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Check-Up of the Hydrogen Sulfide Dispersion Model for the Miravalles Geothermal Field after Four Years of Monitoring

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ABSTRACT

The environmental impact assessment for the Miravalles Geothermal field establishes the limit for the emissions of hydrogen sulfide at 42 μg/m^3 in populated areas and 940 μg/m^3 at one kilometer from the power plants, therefore this gas is monitored at populated areas and also around the power plants. This paper compare the results of the computer model Industrial Source Complex (ISC) modeling the effect of the power plants Miravalles I, Miravalles II and Miravalles III simultaneously against the data obtained using electronic instruments for the measurements. The model dispersion can be as short as one hour with three hours being the average time.

1. INTRODUCTION

The Miravalles Geothermal Field is located at the Miravalles Volcano in Bagaces Guanacaste between the basins of the rivers Blanco and Cuipilapa. The power plants Miravalles I and Miravalles II are located at the coordinates 298 000 N-405 700 E at 610 m a.s.l and the power plant Miravalles III 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 about 240 °C. The proven reservoir area is about 12 km^2, 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, pH of about 8 and a sodium chloride type water characterize most of the fluids from the Miravalles geothermal wells.

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 in tracer quantities. The CO_2 (96-97%), and H_2S (less than 1%) are the most important because of possible effects on environment and human health, for that reason this gas has been modeled. This model tries to establish if the emission from the power plants can be over the maximum permit limits in populated areas. The environmental impact assessment (ICE, 1996) established the maximum concentration to be 42 μg/m^3 in populated areas and 938 μg/m^3 at 1000 meter from the power plants.

In the different environmental impact assessments for Miravalles the hydrogen sulfide emissions were modeled separately for each power plant (ICE, 1988 and 1996). The models estimated concentration of H_2S under 42 μg/m^3 in town and less than 938 μg/m^3 at 1000 m from the power plants.

In 1999, Guido model the hydrogen sulfide dispersion considering the three power plant's effect simultaneously to obtain very similar prediction of hydrogen sulfide concentrations.

This paper shows the comparison of the result of the ISC model against the data obtained between the years 2000 and 2004, using electronic instruments for the measurements.

2. HYDROGEN SULFIDE

H_2S is a poisonous gas that comes from natural sources like volcanic gases, geothermal springs, and decaying organic matter from manmade sources and also from industrial sources. 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. In relative high concentrations can produce human health problems, effects on flora and fauna and damages to human constructions by corrosion and higher quantities may cause death.

Some countries have strict regulation for the maximum emission levels to the atmosphere. Table 3 shows some different international standards for H_2S emissions

TABLE 1: 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 air (Brown, 1995). H_2S smells like rotting eggs and the smell is perceptible in concentrations less than 42 μg/m^3. When the people has exposure to low concentrations of H_2S, it can cause lacrimation, photophobia, and irritation of the nasal mucosa also has a profoundly irritant effect on the cornea producing

paint and blurring of vision and keratitis **(**Waldron, H. 1979).

At 500 $\mu g/m^3$ has a clearly perceptible odor and begins to cause damages to some delicate plants. In the range of 280 000 and 700 000 $\mu g/m^3$ it will produce intoxication and above 840 000 $\mu g/m^3$ it can produce rapid death by asphyxia. (ICE, 1996)

Corrosion is another important aspect to keep in mind when there is H_2S in the atmosphere.

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).

3. HYDROGEN SULFIDE DISPERSION MODEL

The Industrial Complex Source model program was used to model the H_2S dispersion, this program use an equation to describe the puff dispersion in time considering the decay and deposition of material.

3.1 Data used in the Miravalles H_2S dispersion model

The program needs data on meteorological conditions and the source of emission. The meteorological data are used to model the transport and dispersion of the pollutants.

3.1.1 Emission rates

In Miravalles there are different outlet points where non condensable gases could be released the atmosphere. The amount of H_2S for the power plants Miravalles I and Miravalles II are estimated as 232.5 tons per year for each one. (Bogarin, 1996) and for Miravalles III 60.4 tons per year (ICE, 1996). These are the values used in the model.

