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Environmental Management in Geothermal Development: Case History for Costa Rica

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ABSTRACT

The great biological diversity of Costa Rica represents one of its biggest resources, and it's a focal point of the country's policies of environmental protection. For this reason the country is recognized worldwide as a leader in protecting the environment. This characteristic constitutes an important challenge for developing the geothermal energy according to these policies, due to a great part of the recognized resources that are associated to areas with different degrees of environmental protection.

This document discusses the different environmental aspects related to the geothermal resources at the Miravalles Geothermal Field and Las Pailas Geothermal field, how the environmental management has been carried out and the results of this management so far. As a conclusion the feasibility of the sustainable development of geothermal projects can be shown as a tool for protecting the environment, but also as a means to recover the environmental quality in areas that have been previously affected by the human activity.

1. INTRODUCTION

As a result of the first geothermal studies many areas of potential geothermal resources were located, and two of these areas are Miravalles and Las Pailas. Miravalles represents the first experience in geothermal development in Costa Rica and Las Pailas is now under construction.

The Miravalles Geothermal Field is located at the Miravalles Volcano in Bagaces, Guanacaste, between the Blanco and Cuipilapa rivers basins. This field is a high-temperature liquid-dominated reservoir with temperature of about 240 °C. The proven reservoir area is about 12 km^2 and it is encountered at 700 m depth and the estimated thickness is between 1000–1200 m. The field is an active hydrothermal area confined to a Caldera-type collapse structure with 15 km diameter (Vallejos, 1996).

Total dissolved solids in the range of 7000-8000 ppm characterize most of the fluids from the Miravalles geothermal wells. These fluids are sodium chloride type water with a pH of about 8 in surface. The geothermal non-condensable gases emitted to the atmosphere are CO_2, H_2S, N_2, CH_4, O_2, H_2, Ar, He and other ones in tracer quantities.

The environmental impacts assessment for Miravalles was made in 1988 (ICE, 1988). Since it was the first EIA ever done in Costa Rica at that time it would change the way models for any new large project in Costa Rica would be presented in the future. In order to obtain financing the Costa Rica National Congress made the exigency to complete an EIA to demonstrate the environmental feasibility of the project. As a result of this study the most important environmental aspect to monitoring was established.

Las Pailas Geothermal Field is located at the Rincon de la Vieja Volcano in Cañas Dulces Liberia Between the basins of the rivers Colorado and Blanco. The figure 1 shows the location of the projects

The environmental management at the geothermal projects start before the projects are under operation; the main purpose of this early beginning is to create a background that allowed comparison of environmental quality before beginning commercial utilization and assessing any future impact due to the utilization of the resources.

Brief comments on the management and monitoring of some of these environmental aspects are presented in this paper.

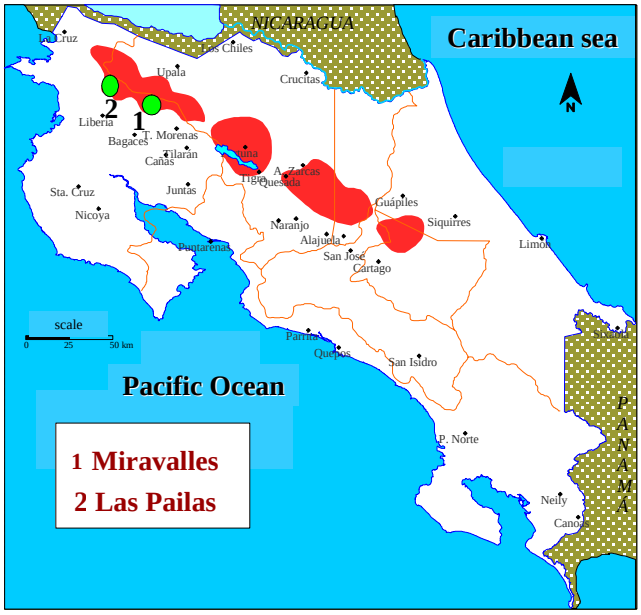

Figure 1: Geothermal Projects

2. ENVIRONMENTHAL MANAGEMENT AT THE GEOTHERMAL PROJECTS

At the Miravalles Geothermal Field the environmental studies had been going on since 1987, before the beginning of the first power plant commissioning in 1994. The environmental monitoring in Pailas start in 2002. The project is still under construction.

