Geochemical Characteristics of Bakreswar and Tantloi Geothermal Province, India

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ABSTRACT
Present investigation is based on the geochemistry of thermal springs located at Bakreswar (West Bengal) and Tantloi (Jharkhand) geothermal fields. These thermal springs are issuing through Precambrian granites that are enriched in radioactive elements like uranium, thorium and potassium. The helium and radon emanations in the thermal gases are 3 % v/v and 885 kBq/m³ respectively. Considering the fluid flow rate, radioactive element content in the granites, geothermal gradient and heat flow values, these sites can generate minimum of about 500 MWe.

1. INTRODUCTION
West Bengal generated about 7620 MWe of electricity in 2012-2013 from coal based power plants, 16 MWe from biomass and 4.3 MWe from wind (MSPI, 2013). The amount of CO₂ emission from the power plants, assuming 978 kg CO₂ /MWh (Chandrasekharam and Bundschuh, 2008), is about 7 million kg. Although west Bengal has excellent, high temperature geothermal systems at Bakreshwar, the state government and the energy policy makers did not see or recognize this resource. Further, Tantloi geothermal site which falls in the State of Jharkhand is located only a few kilo meters north of Bakreshwar in west Bengal. Besides heat, the gases associated with the geothermal system are enriched with helium. The Bakreshwar thermal power plant located a few kilometers from the geothermal site is generating 1050 MWe. This paper reports the details of Bakreshwar and Tantloi geothermal sites in west Bengal and Jharkhand-west Bengal state border.

2. GEOLOGY AND STRUCTURE
The SONATA lineament that extends from Gujarat to west Bengal is a mega-mid-continent lineament and represents a major suture zone (Naqvi, 1976). The well-known Tattapani thermal springs are located over this lineament (Chandrasekharam and Antu, 1995, Chandrasekharam, 2000, 2005, Chandrasekharam and Chandrasekhar, 2010, Minissale et al., 2000). This lineament extends eastwards towards Jharkhand and West Bengal and is cut by a N-S trending fault. Precambrian granites and gneisses, Gondwana sedimentary rocks and Rajmahal volcanics characterize this region (Fig. 1). The Bakreshwar and Tantloi thermal springs follow along the N-S trending fault that cuts the main mega SONATA lineament (Nagar et al., 1996, Singh et al., 2014). The N-S fault is characterized by silicification and brecciation, that can be traced over 1.4 km. The overall geological formations are similar to that of Tattapani, located over the SONATA lineament (Chandrasekharam and Antu, 1995, Minissale et al., 2000).

Figure 1: Regional geological setting, location of the study area and water samples collection site modified after Nagar et al., 1996, Singh et al., 2014).
Singh et al.

Two boreholes (< 200 m deep) have been drilled at Tantloi to decipher the sub-surface geology. The boreholes yield continuous discharge of hot water of 65°C with profuse steam. The geothermal gradient measured in two boreholes is 90 °C/km and the reported heat flow value is 200 mW/m² (Shankar, 1988).

3. HYDROGEOCHEMISTRY

The concentration of major ions in five thermal springs from Bakreshwar-Tantloi area is given in Table 1.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>pH</th>
<th>T °C</th>
<th>TDS</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>HCO₃⁻</th>
<th>SO₄²⁻</th>
<th>SiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.5</td>
<td>70</td>
<td>489.9</td>
<td>102.17</td>
<td>2.13</td>
<td>1.33</td>
<td>0.01</td>
<td>107.47</td>
<td>50</td>
<td>29.42</td>
<td>98.6</td>
</tr>
<tr>
<td>2</td>
<td>9.3</td>
<td>68</td>
<td>464.2</td>
<td>95.4</td>
<td>2.41</td>
<td>1.46</td>
<td>0.15</td>
<td>98.98</td>
<td>25</td>
<td>35.56</td>
<td>101.2</td>
</tr>
<tr>
<td>3</td>
<td>9.2</td>
<td>65</td>
<td>486.2</td>
<td>109.02</td>
<td>2.28</td>
<td>1.23</td>
<td>0.01</td>
<td>114.97</td>
<td>55</td>
<td>18.21</td>
<td>92.6</td>
</tr>
<tr>
<td>4</td>
<td>9.3</td>
<td>56</td>
<td>515.3</td>
<td>115.34</td>
<td>2.24</td>
<td>1.26</td>
<td>0.01</td>
<td>122.46</td>
<td>65</td>
<td>12.8</td>
<td>97.9</td>
</tr>
<tr>
<td>5</td>
<td>9.3</td>
<td>70</td>
<td>502.7</td>
<td>110.8</td>
<td>2.24</td>
<td>1.26</td>
<td>0.01</td>
<td>117.46</td>
<td>60</td>
<td>16.65</td>
<td>97.0</td>
</tr>
</tbody>
</table>

