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OCCUPATIONAL RISK ASSESSMENT FOR HYDROGEN SULFIDE CONCENTRATIONS FROM A GEOTHERMAL POWER PLANT

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ABSTRACT

One of the main risks in a geothermoelectric power plant is the gases emitted in this type of facility. Sulfur gasses (SO_2 y H_2S) and carbon dioxide emissions (CO_2) are of great importance in their monitoring due to the damage that their presence can provoke in the equipment and facilities as well as in human beings and in the environment.

H_2S is a volatile compound in which many environmental factors infer in its oxidation rank, such as radiation, precipitation, temperature, and the concentration of other substances, that could determine the presence of dangerous concentrations. Therefore, this is one of the substances that presents a great danger to human health (due to the exposure of the worker when performing activities in this kind of plant) because it is emitted in natural geothermic areas as steam; and it has been observed that when a new geothermic generation power plant is developed, these emissions are increased.

In this work the risk to the worker´s health is assessed during the electric power generation process in the Generation Units in a Geothermoelectric Power Plant by three main methods: EPA's Risk Assessment, Lopez's "Modified On-Site Diagnosis" and the NOM-010-STPS-1999's "Risk Qualitative Classification".

The main objective is to determine and to characterize the apparent danger and the inherent risks of the work environment having studied the hydrogen sulfide´s concentration.

At the end of this research, valuable information was obtained about the danger´s characteristics, such as duration, frequency and intensity, which will help to determine the degree of health risk.

Key Words: Hydrogen Sulfide, Geothermoelectric Plant, Risk Assessment, Worker`s health.

INTRODUCTION

Geothermal energy is among the different technologies for electricity generation, and Mexico is in the top four countries worldwide production capacity for this type of energy, with an estimated of 953 MW at a national level which represents 3.3% of the total energy production.

In the geothermal field, are vented to the atmosphere, along with the steam, uncondensable gases where H_2SO_4 represents 8% of the gases emitted and it is carried by air currents, causing its concentration within the zone of influence were of importance. Another component of the geothermal steam is H_2S that causes unpleasant odor nuisance that generates, at high concentrations may damage respiratory system and higher concentrations can be fatal.

Ammonia (NH_3) is irritating and Radon (Rn) is carcinogenic by inhalation, although emissions are low and usually cause no problems. Emissions of Boron (B) and Mercury (Hg) are generally too low to pose a risk to health, but these metals can be deposited in the soil and if carried by runoff can contribute to pollution of groundwater and surface water.

There is previous research which has determined the environment impact of geothermal steam use as feedstock for electricity production (Pastrana, J. *et al.*, 2005) and it has been found that the uncondensable gases equivalent to 3.2% by weight, on average, the total steam (water).

This percentage is made up of a 3.15% by weight of CO_2, 0.03% by weight of H_2S (8% in volume) and smaller amounts of other gases such as methane, argon and hydrogen. Hydrogen sulfide, being heavier than air, condensation is easily and its dispersion depends only on the weather, so it remains in the environment.

The health effects from exposure to this gas, according to the Agency for Toxic Substances and Disease Registry (ATSDR) provides that a prolonged or repeated exposure causes low blood pressure, headache, nausea, loss of appetite, weight loss, ataxia, inflammation of the lining of the eye, and chronic cough. Neurological symptoms, includes psychological disorders.

Given the harmful effects of H_2S on health, this paper assesses the risk to the health of workers, caused by geothermal steam in the workplace and the possible biological effects.

METHODE

Intending to make the identification of areas that present the risk and hazard assessment existing geothermal steam exposure, has been under observation a Generating Unit, taking the following steps:

1. As a diagnostic method was used “Modified Situational Diagnosis” (López 2009), which considers:
    a. Identify hazards through risk mapping (PTR).
    b. To assess contaminant exposure.
    c. To assess the dose-response of the worker.
    d. Characterizing the hazard and determine the risk factors to health.
2. To determine the concentration levels of the chemical in the environment we used a portable digital measuring equipment for H_2S.
3. In a personalized clinical assessment was carried out by a workers questioning and physical examination to establish medical diagnoses related to possible biological effects caused by exposure to chemical agent.

