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Environmental Management at the Miravalles Geothermal Field

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ABSTRACT

The great biological diversity of Costa Rica represents one of it's 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 utilization of the Miravalles 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 can be shown as a tool for protecting the environment, but also as a mean**s** to recover the environmental quality in areas that have been previously affected by the human activity.

1. INTRODUCTION

The Miravalles Geothermal Field is located at the Miravalles Volcano in Bagaces Guanacaste between the Blanco and Cuipilapa rivers basins. The Miravalles I and Miravalles II power plants are located at the coordinates 298 000 N-405 700 E at 610 m a.s.l and the Miravalles III power plant at the coordinates 300 150 N-407 050 E at 720 m a.s.l. 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.

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 (EIA) for Miravalles was made in 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.

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

2. ENVIRONMENTHAL MANAGEMENT

The environmental management at the Miravalles Geothermal Field had been going on since 1987, before the beginning of the field utilization in 1994. The main purpose was to create a background that allowed comparison of environmental quality before beginning commercial utilization and assessing any future impact due to the utilization.

2.1 Air Quality Management

In Miravalles there are different ways the gas is disposed into the atmosphere. The gas can be released from the silencer when the wells are out of production. 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 1 shows the flow of the non-condensable gases from the production wells through the power plant and how they are disposed into the atmosphere.

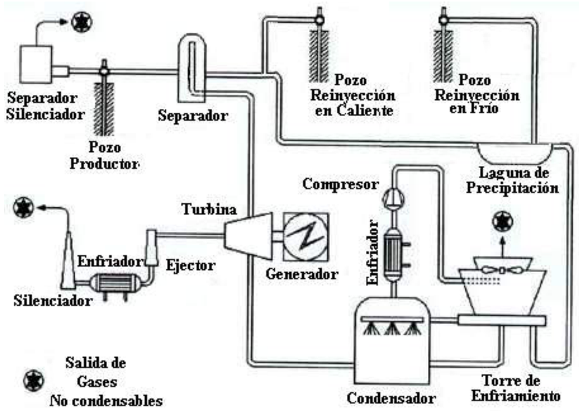

Figure 1: Outlet points for non-condensable gases

Of these gases, CO_2 (96-97%), and H_2S (less than 1%) are the most important because of possible effects on environment and human health.

2.1.1 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 °C 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.

The presence of H_2S in the atmosphere increases health risks. Low concentrations can produce human health problems, effects on flora and fauna and damages to human constructions by corrosion and higher quantities may cause death.

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 3 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]	28 000 μg/m^3 acceptable ceiling; 70 000 μg/m^3, 10 minutes maximum ceiling.
RELs NIOSH [a]	14 000 μg/m^3 ceiling 10 minutes on exposures up to ten hours
ACGIH [b]	14 000 μg/m^3 like 8 hour average and 40 hour per week to workers
Italy [c]	42 μg/m^3 as 24-hour averaging time in urban areas.
California [d]	42 μg/m^3 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 42 μg/m^3. When people have exposure to low concentrations of H_2S, it can cause lacrimation, photophobia, and irritation of the nasal mucosa it also has a profoundly irritant effect on the cornea producing pain and blurring of vision and keratitis.

At 500 μg/m^3 **H_2S** has a clearly perceptible odor and begins to cause damage to delicate plants. In the range of 280 000 and 700 000 μg/m^3 it will produce intoxication and above 840 000 μg/m^3 it can produce rapid death by asphyxia.

Aluminum conductors in substations and on transmission lines will usually take on a protective coating of black sulphide which inhibits further attack. However instruments and relay contacts will almost certainly suffer if they feature exposed copper, as sealing is seldom perfect. Contacts and bare connectors of silver are advisable. Exciter commutators of copper can be very troublesome, not only because the copper itself is attacked by H_2S but also because the sulphide film causes sparking at the bushes which wear away at an alarming rate (Armstead, 1983).

The Miravalles environmental impact assessment (ICE, 1996) established the maximum concentration as 42 μg/m^3 in populated areas and 938 μg/m^3 one kilometer from the power plants.

In Miravalles the hydrogen sulfide emission was modeled (ICE, 1988 and 1996). The models estimated H_2S concentrations under 42 μg/m3 in town and less than 938 μg/m3 at one kilometer from the power plants (Guido, 999). In order to study the H_2S evolution, the Instituto Costarricense de Electricidad (ICE), operates seven stations for H_2S monitoring.

For the measurements of hydrogen sulfide, electronic equipment with the capacity to measure H_2S concentrations from 4.2 μg/m^3 is used. The CO_2 is measured using equipment with the range of 0 ppm to 10 000 ppm. Figures 2, 3, 4 and 5 show the results of the measurements in four representative stations.

