Assessment on the uses of geothermal brine at the Berlín Geothermal field, El Salvador

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Abstract

The Berlín Geothermal Field is located 100 km east of El Salvador. It began its commercial operation in 1992 with two 5 MWe back pressure units. In 1999, two 28 MWe condensing units were commissioned. At the present, 100% of the brine is injected into two aquifers: the deeper and the shallow. Geotérmica Salvadoreña (GESAL) plans to carry out projects along with the surrounding communities in the utilization of the brine, which is feasible for chemical recovery and direct uses. This project could bring possible benefits and improve the economical and social development of the communities. Three main municipalities are located within the geothermal field. The main economical activity is agriculture of seasonal products like corn and bean usually grown during the wet season. The utilization or direct use of the brine is quite limited in the country. Several well-known applications have been evaluated and the results indicate more feasible uses related to resort place, fish farming, fruit drying and chemical recovery (NaCl, KCl, Cl, etc.).

Keywords: *direct utilization, chemical recovery.*

1 Introduction

The direct use of geothermal brine around the world deals with heat extraction by heat pump, heat exchanger or direct use of geothermal water. Chemical recovery uses are quite limited. An example is the Salton Sea in California (Clutter, 2000) case, which is well known for its zinc factory.

The common way to dispose of the brine is to inject it into the wells at temperature of 100-180°C, and during the process heat and chemical contents are lost in large quantities.

GESAL considers the use of the brine as alternative applications to have additional benefits. At the present different scenarios for the direct uses are being evaluated to provide several possibilities of uses for the community.

2 The Berlin geothermal field

The Berlin geothermal field is located in the east of El Salvador, 100 km away from San Salvador. The first evaluation of the field was undertaken in 1966 during the UNDP project, followed by the drilling of well TR-1. The results showed reservoir temperature higher than 230ºC. Five additional wells were drilled from 1978 to 1981. The results of these wells showed high temperature reservoir of 300ºC. In 1992, the company opted to start the short-term exploitation period of the field using two 5 MW backpressure units. In 1999, two condensing type units of 28 MW each were commissioned and 18 new wells were drilled to complete the production and injection capacities.

Two areas were identified, the steamfield to the south, where the upflow zone is postulated, and the injection zone to the North. The fluid flow path of the Berlin reservoir is controlled by a graben structure. Two aquifers are observed in the field, a shallow one at sea level depth and the production reservoir at –1000 m.a.s.l, located at

the basaltic andesite rocks. Figure 1 shows the location of the wells and the power station.

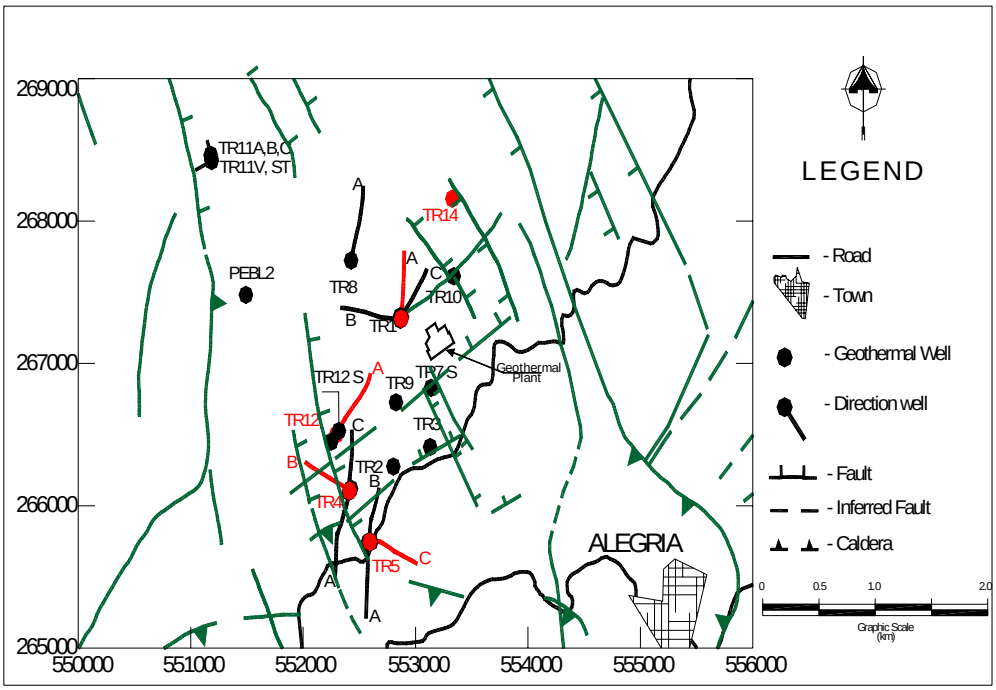

Figure 1: Well and power plant location.