Figure 1 shows the flow of the non-condensable gases from the production wells through the power plant and how they are disposed to atmosphere.

3.1.2 Modeling area

The main idea of the study is to predict the concentration of H_2S in the towns. The approximated coordinates for the towns close to the power plants are as follows: La Fortuna 295000 N-450000 E, Guayabo 298500 N-402000 E, Cuipilapa 294200 N-408000 E, San Bernardo 291000 N-406000 E, San Pedro 294000 N-401000 E, Guayabal 304500 N-405000 E and Pueblo Nuevo 301500 N-400000 E. The total area selected for the model is between the coordinates 290000-305000 N and 400000-411000 E.

3.1.3 Topographical conditions

The topography and in general the surface characteristics in the zone are irregular. Using the coefficients given in the programs the surface roughness lengths are in the range of 1.3 and 0.25 m.

3.1.4 Meteorological data

The model need hourly data on atmospheric conditions at the surface like temperature, dry bulb temperature, cloud cover, cloud height, win speed and direction. The model also needs upper air data about the mixing layer height. In the Industrial Complex Source model the mixing layer height could be estimated using surface data.

The existing meteorological data for the model are from the station Casa de Máquinas located at the co-ordinates 297800 N-405700 E close to the Miravalles I and Miravalles II power plants. This station collects data on temperature, humidity, precipitation, atmospheric pressure, wind speed and direction. The used are hourly data for the period between May and August 1999.

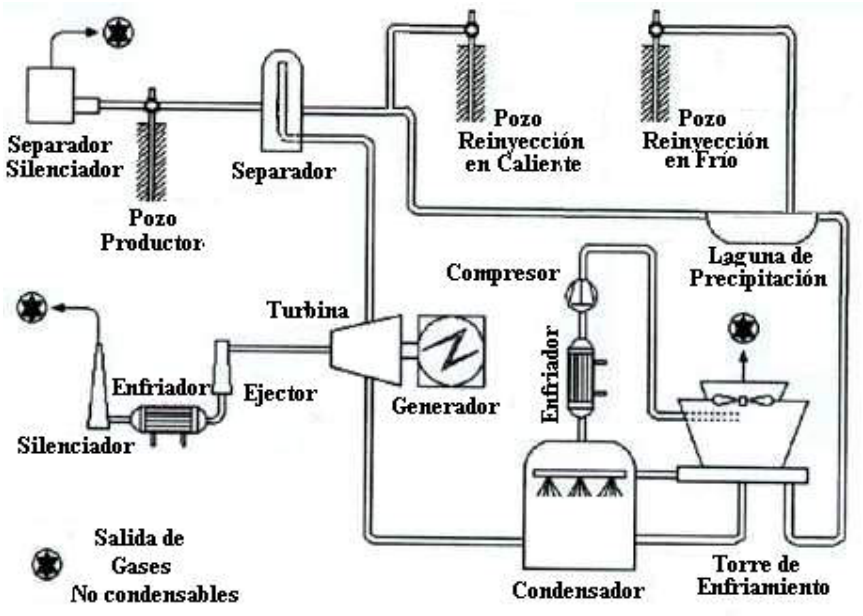

Figure 1: Outlet points for non-condensable gases

3.1.5 Stability parameter

Default parameters established for the Environmental Protection Agency (EPA) considering the atmospheric condition provided by the meteorological data are used.

3.2 Result for the Industrial Complex Source model

Figure 1 shows the results for the one-hour averaging time. The simulation indicated that the possibilities to obtain concentrations of H_2S close to the value of 42 μg/m^3 in the towns are substantial. On the other hand the maximum level obtained within one kilometer of the power plants are less than 442 μg/m^3.