2.1 Air Quality Management

There are different ways to dispose the gas into the atmosphere. The gas can be released from the silencer when the wells are out of the production system. In the centrifugal separators the waste water is sent to injection wells and the steam towards the turbine. In the power plant

the gas ejector system extracts the non-condensable gases from the turbine condenser. This gas is cooled and discharged into the atmosphere through the cooling tower.

Figure 2 shows the flow of the non-condensable gases from the production wells through the power plant and how they are disposed into the atmosphere.

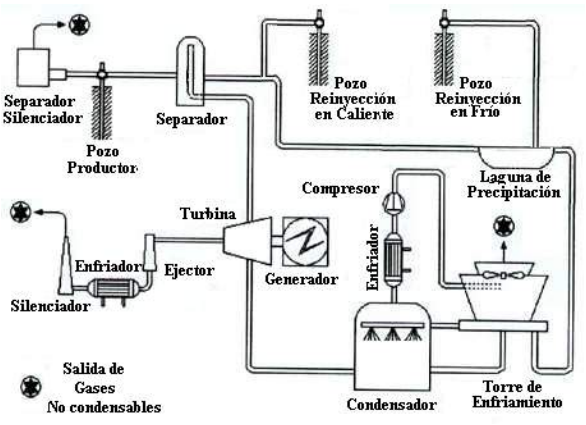

Figure 2: Outlet points for non-condensable gases

Of these gases, CO_2 and H_2S are the most important because of possible effects on environment and human health.

In Las Pailas the emission will come mainly from the wells, during production test, and also in the power plant but in minor quantities because this power plant will be a combined cycle.

Carbon Dioxide (CO_2)

The CO_2 is a heavy gas naturally present in air at a concentration of 0.03 – 0.06 percent. It is odorless and acid taste. In a concentration higher than 5% it will produce mental confusion, headaches and eventually a loss of consciousness, over a 10% concentration produces a loss of consciousness in few minutes and larger concentrations cause death due to an alteration of blood pH (Brown, K., 1995)

CO_2 is also one of the principal greenhouse gases (GHGs). It is estimated that, due to the accumulation of greenhouse gases the global surface temperature will have risen between 1.5 to 3.5 ^oC by the year 2100 (WHO, 1997). There are international standards to control the maximum quantities emitted into the atmosphere. This climate change has indirect effects over ecosystems and over the distribution patterns of vector populations. Table 1 shows some different international standards for CO_2 emissions.

TABLE 1: Different standards for CO_2 emissions

Norm	Standard
OSHA	5 000 ppm, 8 hour TWA
NIOSH	10 000 ppm TWA; 30 000 Ceiling (10 min)

Occupational Safety and Health administration (OSHA) regulations and National Institute for Occupational **S**afety and Health (NIOSH) recommendations, 1986)

CO_2 is relatively low in geothermal steam. The emitted level is more environmentally benign than sources such as thermal plants. One important aspect is that the geothermal steam does not emit NOx type gases to the atmosphere.

Hydrogen Sulfide (H_2S)

H_2S is a poisonous gas. It can come from natural sources like volcanic gases, geothermal springs and decaying organic matter, from manmade sources and also from industries. It is a colorless flammable gas with vapor density of 1.189 and soluble in water, alcohol ether and glycerol.

Due to the toxic characteristics of the hydrogen sulfide different health and environmental organizations have established exposure standards for work areas and for populated areas. Table 2 shows different international standards for H_2S concentrations.

The OSHA, NIOSH and ACGIH standard are for work areas, and the Italy and California standards are for populated areas.

TABLE 2: Different standards for H_2S emissions

Norm	Standard
TWA PELs OSHA [a]	20 ppm acceptable ceiling; 50 ppm, 10 minutes maximum ceiling.
RELs NIOSH [a]	10 ppm ceiling 10 minutes on exposures up to ten hours
ACGIH [b]	10 ppm like 8 hour average and 40 hour per week to workers
Italy [c]	0.03 ppm as 24-hour averaging time in urban areas.
California [d]	0.03 ppm like 1-hour averaging time.