RESULTS

In brief, the results are:

Risk Mapping

Firstly, an investigation was conducted to determine the characteristics of work, which are:

1. There are three areas to the “Department of generation”: Operation, Maintenance and administration.
2. The area of “Operation” has three shifts, working 365 days a year; in addition, there are three jobs and 11 workers.
3. The nearest hospital is 13 km away.
4. All operating personnel has its personal protective equipment according to Chapter 600 of the work rules.

Therefore, it was decided to take observation to “Department of Operation” in a Generation Unit.

Through the observation of the activities of each worker, the following stages were established to perform the “Operation” of a Generation Unit:

1. Driving to the Generation Unit (GU) or to the Camp.
2. Access to the GU.
3. Inspection and testing of the “main stop valve”.
4. Inspection and testing of the “turbo-pump oil”.
5. Backwash (Filter change).
6. Inspection to the “control room”.
7. Inspection to the “turbo-generator”.
8. Inspection of the “reverse osmosis”.
9. Inspection of the “valve leave”.
10. Closing the unit.

At all stages, it has the characteristic odor of H2S, so it is understood that the pollutant is present, in addition to the dangers of “Postural Overload”, “Temperature afflicted”, “Noise”, among others.

Exposure Assessment

The observation of activities, also gave us the time and frequency with which workers perform their work (Figure 1). Resulting in:

a) The total time of the “normal operation” of a GU is 15 minutes, without making the “backwash”.
b) If it is performed the “backwash”, the estimated time would be 30 minutes.

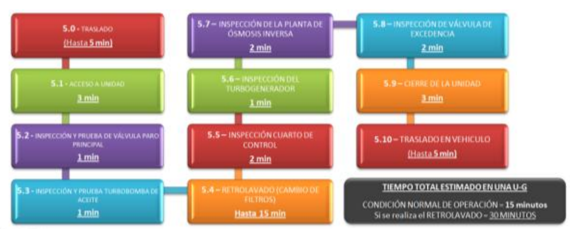


Figure 1: Sequence and timing of completion of each stage.

The frequency of the “operation” of the GU, was determined according to “operators” must make 3runs at 8 GU (Figure 2).

c) The frequency is given by 3 runs at 8 GU, so that 24 repetitions are considered.
d) The total exposure time during “normal operation” of a GU is 24 repetitions times 15 minutes, resulting in 360 minutes or 6 hours.

It is considered that for every “backwash” performed, the exposure increases by 15 minutes.

Finally, the evaluation of the concentration levels of hydrogen sulfide was determined using the H_2S measuring device owned by the company.

Figure 2: Frequency of stages.

The procedure was to carry the device in each of the stages of "operation" of a GU to determine the concentration levels. This was done on a monthly basis for one year.

When handling data, phase measurements, is generalized to three main areas:

1) Front of the GU.
2) Inside the GU.
3) Back of the GU.

Figure 3: Concentration measured in the environment.

As shown in Figure 3, the average concentration measured in the environment is: 1) 2 ppm in the front of the GU, 2) 4 ppm inside the GU and 3) 9 ppm in the back of the GU.

Workers Dose-Response Assessment

Based on the signs and symptoms that occur in humans when exposed to hydrogen sulfide according to the ATSDR, and clinical evaluation conducted by the occupational physician, we have the following:

Correlations:

- Headache.
- Nausea.
- Ataxia.
- Inflammation of the lining of the eye.
- Chronic cough.
- Conflicting work environment.

Findings:

- High blood pressure.
- Dry eye syndrome.
- Thermal burn keratitis.
- Epistaxis.

The research data on dose-response can be seen in Figure 4.