The thermal water are enriched in Cl relative to HCO₃ and the Na⁺K content is far greater than Ca and Mg. Thus the water samples can be grouped as Na-Cl type. Such type of waters, where Cl is greater than HCO₃, is very common in water circulating in granite aquifer for a long period of time. Prolonged interaction with rocks of granitic composition makes the waters saline due to release of chlorine from minerals such as mica and apatite. Granite water interaction experiments conducted at elevated temperatures confirm incidence of such high chloride content in thermal waters (Savage et al., 1985, 1987, Chandrasekharam and Antu, 1995, Singh and Chandrasekharam, 2010, Singh et al., 2014). Further, low HCO₃ content and high issuing temperature indicates that the thermal waters are not mixing with any other source of water, like groundwater during its ascent. Hence the cation geothermometers should give near reservoir temperatures.

The most significant feature of these thermal springs is that the thermal gases associated with the thermal springs contain anomalous high content helium. The measured helium content in the gases vary from 1 to 3 % v/v (Ghose et al., 2002) and is similar to that reported in the thermal gases of Tattapani thermal springs located over the SONATA lineament (Minissale et al., 2000, 2003). The measured radon activity in the thermal gases is about 885 kBq/m³ and in the thermal springs is 46.9 kBq/m³ (Chaudhuri et al., 2010). This could be due to the decay of radioactive minerals in the granite which causes the production of helium as well as radon in the thermal gases.

A pilot plant to extract helium from the thermal gases at Bakreshwar was installed and this extraction plant demonstrated the feasibility of extracting helium from geothermal gases and purifying the same to 99.9% on a commercial basis (Fig. 2).
Even the soils around these sites are enriched in helium and the helium content in the soils varies from 46 to 83 ppm (Nagar et al., 1996; Chandrasekharam, 2000). Very high He and very low Kr/Xe ratio (0.262) in the gases suggests the source for these elements to be the basement granites (Ghose and Chatterjee, 1980; Ghose et al., 1989).

4. GEOTHERMOMETERS

Estimated reservoir temperature calculated based on the chemical geothermometers (Table 2) gave values between 119 and 139 ºC. However, the oxygen isotopes registered oxygen shift (Singh et al., 2014) indicating temperatures > 220 ºC as only above this temperatures exchange of oxygen isotopes occurs between rocks and fluids in contact (Nuti, 1991; Giggenbach and Soto, 1992; Giggenbach, 1992). Considering the geology and tectonics of this region, the granites must be the main reservoir supporting the geothermal system in this region.

Table 2: Estimated reservoir temperature based on cation and silica geothermometers

<table>
<thead>
<tr>
<th>Surface</th>
<th>T ºC</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>111.5</td>
<td>132.0</td>
<td>120.1</td>
<td>136.4</td>
<td>132.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>68</td>
<td>119.1</td>
<td>139.3</td>
<td>125.0</td>
<td>137.9</td>
<td>133.3</td>
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<tr>
<td>3</td>
<td>65</td>
<td>109.8</td>
<td>130.3</td>
<td>120.6</td>
<td>132.9</td>
<td>129.1</td>
<td></td>
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<tr>
<td>4</td>
<td>56</td>
<td>107.8</td>
<td>128.4</td>
<td>119.2</td>
<td>136.0</td>
<td>131.7</td>
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<tr>
<td>5</td>
<td>70</td>
<td>109.9</td>
<td>130.4</td>
<td>120.3</td>
<td>135.3</td>
<td>131.3</td>
<td></td>
</tr>
</tbody>
</table>


5. POWER GENERATION CAPACITY

The Bakreshwar thermal springs are being monitored for the temperatures, helium gas discharge and the fluid flow rate by the Variable Energy Cyclotron Centre at Kolkata since 1996. The measured cumulative flow rate of three springs in Bakreshwar is 20 L/m of gas and 800 L/m of fluid. Like other geothermal sites located in granite reservoirs (Chandrasekhar and Chandrasekharam, 2009, Chandrasekharam and Chandrasekhar, 2008), the Tantloi and Bakreshwar geothermal systems are also located in high hat generating granites. Based on the radioactive element content, heat flow values and the area occupied by these high helium emitting granites, the power generation capacity of these granites have been estimated following the procedure adopted by Somerville, et al., (1994). The estimate shows that these sites are able to generate energy equivalent to 3.133 x 10¹⁰ BTU saving about 10⁶ Kg CO₂.

6. CONCLUSIONS

The Bakreshwar-Tantloi geothermal sites appear to a part of the EGS located along the SONATA lineament that hosts similar kind of geothermal systems. These sites are located very near to the Bakreshwar coal based thermal power plant that is generating 7620 MWe of electricity emitting about 7 million kg CO₂. The geothermal sites as discussed above can support part of the present demand thus reducing about 1 million CO₂ emissions. This will help the rural population to get clean energy and replace the current practice of generating power from biomass.

REFERENCES


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