[a]OSHA and NIOSH, 1986; [b]Brown, 1995; [c]ICE, 1996

[d]California air resources board, 1999

The human body does not accumulate H_2S, it is excreted in the urine, intestines and expired into the air (Brown, 1995). H_2S smells like rotting eggs and the smell is perceptible in concentrations less than 0.03 ppm.

The environmental impact assessment for geothermal projects in Costa Rica, established 0.03 ppm as the maximum concentration in populated areas and 0.67 ppm one kilometer from the power plants (ICE 1996).

For the measurements of hydrogen sulfide, electronic equipment with the capacity to measure H_2S concentrations from 0.001 ppm is used. The CO_2 is measured using equipment with the range of 0 ppm to 10 000 ppm.

The Figures 3, 4, and 5 show the results of the measurements in four representative stations in Miravalles, and the Figures 6, 7 in two representative stations in Pailas.

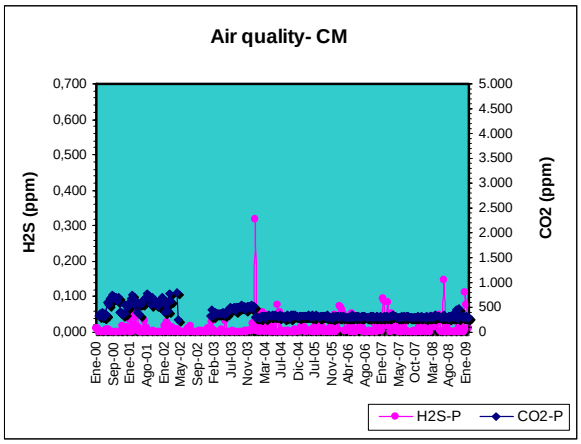

Figure 3: H_2S at Casa de Máquinas – Miravalles

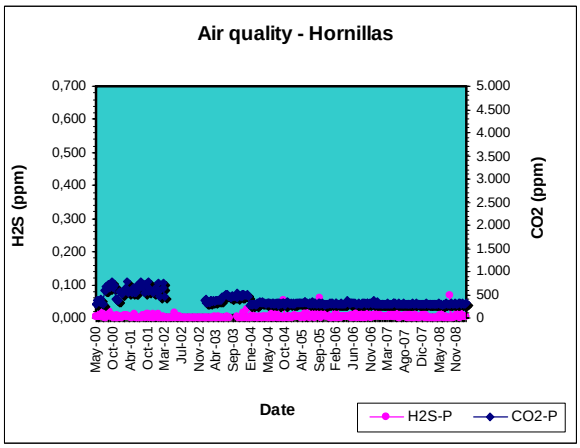

Figure 4: H_2S at Las Hornillas – Miravalles

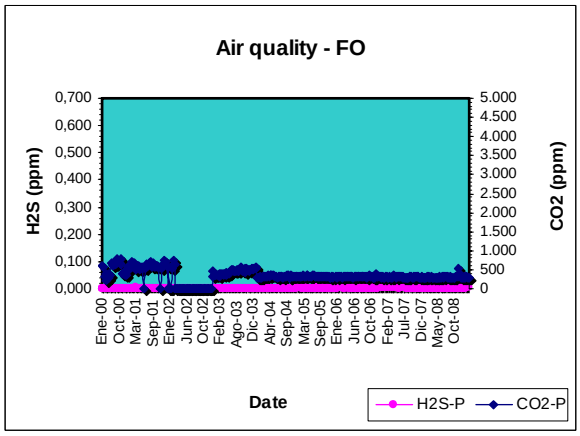

Figure 5: H_2S at La Fortuna - Miravalles

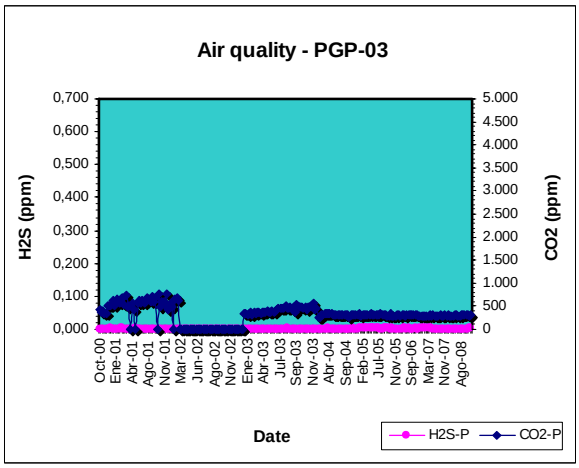

Figure 6: H_2S at PGP03 – Pailas

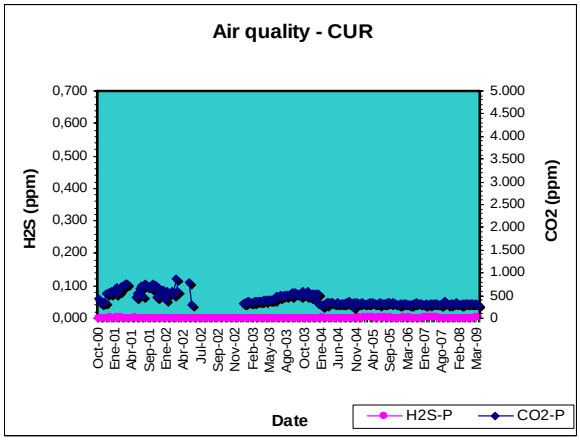

Figure 7: H_2S at Curubande - Pailas

2.2 Water Quality Management

In Costa Rica the hot geothermal water is re-injected into the reservoir using deep wells. It therefore does not represent a pollution problem to the groundwater system. In some cases it is necessary to store the geothermal water in surface ponds prior to injection and due to possible leakage the groundwater can become contaminated.