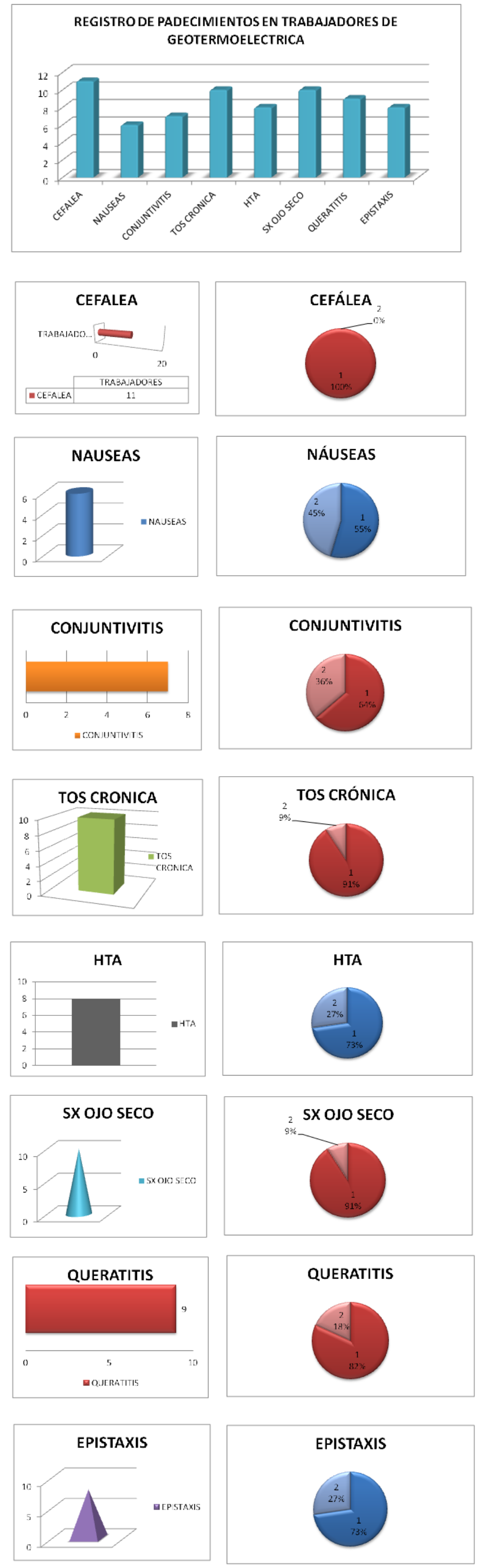


Figure 4: Research data on the dose-response.

Risk Characterization

Using the method of NOM-010-STOPS-1999 to determine the “Qualitative risk classification”, the following results were obtained:

1) The health effects degree of the contaminant in the work environment is: “Level 2, Reversible effects”.

Obtained according to the “Median Lethal Concentration”, CL50=444ppm for hydrogen sulfide.

Table 1: Health effects degree of the contaminant in the work environment.

TABLA 1
GRADO DE EFECTO A LA SALUD DEL CONTAMINANTE
DEL MEDIO AMBIENTE DE TRABAJO

GRADO DE EFECTO A LA SALUD	EFECTO A LA SALUD	CRITERIOS DE TOXICIDAD			
		RATA DL_{50} VIA ORAL	CONEJO DL_{50} VIA CUTANEA	RATA CL_{50} VIA RESPIRATORIA	
		mg/kg	mg/kg	mg/l	ppm
0	EFECTOS LEVES REVERSIBLES O SIN EFECTOS CONOCIDOS	MAYOR QUE 5000	MAYOR QUE 2000	MAYOR QUE 20	MAYOR QUE 10000
1	EFECTOS MODERADOS REVERSIBLES	MAYOR QUE 500 HASTA 5000	MAYOR DE 1000 HASTA 2000	MAYOR QUE 2 HASTA 20	MAYOR QUE 2000 HASTA 10000
2	EFECTOS SEVEROS REVERSIBLES	MAYOR QUE 50 HASTA 500	MAYOR QUE 200 HASTA 1000	MAYOR QUE 0.5 HASTA 2	MAYOR QUE 200 HASTA 2000
3	EFECTOS IRREVERSIBLES. SUSTANCIAS CARCINOGENAS SOSPECHOSAS, MUTAGENAS, TERATOGENAS	MAYOR QUE 1 HASTA 50	MAYOR QUE 20 HASTA 200	MAYOR QUE 0.05 HASTA 0.5	MAYOR QUE 20 HASTA 200
4	EFECTOS INCAPACITANTES O FATALES, SUSTANCIAS CARCINOGENAS COMPROBADAS	IGUAL O MENOR DE 1	IGUAL O MENOR DE 20	IGUAL O MENOR DE 0.05	IGUAL O MENOR DE 20

2) The potential exposure degree is:

a. With regard to 6 hours accumulative exposure and a concentration of 2 ppm is “Level 1, infrequent exposure to low concentrations”.

