Commercial Utilization of West Coast Geothermal Resources of Maharashtra, India

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Abstract- The purpose of this paper is commercial evaluation of West coast geothermal resources of India. The western parts of Maharashtra State are also known as the economic back-bone of India, where in about 60% of Agro-Industrial products is being manufactured from this part. Considering this fact, it is necessary to evaluate the west coast geothermal resources for non-electric uses. To save the expense of drilling investigation, indirect methods of evaluation of reservoir are chosen. The petrological, mineralogical, geochemical and geophysical survey reports of the areas are thoroughly studied. On the basis of pre-existing data, the evaluation of the area reveals low temperature. Geochemical data reveal that, there is a marginal reduction in alkalis at 100˚C, where as they registered enrichment in the resultant solution of experiments at 150˚C.The chemical analysis of the basaltic gains after reaction at 175˚C and 200˚C indicates an increase in tempreture. On the basis of above data, the area was found to be suitable for commercial utilization of geothermal energy for non-electric uses in agricultural and industrial sectors.

Keywords- West Coast Geothermal Resources of India (WCGRI), Non-Electric Uses (NEU), Low Grade Geothermal Energy (LGGE).

1. Introduction

The energy crisis has indisputably demonstrated that there is an urgent need to rapidly develop all possibly conceivable, renewable, alternative natural resources to meet the ever increasing global and domestic demands of energy for multipurpose applications. The unfavorable effects of the rapid growth of fossil fuel prices stimulated much new work aimed at identifying alternative, cheap and renewable energy resources in order to reduce most of the polluting emissions in the atmosphere while meeting energy requirement posed by these industries. This resulted in the revision of many previous opinions about the economic viability or practicality of using sources of low grade thermal energy of west coast of India. The low grade heat content of geothermal springs had been considered as uncompetitive with any fossil fuel. The particular characteristic of each spring needed a separate technical design, individual choice of materials, specific control system etc. resulting in increased capital expenditures and high running costs. If the heat load is carefully selected so that heat demands and consumption are maintained to the demand, specific capability of the spring than it is possible to prepare a design which will be indisputably economical. Therefore, in the west coast of India, there are several establishments which can be connected with such hot springs as the heat consumer, where plants and processes are coupled with thermal energy. In addition, the accumulation of technical know-how makes the investment on geothermal projects less risky and hence, more advantageous. In the world, the non-electric uses of geothermal energy have quite a significant role in the developing and developed nations. In future, geothermal energy would gain greater significance in the west coast of India as well. The energy crisis has demonstrated that there is an urgent need to rapidly tap & develop all possible natural non- conventional resources to meet the ever increasing national demands for energy for commercial uses. Geothermal resources of west coast happen to be the hydrothermal type, medium to low grade, hence, not suitable for electricity generations. Therefore, this area has been ignored for commercial use Pandey, et.al. [7].

According to the National Renewable Energy Laboratory, "The Earth houses a vast energy supply in the form of geothermal resources. Domestic resources are equivalent to a 30,000-year energy supply at our current rate for the United States! In fact, geothermal energy is used in all 50 U.S. states today. But geothermal energy has not reached its full potential as a clean, secure energy alternative because of issues with resources, technology, historically low natural gas prices, and public policies [13]. These issues affect the economic competitiveness of geothermal energy. In spite of the rapid increases in the use of the geothermal energy in the world, it still constitutes a small fraction of total energy consumption i.e., 1 MW in India Roy & Gupta [10]. In India in spite of huge recourses, the geothermal energy is still a relatively new industry as compared to other developing nations such as: Philippines, New Zealand, Costa Rica, Nicaragua, Papua New Guinea, Guatemala, Iceland, Ireland, Mexico, Turkey, Indonesia, Ethiopia, El Salvador, and Kenya.

In the west coast of India as shown in “Fig.1”, over 18 hot water springs, with surface temperatures ranging between 40˚ to 72˚ C, are scattered over a distance of 360 km., yet the systematic studies to assess the value of these indigenous resources were not seriously carried out. The west coast line stretching from Bharuch (Gujarat) to Panaji (Goa) is a significant industrial area in the country with many types of industrial establishments such as Textile, Sugar, Food Processing, Paint, chemicals & Pharmaceutical, Paper & pulps, Plastic, Fertilizers and Petrochemicals.