The physical and chemical characteristics of the geothermal fluids do not allow wastewater disposal at the soil or into the springs or river in the area.

The water quality monitoring program in Miravalles was established in 1987 and it includes 26 points around the project area with the objective of detecting possible geothermal water pollution.

At the beginning the study was more detailed (pH, Cl. B, As, Li, Rb, Cs), but after many years it was decided to reduce the number of chemical species. Actually, the monitoring includes Cl, pH and conductivity, because they can be used to indicate the presence of geothermal and fresh mixed water. The figure 8 shows the result of the monitoring in one of the monitoring points in Miravalles.

In Las Pailas the monitoring has been carried on with the objective of establishing a base line to compare the actual condition of the water without the project presence. This information is quite important to lately determinate the projects' influence over the water resources. The figure 9

shows the result of the monitoring in one of the monitoring points at Pailas.

The figures show variation in the range of 20 ppm maximum in the station AS07 and 5 ppm maximum at the station ASP01.

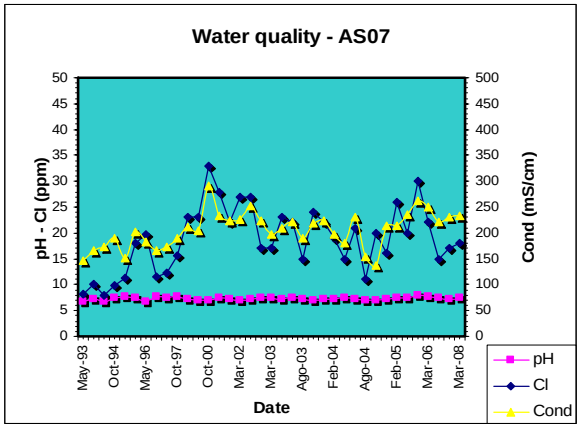

Figure 8: Water quality monitoring - Sitio 7

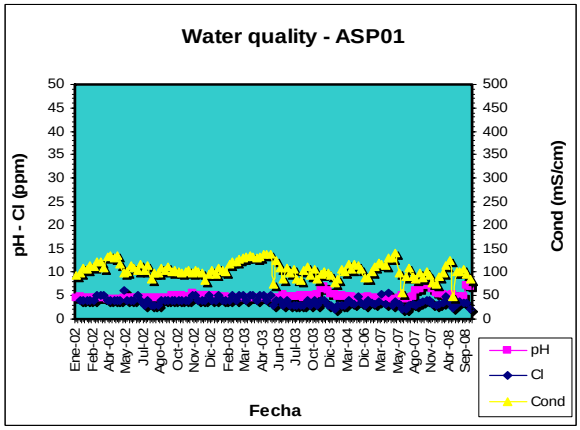

Figure 9: Water quality monitoring – Pailas

2.3 Effects on the Atmosphere

The possible changes of the pH in the rain because of geothermal utilization has been monitored and studied in Miravalles since 1987. One continuous monitoring was established in ten points around the project area. The objective of the monitoring is to determine the pH background, and use it as a comparison line that allows identifying any pH changes after the start of the field operation.