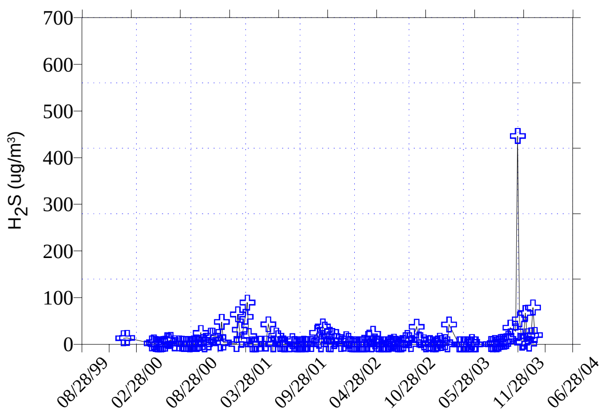

Figure 2: Concentration of H_2S at Casa de Máquinas

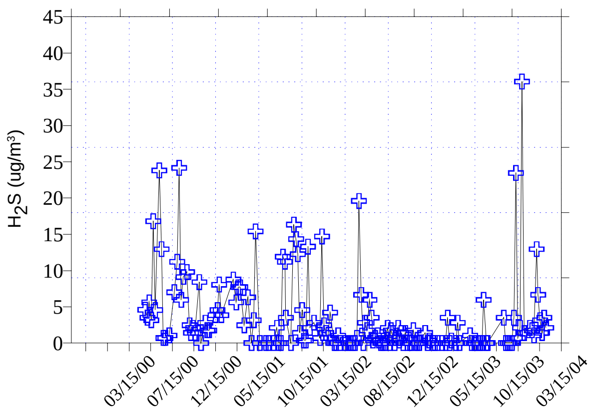

Figure 3: Concentration of H_2S at Las Hornillas

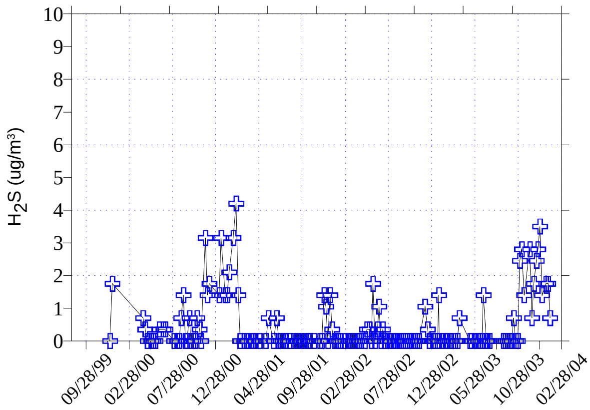

Figure 4: Concentration of H_2S at La Fortuna

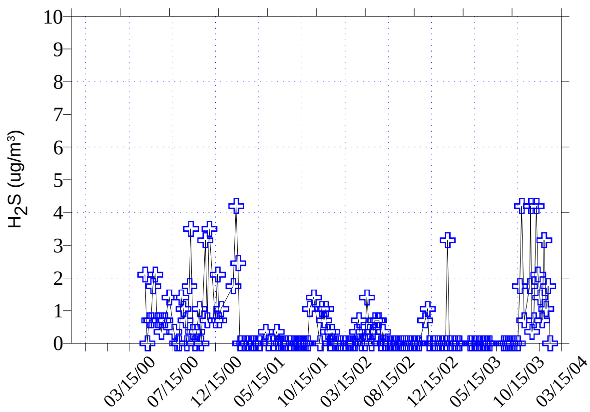

Figure 5: Concentration of H_2S at Cuipilapa

2.2 Water Quality Management

In Miravalles, 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. Figure1 shows the geothermal system.

The physical and chemical characteristics of the Miravalles geothermal fluids do not allow wastewater disposal at the soil or into the springs or river in the area. Table 3 shows some standards for water in different uses.

TABLE 3: Different standards for water compounds

	WHO (1993) drinking water	USEPA (1986) Aquatic life	CCREM (1991) Irrigation
As	0.01	0.19	0.1 – 2.0
B	0.3	0.75	0.5 – 6.0
Li	-	-	0.075 – 2.5
Hg	0.001	0.000012	-
H2S	.05	0.002	-
NH3	1.5	0.08-2.5	100-700-
Cl	250	-	500-3500

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 there 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 6 shows the result of the monitoring in one of the monitoring points in Miravalles.