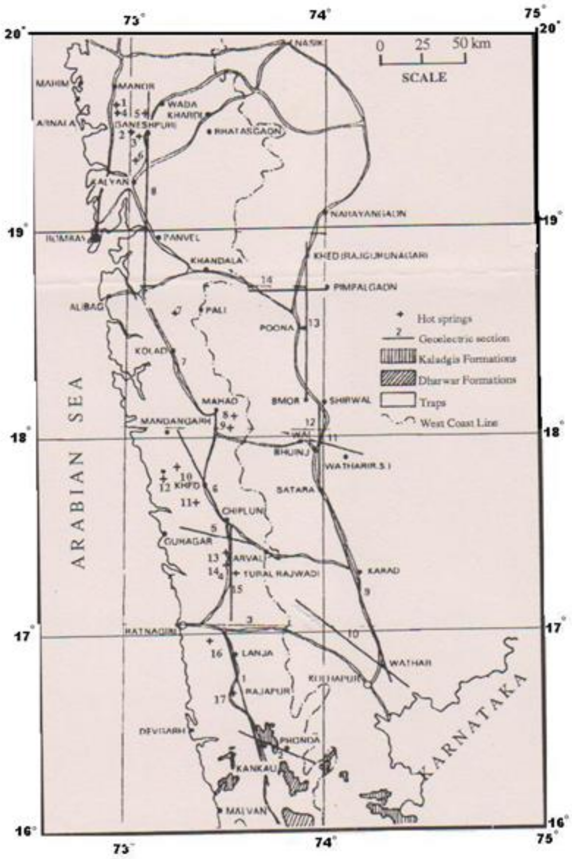

Fig. 1. Location Map of West Coast Geothermal Resources of India.

In order to reduce most of the pollutants released in the atmosphere while meeting the energy requirement of these industries, it is necessary to turn towards the resources such as geothermal energy. The west coast-zone of India supports the extensive agricultural activities having the most productive land of the country. The main agricultural products in the region in which over 90% of the area is being used for cultivations of Sugar-cane, Cotton, Ground-nuts, Tobacco, Soya bean, Onions, Tomato, Grapes and Banana.

2. Pertological Characteristics of West Coast of India

The major part of the west coast of India is occupied by the volcanic units of Indian subcontinent known as Deccan Trap. Horizontal basalts in the Trap are anisotropic in nature, highly fractured, weathered amygdaloidal type, in some places Dolerites, Rhyolites, Granophyres, Gabbros and Limburgites also found to occur in this area. These eruptions are of sub-aerial environmental types, or eruption might take place along linear fissures respectively. The Deccan Trap basalts are found to be remarkably uniform in petrographic compositions. The common type of rock in the area is an Augite Basalt. These basalts consist of plagioclase (labradorite), pyroxenes (augite), quartz, iron ore and olivine minerals in some places. A number of secondary minerals are found such as Zeolite and Netrolite as alteration products of volcanic glass. The only variation between these minerals is clear in the color and textures. The variation in color is from grayish-green, black or its lighter shades, or even a brown buff color. The texture varies from a homogeneous cryptocrystalline mass to coarsely crystalline dolerite Wadia [12]. A remarkable characteristic of Deccan Traps is that, they are persistently horizontal through-out their wide area. In some parts, the traps are warped into very gentle anticlines and synclines, but these are believed to be due to the influences of the subsequent tectonic movements rather than the original inclination flows Pascoe [8]. These basalts generally form shallow unconfined aquifers as shown in the “Fig.2”.