Table 2: Potential exposure degree, regarded for a concentration of 2ppm.

Tabla 2
Grado de exposición potencial

GRADO	* DESCRIPCIÓN DE LA EXPOSICIÓN	** RANGO DEL LMPE (PPT ó CT)
0	NO EXPOSICION CON LA SUSTANCIA QUIMICA	CMA ≤ 0.1 LMPE
1	EXPOSICION POCO FRECUENTE CON LA SUSTANCIA QUÍMICA A BAJOS NIVELES O CONCENTRACIONES	0.1 LMPE < CMA ≤ 0.25 LMPE
2	EXPOSICION FRECUENTE CON LA SUSTANCIA QUIMICA A BAJAS CONCENTRACIONES O EXPOSICIÓN POCO FRECUENTE A ALTAS CONCENTRACIONES	0.25 LMPE < CMA ≤ 0.5 LMPE
3	EXPOSICION FRECUENTE A ALTAS CONCENTRACIONES	0.5 LMPE < CMA ≤ 1.0 LMPE
4	EXPOSICION FRECUENTE A MUY ALTAS CONCENTRACIONES	1.0 LMPE < CMA

b. With regard to 6 hours accumulative exposure and a concentration of 4 ppm is “Level 2, frequent exposure to low concentrations or infrequent exposure to high concentrations”.

Table 3: Potential exposure degree, regarded for a concentration of 4ppm.

Tabla 2
Grado de exposición potencial

GRADO	* DESCRIPCIÓN DE LA EXPOSICIÓN	** RANGO DEL LMPE (PPT ó CT)
0	NO EXPOSICION CON LA SUSTANCIA QUIMICA	CMA ≤ 0.1 LMPE
1	EXPOSICION POCO FRECUENTE CON LA SUSTANCIA QUÍMICA A BAJOS NIVELES O CONCENTRACIONES	0.1 LMPE < CMA ≤ 0.25 LMPE
2	EXPOSICION FRECUENTE CON LA SUSTANCIA QUIMICA A BAJAS CONCENTRACIONES O EXPOSICIÓN POCO FRECUENTE A ALTAS CONCENTRACIONES	0.25 LMPE < CMA ≤ 0.5 LMPE
3	EXPOSICION FRECUENTE A ALTAS CONCENTRACIONES	0.5 LMPE < CMA ≤ 1.0 LMPE
4	EXPOSICION FRECUENTE A MUY ALTAS CONCENTRACIONES	1.0 LMPE < CMA

c. With regard to 6 hours accumulative exposure and concentration of 9 ppm is “Level 3, Frequent exposure to high concentrations”.

Table 4: Potential exposure degree, regarded for a concentration of 9ppm.

