Conference Paper

Hydrogen Sulfide Identification, Monitoring, and Hazard Control in 'XYZ' Geothermal Operation

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Abstract

Geothermal energy is very attractive and has great potential for future development. Over the past 30 years, the geothermal industry has attempted to both improve the productivity of conventional geothermal fields and exploit new unconventional resources by developing techniques that improve steam production. Although geothermal power plants are known as an environmentally friendly form of power production, geothermal steam contains a number of non-condensable gases (NCGs). One of the gases is hydrogen sulphide (H2S), which, if not controlled, may cause safety, health, and environmental problems. Hydrogen sulphide (H2S) is a very toxic gas at normal temperatures. It poses a very serious inhalation hazard. There are numerous case reports of deaths, and most fatalities have occurred in relatively confined spaces (e.g., sewers, sludge tanks, cesspools, depressions on open land, or in buildings). 'XYZ' Geothermal Operation, located in West Java, Indonesia, is a company that produces steam and electricity from geothermal sources. The company implements the H2S hazard control in a systematic manner to prevent high-concentration H2S exposure during normal operations and/or emergencies. In geothermal operations, sources of H2S are present in the wells, the operation process itself, and in the environment. Engineering control, administrative control, and personal protective equipment form the hazard control hierarchy that is implemented in geothermal operations to manage H2S risk. Hydrogen sulfide risk assessment should be provided in all facilities to help mitigate H2S risks.

Keywords: geothermal, non-condensable gases (NCGs), hydrogen sulfide, hierarchy control

1. Introduction

Geothermal energy is very attractive and has great potential for future development. Indonesia, as one of the world's most active volcano clusters, has abundant geothermal reserves. In Indonesia, geothermal resources and reserves amount to as much as 17,546 MW [1].

Although geothermal powers plants are known as an environmentally friendly form of power production, geothermal steam contains a number of non-condensable gases (NCGs). One of these gases is hydrogen sulphide (H_2S), which, if not controlled, may cause safety, health, and environmental problems. In Indonesia, there are numerous volcanic disasters involving the uncontrolled exposure of hazardous gases, including H_2S gas, as occurred in Crater Sinila Dieng in 1979, causing 149 deaths [2]; the eruption of Mount Merapi in 2010, which caused 353 deaths from toxic gas; and several other volcanic eruption events.

There are numerous case reports of HS_2-related deaths, especially in the oil and gas extraction industry [3], sewage maintenance, and farms. Most fatalities have occurred in relatively confined spaces (e.g., sewers, sludge tanks, cesspools, depressions on open land, or buildings [4]. In many cases, multiple deaths have occurred at a single site. Rescuers attempting to save an unconscious co-worker have sometimes entered confined areas without respiratory protection or safety lines. They, in turn, have been overcome by H_2S. Workers who survive a serious short-term H_2S exposure may recover completely or may experience long-term effects [5].

XYZ Company's geothermal steam field began operations in 1994, and via its development, the region has grown, with more and more residential areas being built around the geothermal operation. This increases the risk of exposure to hazardous gases, including H_2S, in residential areas. Based on the results of a study conducted by the company to predict ambient H_2S concentration using the AERMOD dispersion model View 6.7.1, it can be concluded that H_2S dispersion can reach the nearest village (about 2 km away) at a level of more than 5 ppm. In the long term, H_2S exposure at such a concentration will cause health problems [6]. This is why the company is committed to ensuring that the H_2S produced as a result of the geothermal operation is truly managed and controlled.

2. Methods

This research uses descriptive method to describe the application of H_2S hazard management in the geothermal operating environment. This research refers to the Hierarchy of Hazard Control, a system used in industry to minimize or eliminate exposure to hazards. This is a widely accepted system promoted by numerous safety organizations (OSHA, ANSI). This concept is taught to managers in industry and should be promoted as a standard practice in the workplace.

3. Results

The XYZ geothermal steam field began operations in 1994. In its operational phase, it is able to supply steam for a geothermal power plant (Pembangkit Tenaga Listrik Panas Bumi - PLTP). Given the steam characteristics that ultimately result, the fluids from the reservoir are produced by a water-dominated system. In such a water-dominated system, water will fill the cavities and open channels or fractures, while vapors will fill the pores of the rock. It is estimated that 70–80 percent of the reservoir rock contains water, while the other cavities contain steam. The steam and hot water from well production can reach temperatures ranging from 220 to 350^{o}C. These wells were drilled to depths of 1.250 to 3.211 meters, reaching a reservoir of water and steam heat. Then, this fluid easily flows to the surface, and the geothermal steam from the production wells is transferred to the power plant.

