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H_2S Monitoring and Emission Control at the Cerro Prieto Geothermal Field, Mexico

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ABSTRACT

Results of an ambient air monitoring program performed in the Cerro Prieto Geothermal Field (CPGF) are described in this article. According to this study, conducted since 1997 by Comision Federal de Electricidad (CFE), the main government owned Utility in Mexico; it has monitored ambient air concentrations of hydrogen sulfide (H_2S) in the geothermal field as well as in the neighbor villages around the CPGF.

Environmental regulations have been reinforced in many countries for air quality emissions. In this particular case, since Cerro Prieto is located within the 60 mile border zone between United State and Mexico, special attention it is taken to all the atmospheric emissions associated with the operation of this geothermal facility.

In despite of there being no International standards for H_2S, in countries like the USA there is a local regulation in the State of California for a maximum level of H_2S gas in ambient air at 42 μ g/m^3 (30 ppb) per hour average. Many other countries have a “short-term” (usually 30 minutes) standard, which range from 6 to 210 ppb (WHO, 1980). In Mexico there are no environmental H2S criteria, but labor standard sets a maximum of 10 ppm per hour over an eight hours journey.

A complete H_2S analysis in conjunction with regular climate measurements is performed. Graphical results shown that the CPGF always comply Mexican’s labor regulation and most of the time, an international standard criterion in the Mexicali Valley.

1. INTRODUCTION

With the increase in preoccupation and interest of the population of the world concerning the care and preservation of air quality, especially in those zones where industrial activity is a high risk facture for the health of the inhabitants, the government and the local authorities have increased the vigilance and regulations to prevent the negative effects on the health of the population and the deterioration of the quality of the environment. In particular, control of emissions into the atmosphere and the air quality are motives for ever-stricter rules and regulations by environmental authorities over the whole planet.

In any geothermal power plant, the major impact identified with the environment is the emissions released into the atmosphere due to the amount of non-condensable gases (NCG) that are transported with the steam utilized for powering the turbines, which are discharged in the majority of cases, into the atmosphere through chimneys and the cooling tower fans, changing the air quality in the immediate area of the power plants.

Carbon Dioxide (CO_2) constitutes the largest element in the mix of gases discharged by the geothermal wells, making up 95 to 98% of the total gases, followed by hydrogen sulphide (H_2S), with only 2 to 3% by weight of total gases and, in lesser proportions, some ammonia, mercury and radon. Of these gases H_2S is the most dangerous and produces the most concern, mainly for the disagreeable odor of rotten eggs at low concentrations, irritating the eyes at medium concentrations, and at high concentrations, respiratory damage and even death can occur.

Utilization of geothermal resources for power production in Mexico has been in play for more than thirty years. To date there are four geothermal fields in the country under commercial operation with a total installed capacity of 948 MW. All electricity production is under the auspices of, and is administered by, the Federal Energy Commission (CFE) which is responsible for all generation, transmission and distribution of power for public service in Mexico.

The largest and oldest geothermal field in Mexico is the Cerro Prieto geothermal field (CPGF) in Baja California, where the total installed capacity reached its 720 MW in year 2000. There are 13 power units that are fed by the steam extracted from the ground by over 150 production wells connected by an extensive network of steam ducts throughout the field. At Cerro Prieto four generating units of 110 MW are in operation, fed by high and low pressure. Other units of 37.5 and 25 MW are fed off high-pressure steam only, for which there are a large number of wells operating double flash installations.

The amount of non-condensable gas produced by the wells in this field varies from 1 to 3% by weight, depending on the part of the field in which these are located. In general terms, the western part of the field, called CPI, (Cerro Prieto I) is the least producer of incondensable gas, being that between 0.5 and 1%. NCG increases towards the areas of CPII and CPIII, as well as in the area of CPIV, on over to where the major producing wells are producing not only steam but NCG as well, being the deepest wells and the hottest temperature of the field. Figure 1. Chemical composition of the gas that is extracted from the reservoir together with the steam of the surrounding area are 96% CO2, 3.5% H_2S, 0.48% NH3 and the rest being other gases.

Cerro Prieto is located on a flat, arid plain in the Mexicali Valley, with extreme ambient temperatures in the summer as high as 50º C and with a moderate winter temperature of 2º C minimum. Precipitation is very low with averages of 80 mm annually and, in contrast, the annual evaporation rate is 2000 mm. In the beginning when exploitation of the field began, there were only small farming settlements in the area around the geothermal site. The field has now completed thirty years of power production and the

