hydrothermal minerals at Tatapani are smectite, illite, stilbite, quartz, albite, laumontite, chlorite, calcite and pyrite. Widespread silica sinter observed in the area suggests that the geothermal fluid was alkali chloride type. The smectite-illite, and calcite hydrothermal assemblage in boreholes up to 200 m depth indicate that the geothermal field was in the range of 160°C -180°C. Similarly, the laumontite suggests a maximum temperature of 240°C to 250°C (Liou, 1971). At Tatapani, platy calcite is reported at two levels 60 m and >120 m, indicating that the zone of boiling shifted to greater depths with times. Hydrothermal epidote provides unequivocal evidence of temperature in excess of 250°C during hydrothermal activity (Absar, 1991). Microscopic studies revealed the presence of epidote, suggesting that the TGF had attained a temperature of 250°C, in the past, indicating the possibility of higher temperatures at greater depths.

Sl no.	Method of Survey	Indicated temperature
1.	Geochemical aqueous Geothermometers	160 °C to 190°C
2.	Hydrothermal alteration	180°C to 250°C
3.	Fluid inclusion study	140°C to 250°C
4.	Discharge monitoring	138°C

TABLE 3. Inferred reservoir temperatures

Borehole testing

Pressure and temperature profile survey of the bore wells was carried out in collaboration with the ONGC (Fig.7). The maximum temperature recorded in borehole Tat/23 is 112.5°C, at a depth of >200 m. The bottom borehole pressure ranges from 21 bars in bore well Tat/26 at 210m to 34 bars at 350m depth in Tat/ 23. Static pressure in all the wells is higher than the hydrostatic head, and as a result, all wells are going to flow.

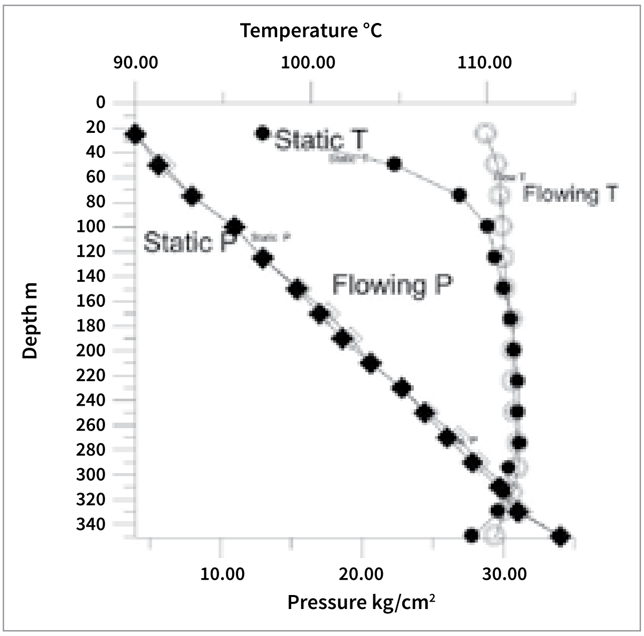

FIGURE 7. P & T profile of bore well Tat/23.

The temperature in the bore well shows a steady increase up to a depth of 250 m below which slight temperature inversion is recorded in boreholes Tat/6, 23 & 25. The permeability is mostly fracture controlled.

The estimated reservoir potential at Tatapaniupto 1500m depth is 11 MW (Sharma & Sud, 2000) to 18 MW (Pitale et al., 1996). The configuration of the geothermal reservoir is elliptical conical in shape (Patbhaje 2014). The binary cycle power potential at a depth of 1500m to 2000m is estimated to be 30 MW, at a temperature of 150°C.

Environment

The thermal water is mostly alkaline with low TDS and low toxicity. The main pollutants are silica, arsenic (2 ppb) and fluorine (10-20 ppm). Monitoring of SiO_2 and F is essential during the production stage to assess pollution effect. Dilution by cold surface water with low fluorine content is low cost, feasible method for control of fluorine toxicity. Gases, H_2S (0.01 mole %) and CO_2 (12.9 mole %) are reported from the geothermal water.

Hot Springs of Gujarat

The main hot springs in Gujarat are Unai (55°), Dholera (42°C to 45°C), Tulsi Shyam (50°C to 60°C), Tuwa (63°C) and Barbara (43.5°). Besides these,numbers of hot springs ranging in temperature from 36° to 42°C are reported from Gujarat (GSI, 2002). Some boreholes drilled for oil exploration in Cambay basin have also reported water and steam.

PDPU is presently working at Dholera hot springs. The

Dholera hot spring contains Silica 12 to 16 ppm, TDS 4844 to 5120 ppm, Na 1107 to 1902 ppm, K 16.6 to 26.7 ppm, Ca 95 to 146ppm, Mg 39 to 72 ppm, Cl 2426 to 4319 ppm, SO4 12 to 56ppm, bicarbonate 40 to 190 ppm, B 3.88 to 4.6 ppm (Shah et al , 2017). Temperatures of 60°C to 75°C is indicated by silica geothermometer and 97°C to 134°Cby Na/K method, for Dholera hot springs. The temperatures estimated from the cross-plots and the Geothermometric analyses show that the springs were a part of the low enthalpy geothermal reservoir system. It is also evident that there is significant mixing of the geothermal waters being produced with the deeply seated circulation system even though the region is located in a sedimentary area (Shah et al., 2017).