In Miravalles the commercial field operation have demonstrated no operational negative effects over the pH range of values because the pH range still between the original values after the star of the field operation. Figures 10, 11 and 12 shows the results of the pH rain monitoring at the Miravalles Geothermal Field. The figures 13 and 14 show the results at Las Pailas.

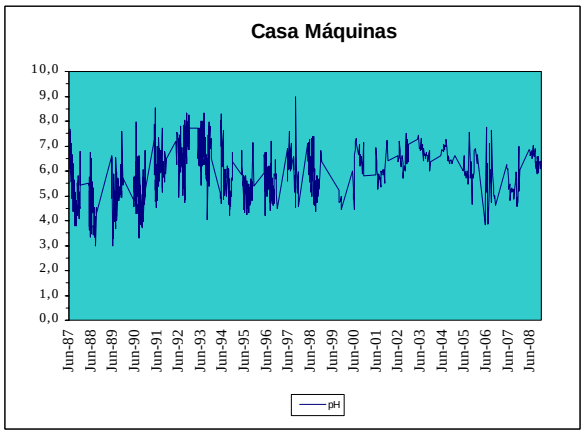

Figure 10: Rain pH Casa de Máquinas - Miravalles

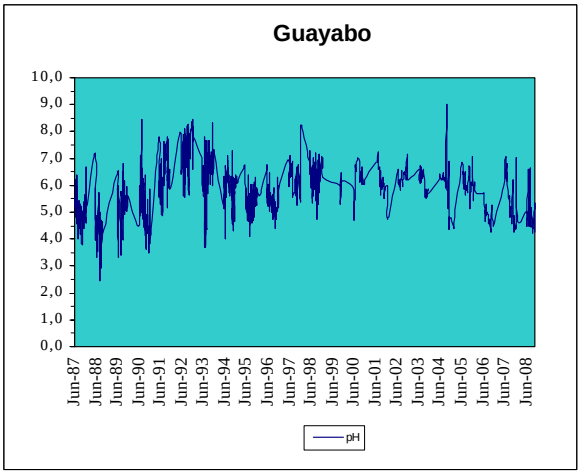

Figure 11: Rain pH - Guayabo- Miravalles

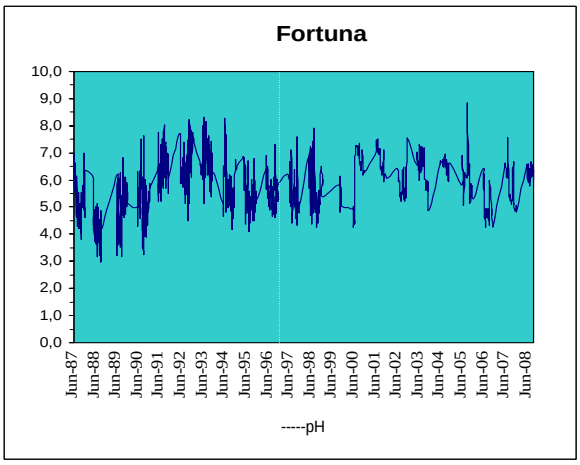

Figure 12: Rain pH – Fortuna - Miravalles

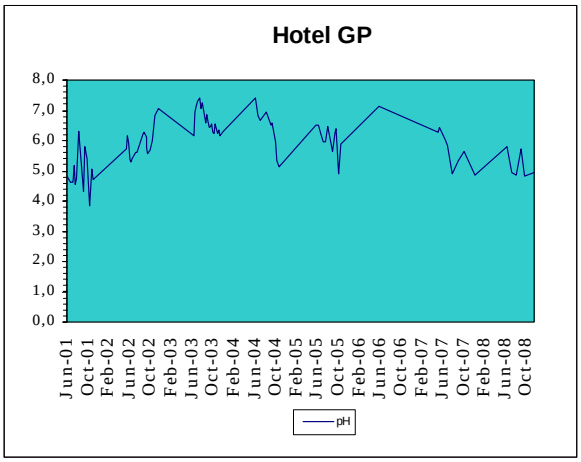

Figure 13: Rain pH – Hotel GP - Pailas

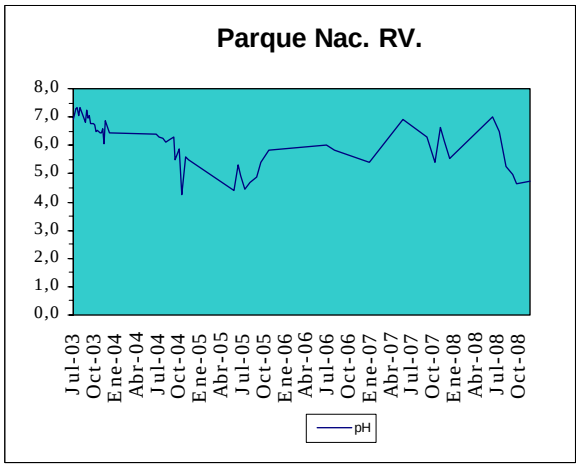

Figure 14: Rain pH – Fortuna – xxxx Pailas

2.4 Effects on the Forest

In Miravalles most of the land acquired for geothermal utilization has been reforested by using local flora and promoting natural recovering. When the geothermal activities began most of the land was used for grazing. ICE has recovered 800 hectares by planting 362, 000 trees in the area. As a natural consequence it is now possible to see animals that were nearly impossible to find earlier.

Figure 15 and 16 shows the difference between ICE´s properties and private ones. In the figure 15 the property is private and the figure 16 shows the actual condition few years after ICE become the owner. It is possible to see the grade of recovery.

2.4 Visual Impacts

The objective of controlling visual impact is to build harmony between nature and the buildings or pipelines. For that reason ICE has been working with some structures to find the way to improve their visual impact. The figures show some of the results of the work for reducing the visual effects of geothermal development. Some of the activities are flora recovery and using various shades of green paint. The results are quite evident in Figures17 and 18.

Figure 15: Comparison between ICE and private areas

Figure 16: Comparison between ICE and private areas

Figure 17: Site before recovery activities (Pailas).

Figure 18: Work site after recovery activities (Pailas).

2.4 Public relations

The relationship with communities and other people related with the environmental issues are maybe the most important issue in the environmental management.