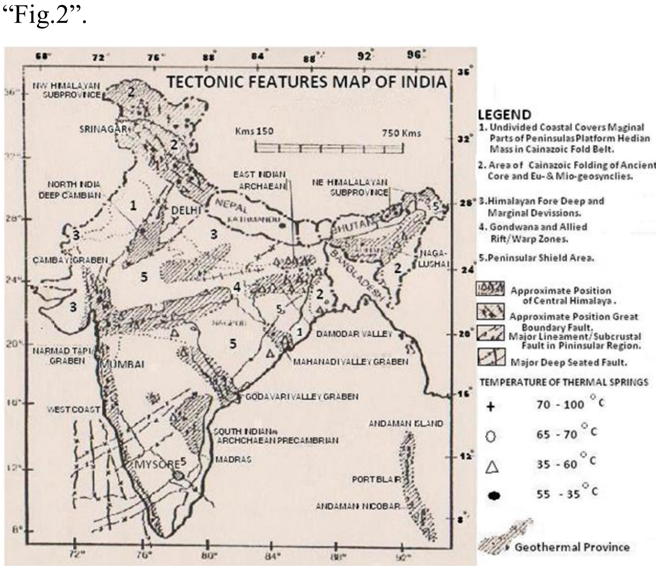

Fig. 2. Shows various Tectonic & Geothermal Province of India.

3. Electrical Resistivity of the West Coast

The geothermal area is mostly situated on plate boundaries and volcanic zones as shown in Figure No.2, where heat flow and permeability are moderate to high and the average density of basalt in the area is approximately 2.8g/cm^3. Such basalts are normally characterized by thermal capability of 0.2 Cal/g. degree centigrade, thermal diffusivity of 0.009 cm^2.sec degree centigrade and thermal inertia 0.053 Cal/cm^2/sec. degree centigrade Agrawal and Joshi [1]. The rocks in a geothermal reservoir head have high porosity and permeability, in order to maintain percolation of geothermal fluid within the reservoir cap rocks. The geothermal reservoir has both vertical and horizontal permeabilities Thomason and Ömer [11]. Since in the west coast of India most of the rocks are homogeneous and basaltic; hence, they are suitable for geothermal reservoir.

The geometry of the west coast of India was delineated from interpretations of previous geophysical surveys. These surveys were used in order to control and have an idea about the thickness and depth of the geothermal reservoirs. Moreover, relevant hydrological information about the basalt in particular porosity and fluid resistivity were also derived mainly from geophysical survey reports Arora [4]. It is observed that heat flow and geothermal gradients are the highest in the volcanic and seismically active zones.

Earthquakes in West Coast of India between 1993-2011 are an indication of availability of active tectonic zones. Based on the detailed resistivity studies that were conducted within an area about 460 km, it is observed that the anomalies are extensive and considerable within the Trap region ranging from 50 to 150 ohm. m. Arora [4]. These studies enable us to reconstruct the data on various levels, the subsurface maps as well as the cross sections as shown in "Fig.3".

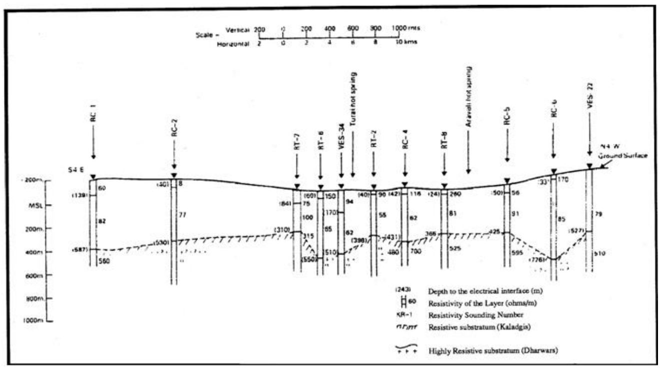

Fig. 3. Shows Geo-electrical Cross Section of West Coast of India after Arora [4].

From the geo-electrical section, it can be seen that a prominent layer having a resistivity value varying between 55 and 110 ohm. m is consistently all along the section, which indicates the presence of the Traps. It may further be seen that the results of the sounding conducted near the Tural hot spring show that the deepest probed layer has a very high resistivity value. Although Tural hot spring discharges from the highly fractured volcanic units which have widespread extension along the western coastline, the high resistivity value represents a very low sea water intrusion along this part of the west coast of India.