Based on the Figure 2, the concentration of H_2S gas, based on the monitoring of Cooling Tower Units 4, 5, and 6 in XYZ, is about 1.29–2.51 mg/Nm3 (Geothermal XYZ, Ltd, 2015). This result is below the threshold value set by the Regulation of the State Minister of the Environment No. 21 of 2008, Annex 5, Concerning the Quality Standard of Unscrupable Sources of Emissions for Businesses and/or Thermal Power Generating Activities (Peraturan Menteri Negara Lingkungan Hidup Nomor 21 Tahun 2008 Lampiran 5 Tentang Baku Mutu Emisi Sumber Tidak Bergerak Bagi Usaha dan/atau Kegiatan Pembangkit Tenaga Listrik Termal).

Management efforts on the part of XYZ Company related to potential H_2S hazards have been carried out thoroughly from upstream to downstream stages so that the levels of H_2S in the air do not exceed the allowed threshold.

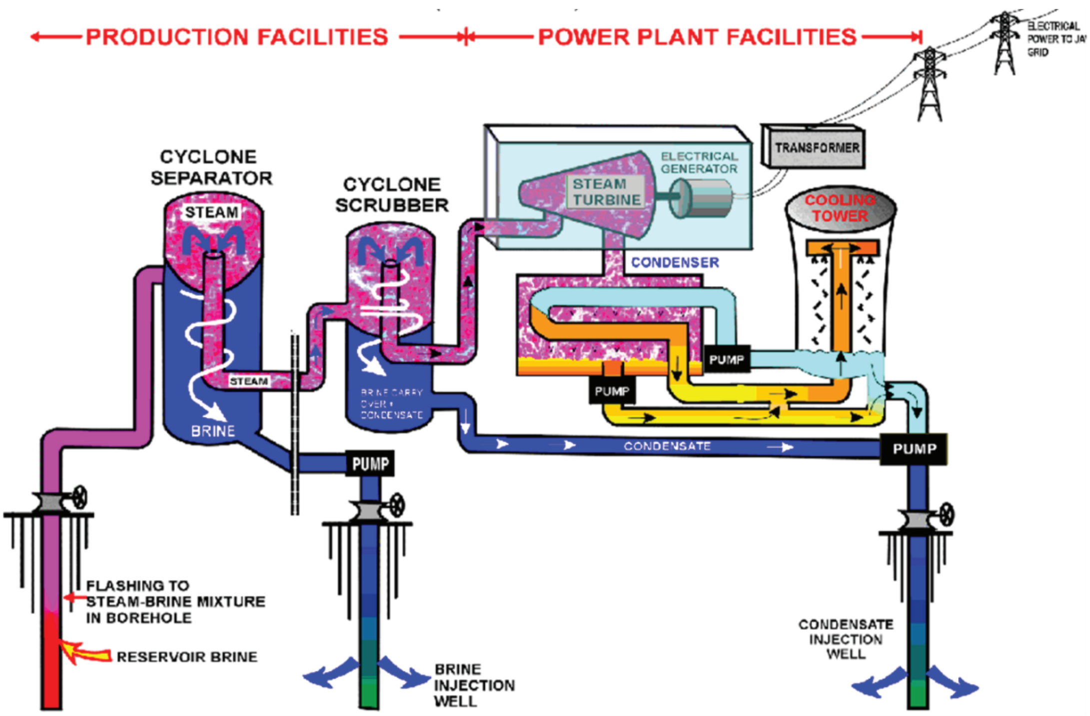

Figure 1: Geothermal power plant scheme.