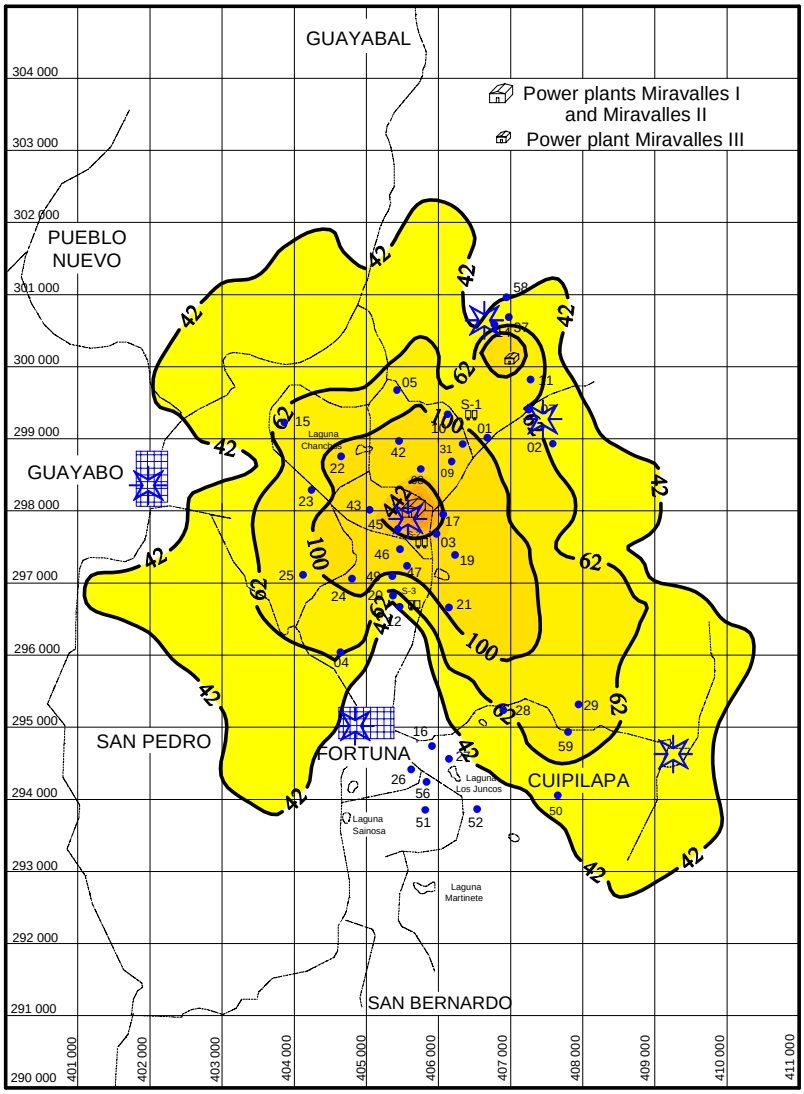

Figure 2: Dispersion plume as one-hour averaging time

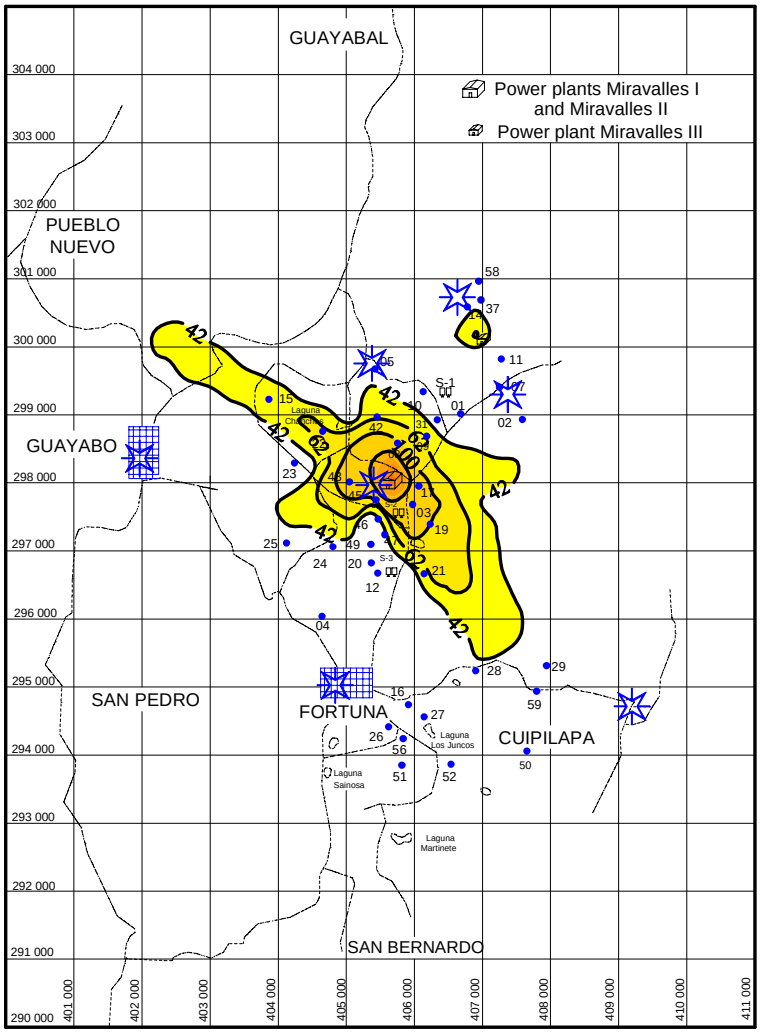

Figure 3: Dispersion plume as Three-hour averaging time

Figure 2 shows the simulation for three-hour averaging time. It is evident that for the three-hour averaging time the presence of Miravalles III does not have effects on the plume dispersion and only represents a short effect close to the emission source. The maximum concentration estimated for the program within one kilometer of the power plant is less is 100 $\mu g/m^3$.

4. FIELD MEASURED DATA

The Miravalles geothermal field monitoring net has been established with six environmental measurement points, distributed in the project area. The star symbols in Figures 2 and 3 show the location of these points.

In these stations the concentrations of hydrogen sulfide are measured by using electronic equipment. This equipment has the capacity of measure H_2S concentrations from 4.2 $\mu g/m^3$.

The Figures 4, 5 and 6 show the concentrations near to the power plants (less than one kilometer) and the Figures 7, 8 and 9 shows the results of the measurements in populated areas.

The results for the one-hour averaging time show measured hydrogen sulfide concentrations low than the model prediction. It means the model result is conservative and could be used as a good tool to study the potential effects of the H_2S emission over the environment and define if an H_2S abatement process is necessary.