4. Hydrochemical Characteristic

According to the graphical representation of Piper diagram of the thermal hot springs water of the west coast India, there are mainly four types of waters. These are:

I). Na-Ca-Cl-SO_4 -Cl,

II). Na-Ca-Cl-SO_4,

III). Na-Ca-Cl-SO_4-HCO_3, and

IV). $NaHCO_3$ types.

Ca^{++} concentration varies from 130-1800 ppm. The Piper diagram reveals that the sea water is intruded through the basaltic terrain and gains Ca^{++} and Mg^{++} but loses Na^+-K^+ during cation exchange along the coastal line as shown in Piper diagram in Figure No.4. The hot water contains high Ca^{++}, very low Mg^{++} and SO_4^{--}. From the previous studies, it is observed that the interaction between basaltic rock and water at elevated temperature caused an increase in the Ca^{++} and depletion in the Mg^{++} contents at 200°C. Interaction of non-saline water with basalt did not yield Ca^{++} rich solutions, whereas interaction with pure sea water does produce Ca^{++} enrichment. This leaves the question open to understand the behavior of low-saline water with basalt, the solution for which would aid in understanding the genesis of these Ca^{++} rich coastal thermal waters. It has also been observed that Ca^{++} tends to attain a steady state level for a particular temperature, where the source water has 4000 ppm or 400 ppm Ca^{++} Mauthuraman [6]. Decreasing Mg^{++} content along the west coast line is related to the extension of the sea water intrusion zone along this part of the study area. Moreover, K^+ uptake from sea water admixtures by basalt at low temperatures has been demonstrated by this research. Such a mode of K^+ depletion in the up flow zone of the thermal water would result in the calculation of low temperatures by the alkali geo-thermometers. However, the majority of the thermal waters, especially the Na^+- Ca^{++}- Cl^- and Ca^{++}- Na^+ -Cl^- types, may owe their salinity to nearby sea/tidal waters or their evaporates.

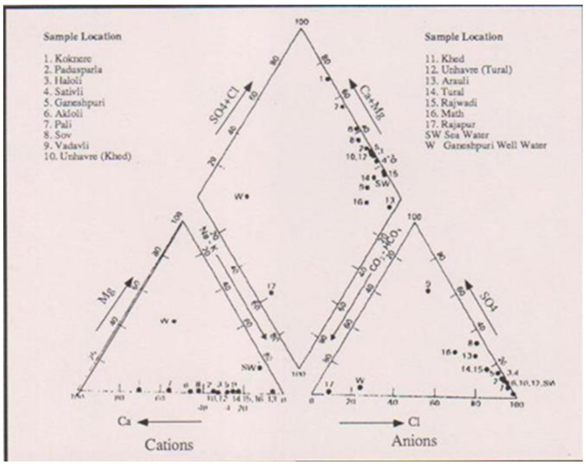

Fig. 4. Piper Diagram of thermal water of west coast after Pandey, et.al. [7].

Dissolved solid of high sulfate thermal waters along the sulfate coast line seems to have been contributed by evaporates rather than sea water. Thus, the high Na^+ - Cl^- and low SO_4^{--} values may not be related only to the sea water intrusion phenomena. But it may also take place through the dissolution of the available evaporates Pandey, et.al. [7]. Table 1 shows surface temperatures and discharge rates of geothermal springs in west coast of India.

Table 1. Surface temperature of geothermal springs in the west coast of India.

S.No.	LOCATION	SURFACE TEMP. IN ˚C	RATE OF FLOW IN LITERS /HRS.
01	KOKNERE	54˚	11280
02	PADUSPADA	42˚	5490
03	HALOLI	44˚	5635
04	SATIVLI	58˚	3670
05	AKLOLI	54˚	3274
06	GANESHPURI	52˚	13092
07	PALI	43˚	2680
08	SOV	42˚	2728
09	VADAVALI	35˚	3489
10	UNHAVRE	71˚	52200
11	KHED	72˚	48990
12	UNHAVRE (TAM)	54˚	6700
13	TURAL	62˚	4546
14	RAJWADI	61˚	8501
15	MATH	39˚	5689
16	RAJAPUR	42˚	8705