3 Fluid production and characteristics

A total of 9 wells are used as production wells, 14 for injection and one is used as a monitoring well. Table 1 presents the production wells data and Table 2 presents the injection well data.

Table 1: Data for producer wells.

Well	WHP (bar)	Steam (kg/s)	Liquid (kg/s)	Total (kg/s)	Enthalpy (kJ/s)
TR-2	11.5	17	47.0	64.0	1,320
TR-9	24.0	9.0	36.0	45.0	1,298
TR-4B	12.0	17.0	56.0	73.0	1,293
TR-4C	11.0	13.0	27.0	40.0	1,390
TR-4	10.2	13.0	33.0	46.0	1,309
TR-5 A	10.8	16.0	37.0	53.0	1,422
TR-5B	10.7	13.0	34.0	47.0	1,350
TR-5C	13.7	23.0	67.0	90.0	1,300
TR-5	11.1	9.0	24.0	33.0	1,452

According to the data, the injection requirement rate is 2:1. Due to the lack of high permeability to the north, GESAL is improving the permeability and mud damage with acid job stimulation.

At present the power plant produces almost 57 MW of electricity. The steam and liquid flow rates are 117 kg/s and 325 kg/s, respectively. The Environmental law prohibits the discharge of geothermal brine on the surface. The injection in the Berlin field is done in two ways: with hot injection into the deep reservoir and shallow aquifer and cold injection into the shallow aquifer.

Table 2: Injection well data.

Well	WHP (bar)	Flow rate (kg/s)	Well	WHP (bar)	Flow rate (kg/s)
TR-1 A	26.9	54.0	TR-11 ST		28
TR-1B	14.5	5.0	TR-12 A		46.0
TR-1C	14.5	11.0	TR-12		35.0
TR-4	6.8	46.0	TR-3		33.0
TR-8	23.6	37.0	TR-7	Cold inj.	
TR-8 A	23.6	7.0	TR-11	Cold inj.	
TR-14	24.1	21.0	TR-10	Make up	

GESAL, as a part of its field management, monitors the chemical composition of the injected brine. The chemical composition of the brine is shown in the Table 3.

Table 3: Average chemical composition of injected brine (ppm).

Na	K	Ca	Li	Cl	SO_4	HCO_3	SiO_2	B	PH
3,685	749	93	13	6,620	15	6	814	124	6

Figure 2 shows the contents of the brine. Based on the data almost 98% of the chemical composition are sodium (55%), chloride (30%), potassium (6%) and silica (7%), less than 2% are another components.

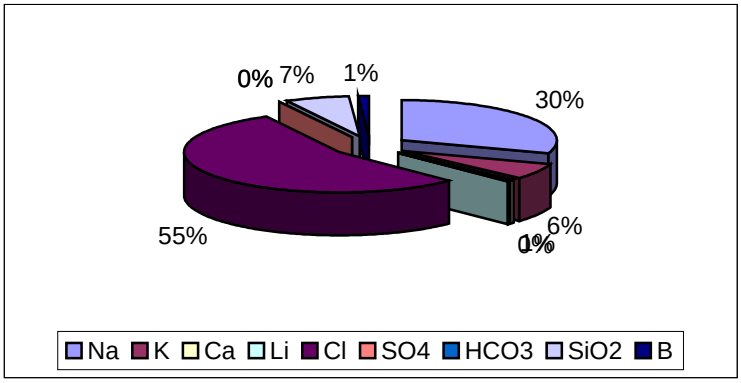

Figure 2: Chemical composition of the brine.

4 Neighbouring communities

The Berlin power plant is located within a large population and extensive coffee farm areas, and there are almost 10,000 people residing within and on the outskirts of the field. Thirteen small villages or communities, who are divided into 3 towns (Berlin, Mercedes Umaña and Alegria), are located there.

The economical activities include agricultural products. Most of the inhabitants are small farmers of seasonal products like corn, beans and “maicillo” (kind of corn for dry season). More than 80% of the people have a monthly income around 100 USD. The land where they work is 50% partly owned and 50% paid for the land use (ISDEM, 1998).

In order to improve the social and economical conditions of the surrounding communities, GESAL developed a special plan to aid the communities (PACO). As part of this, GESAL looks for specific projects in the use of geothermal brine, but investment agencies will be looked for later.