One of the most important actions in public relations is to let the communities know exactly what the project is, and what the negative and positive impacts are over the natural, economical and social aspects. In order to fulfill this objective it was necessary to educate the people working with students and the communities as is shows in the figure 19. It was important to let them know what constituted a geothermal project, what needs to be done in order to obtain the resources, how the environment will be impacted, what needs to be done to control the impact, what are the social and economical benefits of the project and the importance of protecting natural resources.

To manage this situation many strategies have been developed. First it was necessary to identify the people who were strategic, for example: the social organizations such as development associations, religious groups, students of different levels, hotels and tourist developments, business owners and their workers, **NGOs**, and many others.

In Costa Rica 25% of the country is environmentally protected and the most important geothermal areas has been associated with this protected areas. The actual laws in Costa Rica do not allow the energy exploitation in protected areas but due to the increase of the energy requirements and the high costs of the fossil fuels, it is necessary to find the way to use the geothermal resources associated to the National Parks. For that reason actually a new law project was presented to the congress but still in the preliminary steps prior to be discussed by the congress; this project tries to allow the geothermal development into National Parks and of course a hard discussion and negotiation will be necessary before the law projects can ensure the use of a development and exploitation model to ensure the environmental protection in high sensibility areas.

ICE has organized training in conjunction with other governmental institutions. One of the most important is related to tourism development. Now the use of natural hot springs water, fumaroles and geothermal utilization are used as new tourist attractions (Figure 19).

Figure 19: Environmental Education

3. CONCLUSION

- The results of the environmental parameters show that the geothermal development in the Miravalles Geothermal Field is sustainable.
- The natural recovery due to the presence of the Miravalles Geothermal Developments is extremely important over the vegetation and over the fauna.
- The presence of geothermal development produces a new tourist attraction and demonstrates to be compatible with other activities such as tourisms and natural conservation.

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