5. Commercial Application of Geothermal Energy

Various sources of energy are required by industrial sector, but conventional sources of energy in India are electrical, coal and oil energy. Electrical energy is required for electro-mechanical devices, electrolysis and high temperature heating. Direct heating refers to the application of heat to a process without intermediate energy conversion and process steam application includes both the direct use of the steam in a process and the use of steam for heating Pandey, et.al. [7]. The geothermal resources of the west coast will meet the requirements of many direct heat and process steam for industrial applications such as, distillation, drying, evaporation, simple processes heating, and refrigeration by absorption machines, sterilization and washing. While there are many potential industrial applications for the use of geothermal energy, in spite of that, not a single industrial application has presently been made functional in the west coast. Geothermal energy of the west coast of India can be utilized in the following industrial activities which are already in existence in the west coast, such as sugar, textile, brewing and distillation, wood preparation and drying, food processing, milk pasteurization, fish farming, hatchery, green house, etc. The geothermal resources of the area meeting the requirement of various industrial applications are given in the "Table 2.

Table 2. Shows the industrial application of geothermal energy in the west coast of India.

Sr.No.	Water Temperature in ° Celsius	Industrial / Processes Application
1	15° to 20°	Fish farming
2	20° to 35°	Soft Drink Bottling, Swimming Pools.
3	35° to 50°	Mushroom Growing, desalination, Hatchery, Aluminum and Magnesium Hydro-oxidation.
4	50° to 60°	Refrigeration, Green House by Space Heating, Poultry Processing, Animal Husbandry Process.
5.	60° to 80°	Frozen food Processing.
6.	80° to 100°	Drying of Sea Beads and Vegetables, Washing of Wool.

5.1. Food Poultry Industry

The food industry is a significant user of energy. This industrial sector also differs from most of the other major industry users in the size of processing unit can be very large like brewery of canning plants. In this paper particular attention is being paid to reducing steam consumption in Desolventizing-Toasting and Drying of Soya bean processing industry. The Soya bean extraction involves a number of stages, many of which are energy intensive, steam uses are particularly high in toasting and drying. In toasting, combining this with heat-conditioning and using combustion gases is a possibility, although direct use of some combustion gases may not be possible because of contamination. In drying, superheated Hexane could be used for Desolventizing, giving an inherently dryer product, hence minimizing further inputs. Saving of the order of 25% representing in excess of 100Kg. steam per ton soya bean, could be realized if this development is successful Reay [9].

Two large geothermal onion and garlic dehydrators are located in Nevada, in the northwestern part of the United States: Integrated Ingredients near Empire and at Brady's Hot Springs. These two large units are processing almost 12 tones of wet onions per hour and use 35 MJ of geothermal energy per kg of dry product to dry it from about 80 % to 5% moisture content Lund [5]. The west coast of India producing about 60% to70% of onion, garlic, sugarcane, grapes, pomegranates, groundnuts, tobacco, mushroom, etc. of the Indian agro-production, the application of low grade geothermal energy can be utilized for the benefits of the farmers in the area. Geothermal heat can be utilized in the various industrial activities as show in the "Fig 5".

Geothermal brine may supply heat to variety of food industries. Processes that take place between 35° and 75° are best suited to this purpose, such as canning, bleaching, pasteurization, scalding, and hatching. Poultry processing plant require 300KW of heat. This quantity of heat is consumed for cleanup is 70° -74°, scalding 48°-50° and hatchery consumed 38°-40°C.