Unai hot spring near Surat, reported Silica 16 to 32 ppm, Na 158 to 340 ppm, K 10 to 15 ppm, Cl 345 to 540 ppm, SO4 42 to 108 ppm, HCO3 42 to 126 ppm (Sahajpal et al., 2015). The indicated reservoir temperature is 71°C to 86°C by silica method and 178°C to 217°C by Na/K method. MT survey has suggested that a shallow aquifer body is identified below the hot spring, where a temple exists. It is believed, that if a well is drilled up to 1 km, the same may encounter this shallow reservoir (Sahajpal et al., 2015). The temperatures indicated by silica geothermometer are low suggesting probable mixing of saline water at a shallow level. The water analysis by GSI (2002) and PDPU (Shah et al., 2017, Sahajpal et al., 2015), indicated reservoir temperature as mentioned below.

Sample by	Location	T SiO_2	TSiO_2	T Na/K
GSI, 2002	Tulsi1	137	139	202
	Tulsi2	133	134	187
	Dholera	84	86	118
	Tuwa1	83	84	-
	Tuwa2	122	123	88
PDPU (2015 & 2017)	Unai1	71	72	217
	Unai2	86	87	178
	Unai3	86	87	151
	Dholera 1	55	56	134
	Dholera 2	64	65	97

TABLE 4. Indicated reservoir temperature of hot springs of Gujarat

The reservoir temperature indicated by silica and Na- K method differ much, suggesting that the silica content is modified during ascending to the surface, by conductive cooling or mixing with shallow water. Considering this, a hot water sample from below the ground water level will be useful in getting actual geothermal parameters.

The available data suggest that besides Unai and Dholera geothermal prospects, Tulsi Shyam hot spring area is also a promising area for investigation.

Utilization

Besides power generation, the hot water can be utilized for different low temperature, uses in industry and tourism (Lindal 1979).

Binary cycle power plant (Temperature 140°C to 100°C)- The hot water is used to vapourize a fluid of low boiling point which is used to generate electricity. Useful in hot springs of the Himalayan belt, Tatapani Chhattisgarh, Bakreshwar West Bengal, West Coast and hot springs of Gujarat.

Refrigeration for the preservation of fruits and vegetables (Temperature >100°C): The effluent water from the proposed power plant at Puga, Ladakh, Manikaran, Tapoban Himalayan belt, Tatapani Chhattisgarh, Cambay basin, West Coast, Gujarat, geothermal prospects may be used for refrigeration plant of ammonia absorption type.

Greenhouse (Temperature required, 50°C-80°C): The hot water can be used in space heating and hot bed heating in green hose cultivation. Useful at Puga, chhumthang field in Ladakh, Manikaran, Tapoban, Parbati valley in Himalayan belt, Tatapani in Chhattisgarh, Gujarat, West Coast area.

Food processing - Fruits and see-weed drying, drying of vegetables, onions,and fishes, food processing (Temperature <100°C): Used for the food processing industry. Possible at Tapoban, Parbati valley, Manikaran in Himalayan belt, Arunachal Pradesh, Gujarat, Cambay basin, West Coast.

Industrial uses - cement block curing, timber washing, sericulture (Temperature 80-140°C): The low-temperature hot water is used for sericulture, cement block curing, vegetable cleaning,and small-scale industrial uses. Possible at Puga, Manikaran, Parbati valley, Sohna, Tatapani distt Surguja, West Coast, Bakreshwar, Cambay basin, Surajkund, NE Region.

Aquaculture and agriculture, crocodile farming (Temperature <60°C): The hot water of specific composition and temperature is used for aquaculture. Useful in Manikaran, Tapoban, Parbati valley in Himalaya, Arunachal Pradesh, Gujarat, Tatapani Chhattisgarh, Bakreshwar West Bengal, Puga-Chhumthang in Ladakh, Manuguru in Andhra Pradesh.

Tourism, Spa, Swimming pool (Temperature >40°C): Almost all geothermal localities. Puga-Chhumthang, Parbati valley, Manikaran, Tapoban, Tatapani Chhattisgarh, West Coast, Manuguru in Telangana.

Extraction of rare metals, Mineral water industry (Temperature required, >30°C): separation of borax, sulphur, and helium from hot water at Tatapani, Chhattisgarh (Ag, He). Deposition of silver is recorded in the scaling on discharge pipes of boreholes at Tatapani, Dist. Surguja (Pitale et al. 1995).

Conclusion

The hot springs located at Puga, Manikaran, Tapoban in Himalayan belt, Tatapani in Chhattisgarh, Bakreshwar in West Bengal, Manuguru in Telangana are active geothermal systems in India. The investigation at Tatapani geothermal field indicated reservoir temperature of 180°C to 200°C, which is useful for installation of binary cycle geothermal power plant. Besides, direct heat uses like spa, hot water bath, tourism, sericulture, cold storage,etc., may contribute to developing local industry in remote places. The hot springs at Dholera & Unai Gujarat, show cold water mixing at a shallow level. Investigation to a deeper level is necessary to assess the actual potential of these geothermal prospects.

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