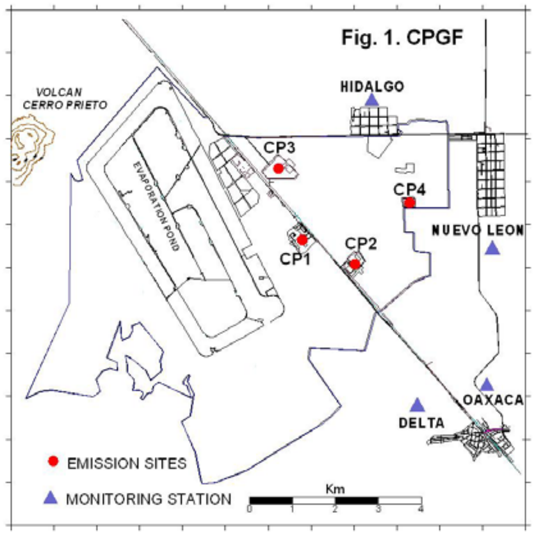

Figure 1: Cerro Prieto Geothermal Field

situation is very different, owing to the population growth resulting from the economic activity generated in this area. It is estimated that in the settlements surrounding the fields now, the inhabitants number around ten thousand, with 1,200 plus working every day on the geothermal facility, thereby making the care and preservation of the environment a prime concern at this place.

In addition, the CPGF is located on the border with the United States of North America, with whom there are international environmental protection agreements in effect for protection along 100 km to the south, and along the entire length, of the border of the United States with Mexico, which is some 2,000 Mi, involving more that 10 million inhabitants along both sides of the border. This requires a control and monitoring programs for the air quality in all of the border cities and towns, especially in Tijuana and Mexicali (Border XXI Program) that are adjacent to the state of California, where the strictest regulations in the world are in place with respect to air quality.

2. PROCESS DESCRIPTION

Extraction of steam to feed the power plants at Cerro Prieto is done through more than 150 production wells, whose average depth is from 2,500 t0 3,000 m, and in which temperatures as high as 350ºC have been registered. Each one of those wells has separation equipment permitting it to send steam to the power plants through a complex network of steam ducts that connect the entire steam field. The separated water is discharged into atmospheric silencers and then conducted through open canals to the evaporation pond, from which part of it is re-injected into the reservoir by way of 13 wells drilled ex profeso for this purpose, and another part evaporates taking advantage of the high temperatures that exists in this desert area. The geothermic steam, upon its arrival at the power plants, is passed through driers before entering the turbines, where the condensates that form during the trip from the wells to the power plants are removed.

At Cerro Prieto all of the condensers utilized are direct contact, varying only in type, being either low level or barometric discharge. The incondensable gases are extracted from the system through ejectors or turbo compressors and then discharged through exhaust chimneys or through discharges located in the fans of the cooling towers for atmospheric dispersion. Table I shows the different types of condensers for each generating unit and the capacity.

Table 1: Cerro Prieto Power Capacity and Gas Extraction

Table 1				
Unit	Year Commissioning	Capacity MW	Condenser Exhaust	Gas Extraction
1	1973	37.5	Barometric	Ejectors
2	1973	37.5	Barometric	Ejectors
3	1979	37.5	Barometric	Ejectors
4	1979	37.5	Barometric	Ejectors
5	1982	30	Low Level	Ejectors
6	1986	110	Low Level	Turbocompresor
7	1987	110	Low Level	Turbocompresor
8	1986	110	Low Level	Turbocompresor
9	1986	110	Low Level	Turbocompresor
10	2000	25	Low Level	Hybrid
11	2000	25	Low Level	Hybrid
12	2000	25	Low Level	Hybrid
13	2000	25	Low Level	Hybrid

In using direct contact condensers, it is possible to dissolve a good quantity of H_2S in the water coming from the cooling towers, substantially reducing the emission of these gases into the atmosphere. Various tests on this kind of condenser have been carried out, measuring H_2S in the steam at the entrance to the turbine, the quantity of sulphurs and sulphates contained in the cooling water from the towers as well as the flow of water from the condensers, and the flow of steam to the turbine, finding that up to 56% of the H_2S contained in the steam dissolves in the cooling tower water (IIE, 1982). This dilution contributes favorably to reduce the quantity of H_2S that is discharged into the atmosphere, and as a consequence the generation of sulphuric mud in the ponds of the cooling towers, jettisoning the sulphur as a consequence of the H_2S reaction in the water. The excess of these discharges, are incorporated in the system of separated water from the field and from there it goes to the evaporating pond for either re-injection or evaporation.

2.1 H_2S Monitoring and Meteorology

Since 1997, CFE has maintained a continuous program of monitoring quantities of H_2S present in the environment, in the geothermal field as well as the surrounding settlements. The continuous operation of five H_2S monitoring stations, using Arizona Instrument analytical meters, Jerome 631-X models, which permit the continuous registering through a range of 0.001 –50 ppm of H_2S, it has yielded a large data base on air quality conditions preventing the exposure of workers in the field to high concentrations of this gas, as well as to prevent inconvenience to the people living in the surrounding area. At the same time meteorological conditions are also registered in the area, since the wind direction and velocity are determining factors in the distribution of the H_2S in the area around the geothermal field.