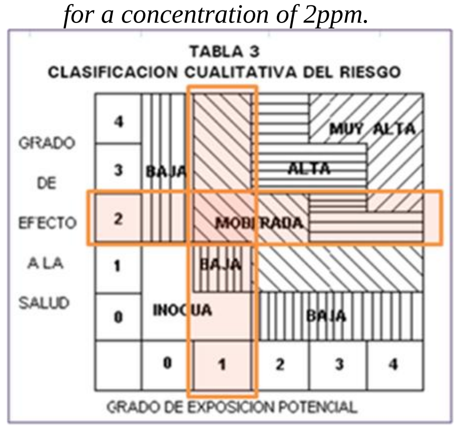
Tabla 2
Grado de exposición potencial

GRADO	* DESCRIPCIÓN DE LA EXPOSICIÓN	** RANGO DEL LMPE (PPT ó CT)
0	NO EXPOSICION CON LA SUSTANCIA QUIMICA	CMA ≤ 0.1 LMPE
1	EXPOSICION POCO FRECUENTE CON LA SUSTANCIA QUÍMICA A BAJOS NIVELES O CONCENTRACIONES	0.1 LMPE < CMA ≤ 0.25 LMPE
2	EXPOSICION FRECUENTE CON LA SUSTANCIA QUIMICA A BAJAS CONCENTRACIONES O EXPOSICIÓN POCO FRECUENTE A ALTAS CONCENTRACIONES	0.25 LMPE < CMA ≤ 0.5 LMPE
3	EXPOSICION FRECUENTE A ALTAS CONCENTRACIONES	0.5 LMPE < CMA ≤ 1.0 LMPE
4	EXPOSICION FRECUENTE A MUY ALTAS CONCENTRACIONES	1.0 LMPE < CMA

3) Finally, with the two previously determined indicators, the “Qualitative risk classification” is:

a. With regard to 6 hours accumulative exposure and a concentration of 2 ppm, is: **MODERATE.**

Table 5: Qualitative risk classification, regarded for a concentration of 2ppm.



MODERADA

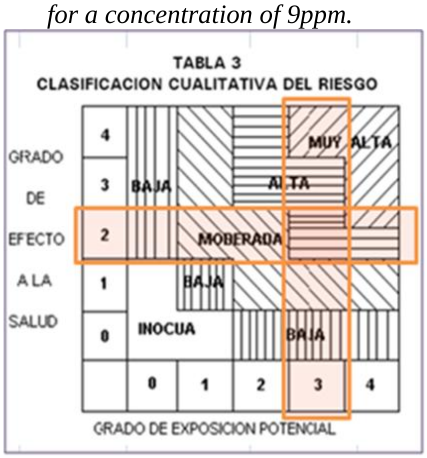
b. With regard to 6 hours accumulative exposure and a concentration of 4 ppm, is: **MODERATE.**

Table 6: Qualitative risk classification, regarded for a concentration of 4ppm.

MODERADA

c. With regard to 6 hours accumulative exposure and concentration of 9 ppm, is: **HIGH.**

Table 7: Qualitative risk classification, regarded for a concentration of 9ppm.



ALTA

CONCLUSION

With the information obtained is evident that the combinations of exposure time and concentration of chemical, qualitative risk classification (QRC) is:

Front of the GU

Regarding a hydrogen sulfide concentration of 2ppm most of the time, so that the QRC is:

LOW, the majority of the workday, and the ranking goes up from 6 hours to stay on the same site, which is unlikely, since their actual day of work in the generations units is 6 hours per shift.

Inside the GU

Regarding a hydrogen sulfide concentration of 4ppm most of the time, so that the QRC is:

LOW, up to 2 hours spent in a Generating Unit, which can occur if an equipment or device has a “fault condition”, as in interviews with managers and workers, say that it is likely to stay 1 or 2 days in the same site at the GU, leaving only to eat.

MODERATE, at 4 hours spent in a GU, which can occur if an equipment or device fails or has conditions of maintenance operations performed.

HIGH, after 6 hours of stay in an UG can occur if an equipment or device has fault conditions, due to the “operation” personnel must be present to turn on the turbine, operate and observe the normal operation and remain there until the equipment can be synchronized with the National Electricity System (Sistema Electrico Nacional, SEN by its acronym in Spanish).

Back of the GU

Regarding a hydrogen sulfide concentration of 9ppm most of the time, so that the QRC is:

LOW, with 1 hour spent in a GU, the time spent by the employees of “operation” does not involve more than 15 minutes.

HIGH, after 4 hours spent in a GU, occurs rarely when there are fault conditions in the reverse osmosis systems, staff more exposed is that of the “maintenance department”, because they are directly responsible for conducting actions to address any deficiencies.

Final

From all the information gathered, it is noted that the “failure scenarios” in a Generation Unit, staff are more prone to risk being exposed from a moderate to a high level, which means to remain for long periods of exposure time.

It should be noted that all the reference data were evaluated for acute exposure, but not by chronic exposure as they really occur in a geothermoelectric power plant.

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INFORMATION

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