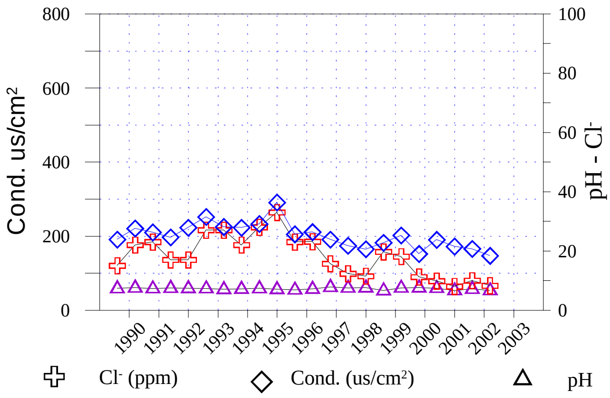

Figure 6: Water quality monitoring - Sitio 7

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. Figures 6 and 7 demonstrate the location of the rain monitoring points. The objective of the monitoring is to determinate the pH background, and use it as a comparison line that allows identifying any pH changes after the start of the field operation.

The commercial field operation started in 1994, and demonstrated no operational effects over the pH range of values. Figures 6, 7 and 8 shows the results of the pH rain monitoring at the Miravalles Geothermal Field.

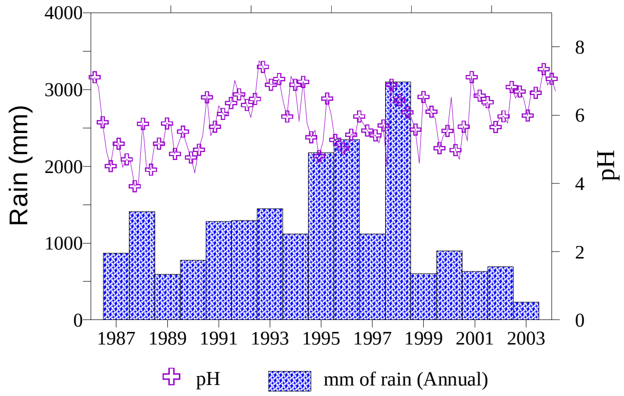

Figure 7: pH and annual Rain - Casa de Máquinas

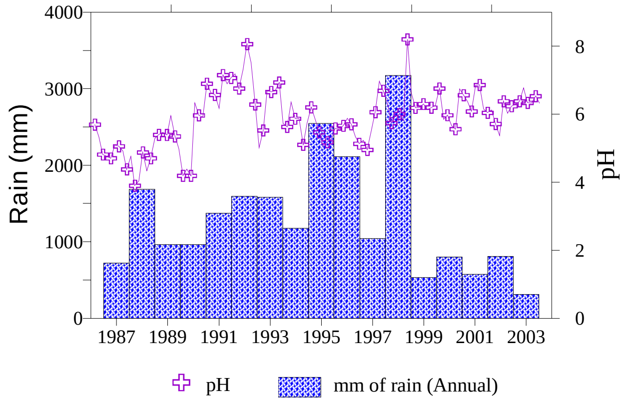

Figure 8: pH and yearly Rain - Guayabo

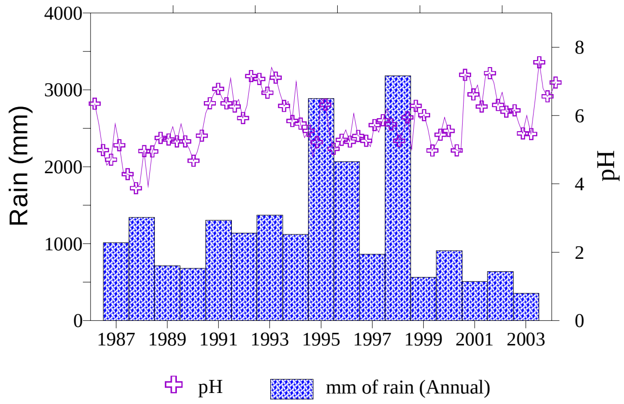

Figure 9: pH and Annual Rain – Fortuna

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 9 shows the difference between ICE´s properties and private ones. The one at the right side of the picture is an ICE property. It is possible to see the grade of recovery.

Figure 10: Comparison between ICE and private areas

2.4 Visual Impacts

The objective of controlling visual impact is to build harmony between nature and the buildings or pipelines. For that reason the company 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 Figures11 and 12.

Figure 11: Work site before recovery activities and paint use.

Figure 12: Work site after recovery activities.

2.4 Public relations

The relations 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. 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.

Figure 13: Environmental Education

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.

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.

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