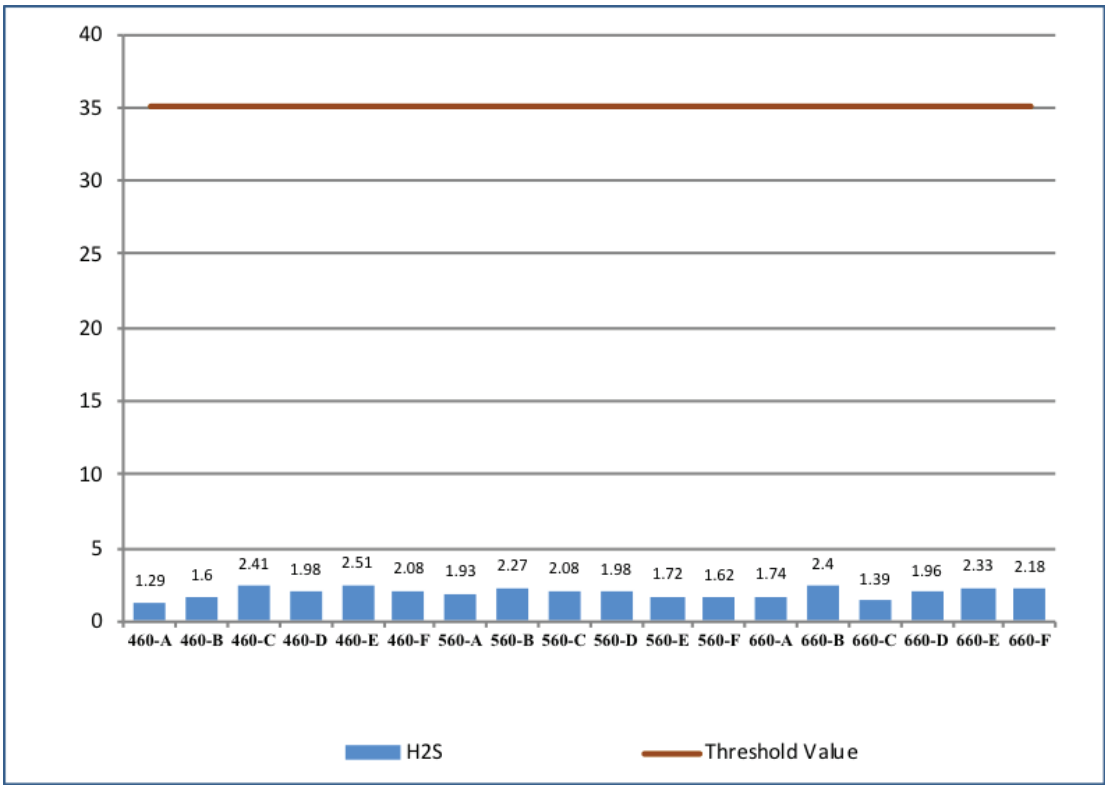

Figure 2: H2S gas monitoring on Cooling Tower 4, 5, 6 in 2015.

3.1. Elimination and substitution

H_2S hazard management with elimination and substitution cannot be done because H_2S is one of the few NCGs that exist naturally in nature.

3.2. Engineering control

Some of the engineering designs used to control H_2S exposure for both workers and the environment include the following:

1. **Material**. Naturally, the steam generated from the production well contains a high concentration of H_2S, so all equipment and piping installations must be resistant to H_2S exposure or protected from H_2S. Some examples of equipment that must be adjusted include the pipeline, valve, pump, wellhead, and flash tank. Most of the materials used are of certain standard thickness and have anti-rust properties, and certain equipment is coated with an insulator (silica and aluminum).

2. **Flash tank**. Flash tanks in geothermal power plants are used to handle geothermal fluids when there is a disruption in their movement from the production wells to the turbines. Hot water coming from the geothermal well enters the flash tank, which has been designed in such a way that downward pressure will cause the water to boil quickly and turn into steam. Steam containing high concentrations of NCGs is then released into the atmosphere.

3. **Gas removal system**. This system serves to minimize the concentration of NCGs in the steam in the main condenser. The gas removal system consists of several process units, that is, the ejector, intercondensor, pump, and separator. The ejector serves to pull and collect steam containing NCGs. Then, this steam will be re-condensed by intercondensor. The remaining NCGs will be pumped to the cooling tower fan and released into the atmosphere.

4. **Alarm system**. This is a system that serves as an early warning sign in case of exposure to H_2S gas in the process of transferring the steam into a power plant. The activation of the alarm device is controlled automatically via the control room and monitored continuously. In some equipment, automatic switches to shut off the equipment are provided to protect against H_2S leaks.

5. **Blower and active ventilation**. Both of these methods are used to ensure that working areas with the potential to accumulate H_2S, especially rooms and low

areas, can be safely entered. A blower is used when there is some activity (i.e., welding, cleaning, inspection, etc.) in a confined space, and this is a requirement that must be met prior to the beginning of work. Active ventilation is applied to ensure that H_2S is not trapped in a room.

3.3. Administrative control

In controlling the risks posed by H_2S for workers, the environment, and equipment, administrative control is carried out with reference to major H_2S management standards. These standards provide guidelines and requirements for mitigating H_2S exposure among at-risk workers.