It can be generally established from the data gathered from the five monitoring stations that the stable conditions, or wind calm times are midnight throughout the year, October and November being the most stable period, since 70% of the time it registers no wind. During the night the winds are from the west in spring and autumn, from the north in winter and from the southwest in summer. In the morning the winds are dominant from the north and northwest all year, except July, when the winds come from the east and southeast. In general 50% of the wind velocities in the mornings are less that 0.5 m/s. The afternoons are windless less than 5% of the time and the dominant winds come from the north during winter, the west during spring and autumn and the south in summer.

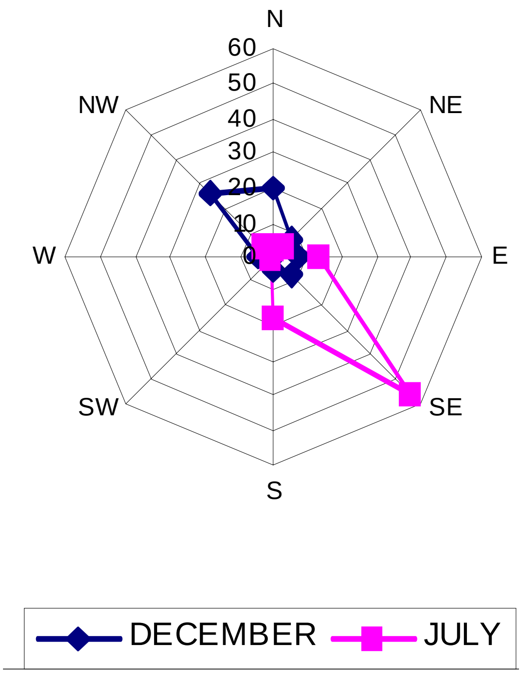

Fig 2: Wind direction 2003

These meteorological conditions favor the atmospheric dispersion of H_2S while also directing the plume of gases in the dominant directions north-east to south-east during the winter and south-east to north-east in the summer months (see Fig.2), therefore the determination of the H_2S in the environment becomes particularly important in the settlements situated to the north and south of the geothermal field, that is to say, the Ejidos Hidalgo, Delta and Oaxaca.

For the purposes of this publication, Table 2 shows the average monthly concentrations of the H_2S in the environment during the second semester of 2003, exclusively, since the operation of the geothermal field is continuous and only occasionally some of the units goes down for maintenance, therefore the emission of gases into the atmosphere is practically constant during the entire year. These concentrations are based on the daily averages of H_2S over 24 hours, because the metering is a constant procedure carried out throughout the year. Additionally, in figures 3 and 4, you can see the typical behavior of the H_2S in the settlements nearest the geothermal field, to the north, Ejido Hidalgo and to the west, Ejido Nuevo Leon, where in almost every case, the average daily concentrations are less than 20 ppb during the whole semester (CFE,2003)

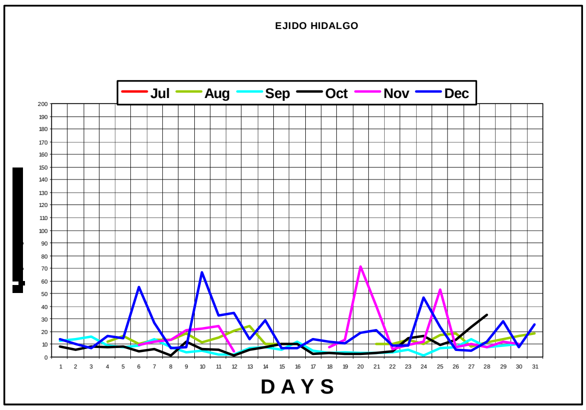

Fig 3: H_2S monitoring program Ejido Hidalgo

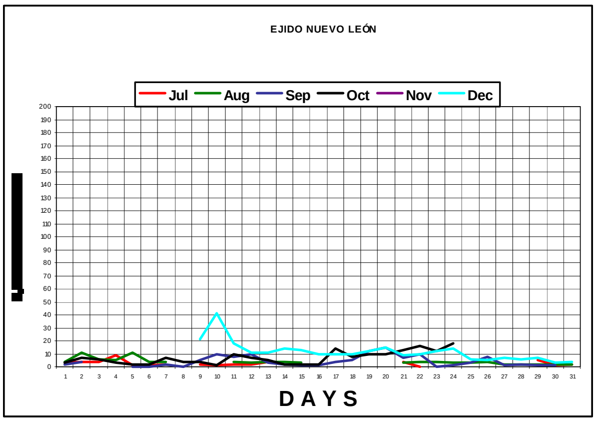

Fig 4: H_2S monitoring program Ejido Nuevo Leon

Table 2. H_2S Monthly Average on the Neighbor Villages

Year: 2003	Ejidos				
	Hidalgo	Nuevo Leon	Oaxaca	Delta	Michoacan
Jul	-	3	2	2	1
Aug	14	4	1	2	1
Sep	7	4	3	2	-
Oct	8	7	15	-	-
Nov	19	-	21	19	-
Dec	19	12	17	41	-