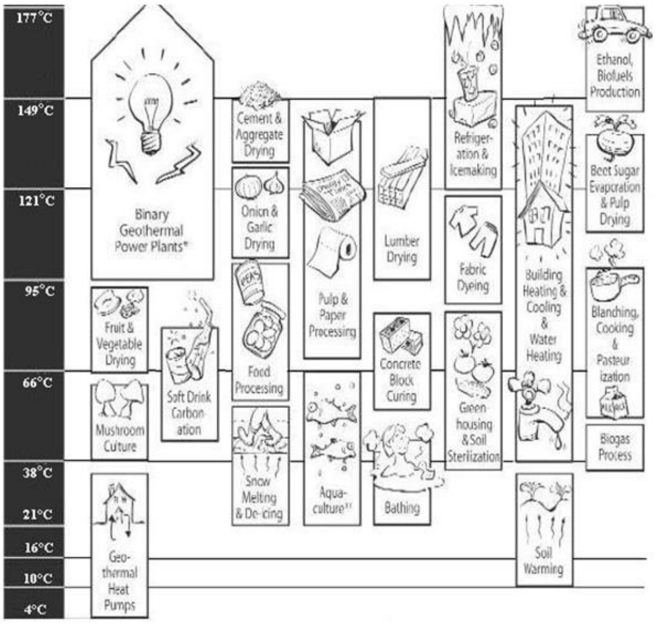

Fig 5. shows various industrial applications in the West Coast of India.

5.2. Production of Chemicals

The Chemical industry is the largest one in the west coast. Large deals of chemical plants and refineries in the surrounding area spend a lot of resources every year for their energy needs. Therefore, it is advantageous to find applications of the geothermal energy in the existing chemical industries.

The fermentation of Ethanol and production of other chemical industries can make use of geothermal energy such as production of Ethanol by the Auto-hydrolysis method Lund [5]. It is observed that energy input per gallon of ethanol varied from 140000 KJ to 17000 KJ depending on the process used, the average amount of energy is 78500KJ, the temperatures in all processes range between 40°C to 72°C and therefore, they can take place by the use of known geothermal resources in the area. Numerous other chemical processes take place at temperatures below 100°C and production may be achieved with the employment of an auxiliary heater. Since, surface temperature is ranging between 40°C to 72°C in the area; they can employ geothermal energy as their primary heat source. Some of the processes are shown in the "Table 3.

Table 3. Processes with Corresponding Range of Temperature.

Sr.No.	Name of the Process	Temperature Required
1	Alkylation of Tetra Ethylene Lead	65°C to 70°C
2	Production of Ethylnedimine	90°C
3	Nitration	50°C to 80°C
4	Chlorination of Organic Compound	100°C

6. Projected Environmental Impacts

Geothermal hot spring contain contaminants in the reservoirs such as dissolved substance and chemical derivatives from the surrounding rocks, including a variety of potentially toxic gases and heavy metals. To date, hydrogen sulfide has attracted most of the attention. However, other gases are emitted from environmental contaminants. These potential emissions such as ammonia, arsenic, benzene, boron, fluorine, hydrocarbons, mercury, radon, sulfur dioxide and sulfur peroxide. It is observed that temperature at surface varies from 65° to 315° C. The geothermal hot water may contain significant amount of dissolved solids, ranging from 300ppm to 300,00ppm Krisnaswamy [3]. Both vapor and liquid dominated reservoir fluids contain toxic non condensable gases which may be environmental problem. In the western coast mainly carbon dioxide and hydrogen sulfide are found in the some of the hot springs Pandey, et.al. [7]. In which the dissolved concentration are very less which will be harmless to the environmental impact.

Hydrogen sulfide content in the following areas is:

Akoli: 6.54ppm

Ganeshpuri: 1.60ppm

The presence of radon is also noted in the area. The radon gas is found only in the Rajapur vicinity. The amount of radon is very faint. The level of radon emitted from the sites (300pCi/l) are similar to natural emission of radon Banergy [2]. Hence radon is not expected to pose environmental hazards from geothermal developments. However the tendency for radiation to amass inside equipments may require some types of maintenance worker protection.

7. Conclusion

Utilization of geothermal energy source in the west cost of India is of major significance, in terms of both the conservation of reserves of fossil fuel and the reduction of pollutant emissions caused such as CO_2 by the conversion of energy from conventional fuels. Besides these, geothermal energy can serve to reduce the danger of climatic changes. The well log data have enabled an efficient updated assessment of the geothermal resources in the west coast of India. Temperature-at-depth indicate that direct-use and combined heat and power (co-generation) applications of these lower grade geothermal resources is widely accessible throughout the west coast of India, while suitable temperature gradients for geothermal electricity generation may be possible at selected locations with suitable financial investment. So far as cost and profitability related to the utilization of geothermal energy in west coast of India is growing concern, it is very important to decide whether preferences should be given to alternative applications.

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