1. **Managing safe work**. There are several procedures related to working safely given the potential for high concentrations of H_2S exposure. These include procedures for working in confined spaces, excavation, and portable gas detection. There are also statutory requirements to control H_2S before such work is carried out.
2. **Training of personnel.** The main objective of this training is to ensure that personnel are equipped with knowledge and skills (competent persons), understand the hazards and risks of H_2S gas in their work, understand how to mitigate these hazards, and know about incident reporting. The methods of delivering such training include classes, briefings before the work, communication through posters/banners, and efforts to change behavior by having workers practice Behavior Base Safety (BBS).
3. **Specific procedure for high-risk activities**. There are certain work-related procedures in which high-concentration H_2S exposure is possible (i.e., flow tests, down comer removals, and well monitoring). During these procedures, the safe steps that should be taken to perform the task are clearly stated, whether these concern the equipment used or specific work instructions.
4. **Portable gas detection—maintenance, testing, and calibration.** It is important to ensure that the workplace does not contain high concentrations of H_2S (exceed the threshold), the availability of portable gas detection (multi-gas detector, single gas detector, and fixed gas monitoring detector), and that the equipment works well via consistent maintenance, testing, and calibration.
5. **Emergency response and preparedness**. These ensure company readiness in the case of an unwanted incident involving H_2S exposure among workers or the

environment. Some of the requirements related to emergency preparedness and response include the designation of safe briefing areas, wind shocks, and the availability emergency personnel when there is a high-risk job. In addition, regular emergency drills and exercises are also required.

3.4. Personal protective equipment

The company has provided personal protective equipment, as a last line of protection against the hazards of exposure to H2S gas, to the entire workforce, as well as visitors to the work site. Some of the PPEs provided by companies related to H2S exposure are as follows:

1. A supplied air breathing apparatus (SABA) is recommended in confined work environments or when working duration is more than 30 minutes.

2. A self-contained breathing apparatus (SCBA) with fully charged air cylinders should be used in working conditions in which SABA cannot be used (i.e., open wells), as well as for rescue activities.

4. Discussion

Based on monitoring in Cooling Tower units 4, 5, and 6 in XYZ, the concentration of H2S gas is about 1.29–2.51 mg/Nm^3 [7]. This result is below the threshold value set by the Regulation of the State Minister of the Environment No. 21 of 2008, Annex 5, Concerning the Quality Standard of Unscrupable Sources of Emissions for Business and/or Thermal Power-generating Activities (Peraturan Menteri Negara Lingkungan Hidup Nomor 21 Tahun 2008 Lampiran 5 Tentang Baku Mutu Emisi Sumber Tidak Bergerak Bagi Usaha dan/atau Kegiatan Pembangkit Tenaga Listrik Termal). This shows that the company has successfully minimized the release of H2S into the atmosphere.

Given the concentration in the cooling tower, the effect of the H2S is limited to a smell. Based on observations of the company and interviews with surrounding residents, this smell is not perceivable. One reason for this is that the area around the geothermal operation is a protected mountainous forest, so the odor does not reach the nearest residential area, about 2 km from the operation area [7]. Health effects in human populations exposed to low levels of hydrogen sulfide over long periods cannot serve as a basis for determining tolerable concentrations, because of either co-exposure to several substances or insufficient exposure characterization [8].

Table 1: Human health effects at various hydrogen sulphide concentrations [8].

Exposure (mg/m^3)	Effect / Observation
0.011	Odor threshold
2.8	Bronchial constriction in asthmatic individuals
5	Increased eye complaints
7 or 14	Increased blood lactate concentration, decreased skeletal muscle citrate synthase activity, decreased oxygen uptake
5–29	Eye irritation
28	Fatigue, loss of appetite, headache, irritability, poor memory, dizziness
> 140	Olfactory paralysis
> 560	Respiratory distress
> 700	Death

The company has identified several potential releases of H2S into the atmosphere and has made engineering control efforts. Administration control, in the form of a comprehensive safety program, has been asserted over activities both general and specific. Similarly, the readiness of human resources facing the dangers of H2S exposure has been increased through training and other communication activities. The company is also concerned with the provision of equipment to support the identification of H2S gas exposure, ensuring that portable gas detection is available and functioning. In some activities involving unavoidable high-concentration H2S gas exposure, the company provides special PPE to ensure that workers can work safely (SABA and SCBA). The company also has specially assigned rescue members for a rapid response in the case of incidents caused by H2S gas exposure.

5. Conclucions

In Cooling Tower units 4, 5, and 6 in XYZ, the concentration of H2S gas is about 1.29–2.51 mg/Nm3, below the threshold value set by the relevant regulation.

The company has systematically designed a comprehensive H2S control effort. This includes the design, engineering, administrative, and compliance aspects of providing PPE to all workers, combined with programs to change the behaviors of workers who may be exposed to H2S.

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