DISCUSSION

Although Mexico has no environmental regulation, at this time, for controlling H_2S emissions released into the atmosphere, CFE is taking into account the regulation of other countries and respecting their basic established limits as environmental criteria. The State of California for example whose limits have been established based on the threshold of odor detection uses 30 ppb as an hourly average. New Zealand for instances, use a limit of 50 ppb also as an hourly average. Those limits has been observed by CFE through these years and permitted Cerro Prieto geothermal field to operate for more than thirty years without major problems or complaints from the residents living around the field. During most of the time, H_2S concentration in the air did not rise above the spectrum of detection by smell in these areas, as can be seen in figures 5 and 6.

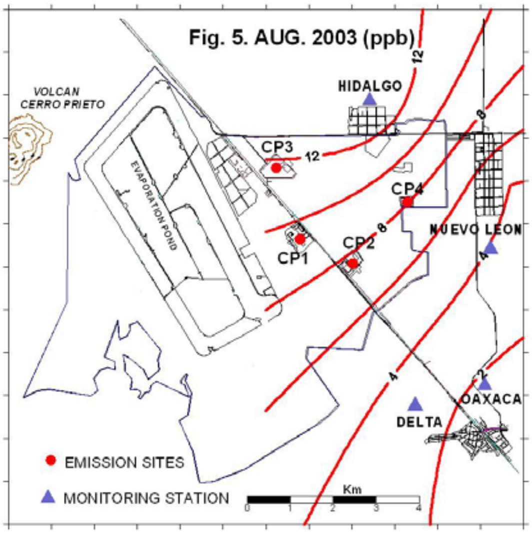

Fig 5: H_2S in CPGF during summer months

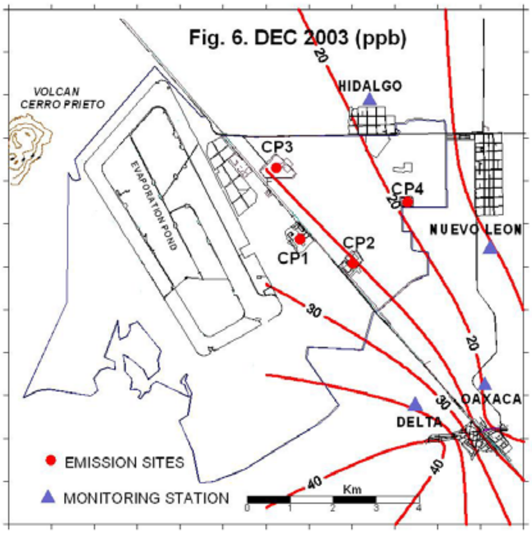

Fig 6: H_2S in CPGF during winter months

In Fig.7 it can be seen that frequency of the hourly average concentration of H_2S recorded by the CFE air quality monitoring network during second half of year 2003. From this picture we can see that values minor or equal to 50 ppb are in the range of 88 to 99.8% in the villages near the geothermal field.y the observance of these criteria it can be concluded that amospheric emissions due to the continues operation of the CPGF has no produce any health damage to either the workers or people living in towns around this geothermal facility.

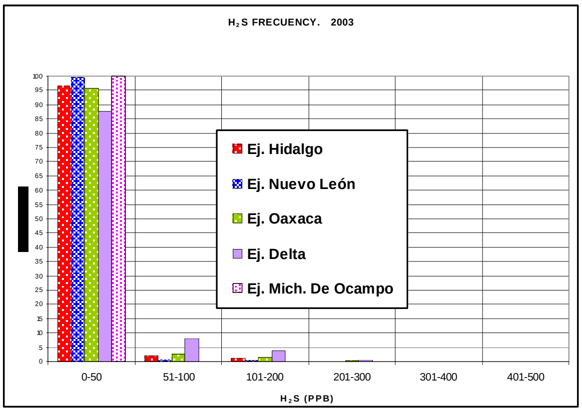

Fig 7: H_2S hourly average recorded around the CPGF.

Nomenclature

CPGF	Cerro Prieto Geothermal Field
CFE	Comision Federal de Electricidad
CP1	Cerro Prieto I
CP2	Cerro Prieto II
CP3	Cerro Prieto III
CP4	Cerro Prieto IV
H_2S	Hydrogen Sulfide
CO_2	Carbon Dioxide
NH_3	Ammonia
NCG	Non Condensable Gases
ppm	Parts per million
ppb	Parts per billon

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