5 Alternatives on the use of the brine

As a part of a preliminary assessment, several alternatives were analysed and evaluated on the use of the brine (Duran et al., 2001). The focus was on additional heat extraction, industrial uses, chemical recovery, and tourist area.

5.1 Tourist area

The Berlin area is in a volcanic landscape covered by coffee farms. All the area has high potential for ecological tourism. The tourist area can include swimming pools, a geothermal museum, a walking area, etc. The initial investment is expected to reach USD 300,000.00 not including land ownership and possible employment for 20 residents.

5.2 Geothermal brick

The first experimental direct use of the brine was the brick fabrication where several tests were carried out. The brine sample was evaporated and compressed in a hydraulic jack but due to the lack of cohesion, the solid sample never reached the physical condition form. Consequent experiments suggested the use of additives (cement, lime, gypsum, etc.) to improve the cohesion and composition of the sample. XRD analysis showed high content of NaCl and KCl as well as chemical analysis. Usually salt has very low physical cohesion.

Due to undesirable results, bricks fabrication was excluded as a part of the feasible use of the brine.

5.3 Geothermal broiler

The injection fluid temperature is 180ºC, which makes it possible to build a broiler with temperature of around 150ºC. The basic design includes a pipeline welded to metal plate of iron or cast iron. The broiler can be constructed in a special cooking area close to the injection line or within the nearby communities.

The construction of the broiler is easy and fast. The cost is very low but the temperature range for cooking has limited use in domestic purposes.

5.4 Fruit drying

The production of dried fruit is growing in the country mainly for export. The dried fruits with high demand are mango, orange and cashew nut (marañon). The use of the brine heat for drying is suitable for the activity within the communities.

The basic design includes an air flow heat exchanger using the heat from 180°C brine. The air temperature is designed to reach 50-150°C. Several plates (10-30 pieces) with the fruits are placed inside. The time for drying can reach up to 24 hour. This process has a capacity of 400 kg of fruits.

The investment for a small drying factory is USD 50,000 with the possibility to employ up to 30 residents.

5.5 Salt extraction

The salt (NaCl) extraction from the brine appears to be suitable for the disposal fluid at the Berlin area. The standard salt produced in the area has several uses like cooking, food preparation and industrial uses. The salt from the geothermal brine can be used for industrial purposes like textile, soap, leather treatment, etc.

The basic extraction process is the evaporation of the brine in large ponds where the capacity of the ponds will depend on the season and the required production level. The most popular way in the country to extract salt is the evaporation of seawater in large ponds. The main constraint on this use is the silica content. At present it is not possible to say which type of problems may occur in this application. However, according to our data, for industrial applications there is no significant effect.

Several preliminary experiments have been undertaken to assess the salt extraction from the brine:

a) Chlorine (Cl) in gas phase by electrolysis
b) Caustic soda (NaOH) by electrolysis.
c) Potassium chlorate ($KClO_3$) by electrolysis.

Laboratory experiments were carried out to evaluate the content of the salt formed by electrolysis. Results indicated quite low content range despite the fact that there are industrial processes with high extraction range. The process could be improved to gain more profit in the salt recovery, however the cost will increase.

6 Conclusions

- The injection of disposal fluid from the power process is getting expensive due to low permeability of the injection area and the large number of injection wells to fulfill the total capacity. The use of a part of the injected brine will reduce the cost of the total injection.
- The injected fluid has a rich chemical content and it can be recovered by using several processes. The main components are Sodium chlorine, Potassium chlorate and Silica.
- The relationship between GESAL and local communities can be improved if their social and economic conditions are improved. GESAL can contribute to research and transfer technology on the extraction process of the brine. The communities together with non-profitable organisations could implement all commercial and industrial activities.
- It is feasible to develop the surrounding communities using the geothermal brine. Social and economic conditions can get better with relatively low investment and accessible technology.

7 References

Duran, A., Funes, E. and Pineda, A. (2001). *Factibilidad Tecnico-Económica y Social de las Diversas Alternativas de los Usos Comerciales de las Aguas Termales Residuales de la Planta Geotérmica de Berlín.* Tesis de grado, Universidad Albert Einstein.

Clutter, T. (2000). *Mining Economic Benefits from Geothermal Brine*. CalEnergy Mineral Recovery Project. GHC Bulletin.

Instituto Salvadoreño de Desarrollo Municipal, ISDEM. (1998). Plan de Desarrollo Local de Alegría, Departamento de Usulutan.