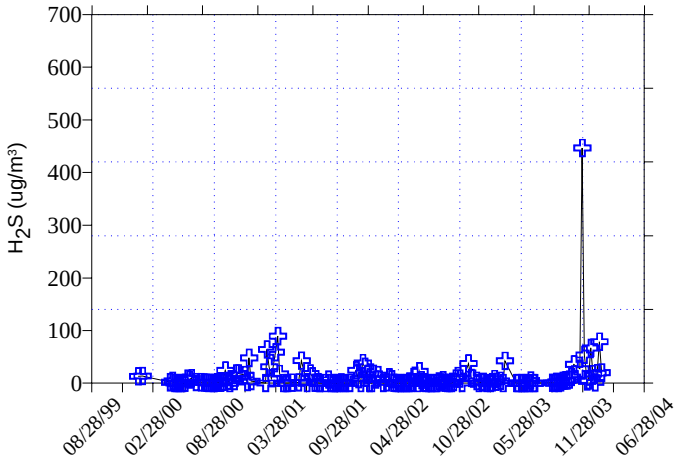

Figure 4: Concentration of H_2S at Casa de Máquinas

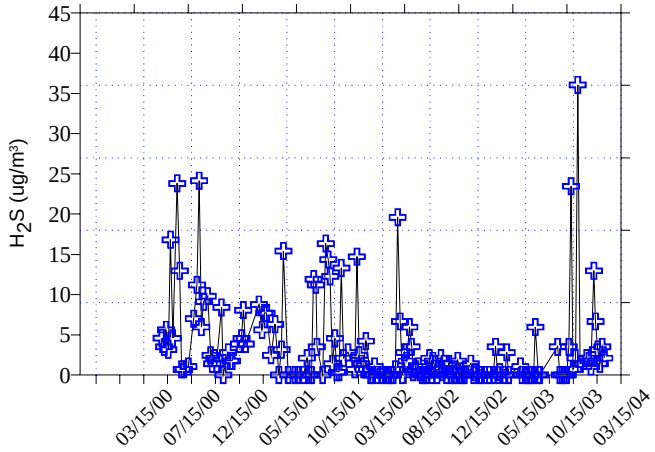

Figure 5: Concentration of H_2S at Las Hornillas

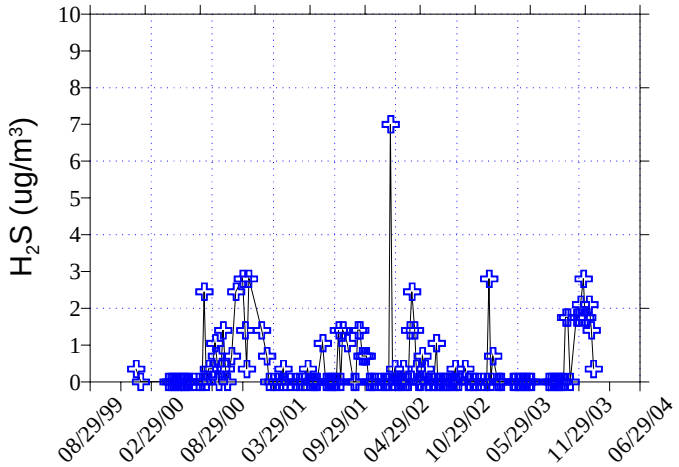

Figure 6: Concentration of H_2S at PGM-14

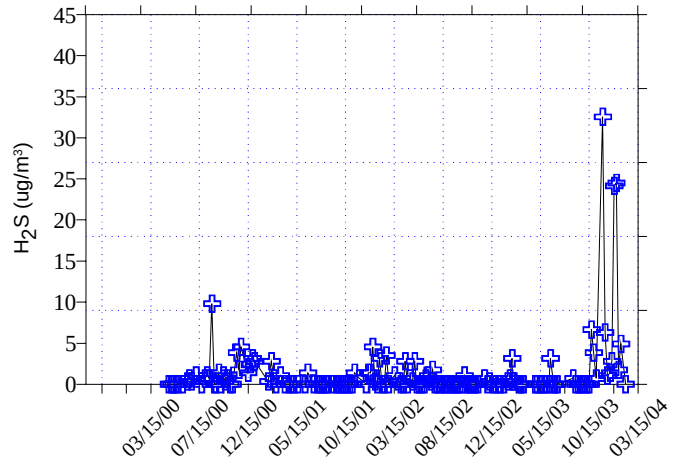

Figure 7: Concentration of H_2S at La Unión

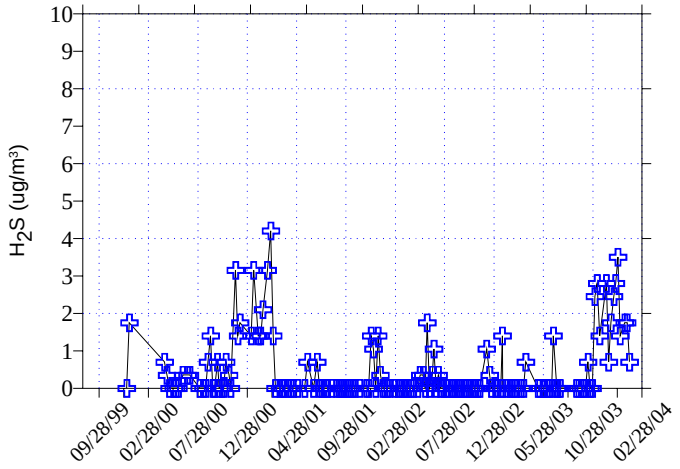

Figure 8: Concentration of H_2S at La Fortuna

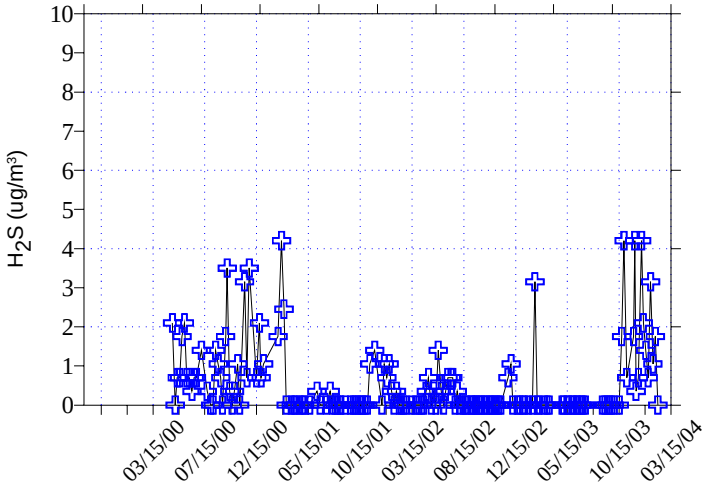

Figure 9: Concentration of H_2S at Cuipilapa

It is necessary to underline that the monitoring point presented in the Figure 5 (Las Hornillas), in the Figure 6 (PGM-14) and in the Figure 7 (La Unión) are near to a natural source of H_2S emission (Fumaroles). That can help to explain the changes in the concentration. The concentration at Fortuna, Guayabo and Cuipilapa are under 4,2 $\mu g/m^3$, its means are under the minimum equipment measurement range.

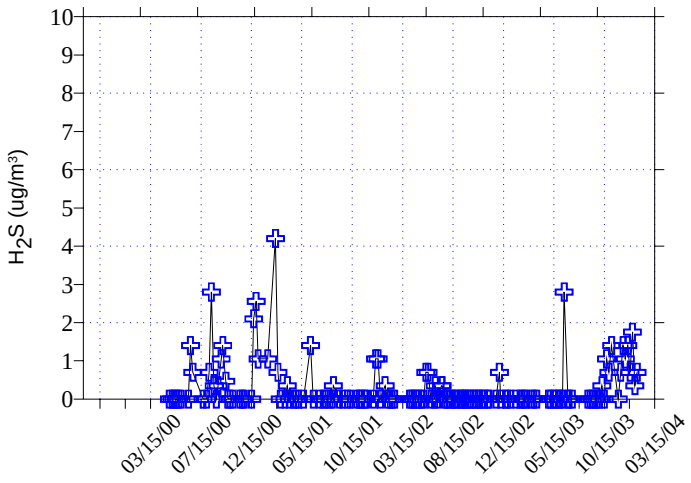

Figure 10: Concentration of H_2S at Guayabo

5. CONCLUSIONS

The major concentration of H_2S is present near to the power plants but it is still under the maximum limits.

The concentration in towns are under 4.2 µg/m^3 and it is still in the range of error of the instruments. For that reason it can be considered like there is no H_2S concentrations at populated areas.

The exploitation of the geothermal field does not represent H_2S problems, because the concentrations of hydrogen sulfide are under the maximum limits.

The model does not consider the emission present at the natural sources like fumaroles and volcanic activities. It could be important to model the effect of this emissions to compare with the obtained results.

The monitoring shows that the computer model for Miravalles is conservative, because the concentrations measured are lower than the model prediction.

It is necessary to improve the Miravalles computer model to obtain more accuracy results.

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