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AIR QUALITY IMPACT ASSESSMENT OF SABALAN GEOTHERMAL POWER PLANT PROJECT, NW IRAN

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ABSTRACT

This study is a regional assessment of the potential impacts on air quality of utilization of Sabalan geothermal power plant northwestern Iran. A network of thirty sampling point and a meteorological station were installed to characterize the air quality and atmospheric transport properties of the area before development. These instruments measured the concentrations of H_2S, CO_2, SO_2, NO, NO_2 and particulates. Wind velocities and directions were also measured to determine atmospheric stability. By using these data the background dispersion model for each gas were prepared in the GIS environment.

In the current study the prediction distribution of H_2S after utilization of geothermal power plant (GPP) were modeled. To achieve this goal the geothermal steam were analyzed chemically to estimate potential emission rates of air pollutions from the planned 50 MW geothermal power plant.

The Industrial Source Complex Model (ISC3View) was applied to make the prediction dispersion model of H_2S which will be release to the local atmosphere from the 50 MW planned geothermal power plant. The prepared background and prediction model were combined in the GIS environment.

The results show that the H_2S concentrations will be lower than standard in 98% of the area and the pollutant from power plant, will be transferred to the northeast and east. The maximum concentration of H_2S about 31 ppb will be in the areas close to the powerhouse. The concentration of H_2S will be close to the Department of Environment (DOE)'s standard level for ambient air quality. In the study area will be only small impacted parts of the areas close to wells in site A and C. The concentrations of H_2S in these areas will be 28-31 ppb which can be defined as areas under risk. These mean at least once a year in these areas the concentration of H_2S will be exceed than air quality standard. Therefore monitoring of H_2S periodically is recommended. The areas under risk are 5.8 km^2 which is around 2% of the study area.

INTRODUCTION

There are well proven computer models for predicting dispersion of the gas plume in the atmosphere. In these studies, the meteorological conditions and potential emissions were used to prepare predicted dispersion model of H_2S concentrations and defined the area under risk. Modelling results can be used to assess whether to employ pollution abatement technology and monitoring areas. The Industrial Source Complex Model ISC3View, (Jesse and Cristiane, 1998) was used for H_2S dispersion modelling in the Sabalan area. This model is a Gaussian diffusion model designed for two emission categories, continuous (steady-state) or instantaneous (transient). In steady-state releases, source characteristics do not vary with time and the release duration is long.

The Sabalan area in northwest Iran has considerable geothermal energy resources that can be used for power generation. The Sabalan Geothermal Power Plant, Environmental Impact Assessment Project (GPP-EIA) tries to evaluate the potential effects of the project. Its aim is to ensure that any development proceeds in an environmentally acceptable manner. An integral part of this project is assessment the potential impact of the project on the local air quality.

Basically GPPs release a variety of gaseous to the atmosphere. From an environmental perspective the most important gaseous contaminants are CO_2, H_2S, NH_3, CH_4, Rn, Hg, H_3BO_3 and As. The experiences of other GPPs show that the principle gases of concern are H_2S and CO_2 and other constituents are less likely to have a significant adverse effect on the surrounded environment. Contaminant non-condensable gas concentration in the exhausted gas and steam will depend on the steam chemistry, power plant technology and the ambient air quality.

In this study to evaluate the impacts of non-condensable gases on the environment, the Khiavchai river watershed as a study area and the following tasks were addressed:

- Investigating and modelling of the background air quality prior to utilization,
- Estimate potential contaminant flow rate from the planned GPP and make predicted model,
- Combination of background and predicted model to defined the impacted and the areas under risk.

To carry out these tasks a network of 30 sampling point and a meteorological air quality monitoring stations were erected in the study area. Each station gathered air quality data on the concentration of selected gaseous, pollutants and airborne particulates.

STUDY AREA

The Sabalan geothermal field is located in northwest part of Iran. The study area is 282 km^2 including Khiav river watershed located in the east of the field.

It is located between 38° 12' and 38° 22' North and 47° 39' and 47° 49' east. its population centers are villages Moil, Valezir and Dizo. Moil the biggest village with 400 families located approximately 16 kilometer paved road from Meshkinshahr city. (Yousefi, 2004).

The study area is remote, covered by intensive grass and full of hot and cold springs. The location of the study area is shown in Figure. 1.

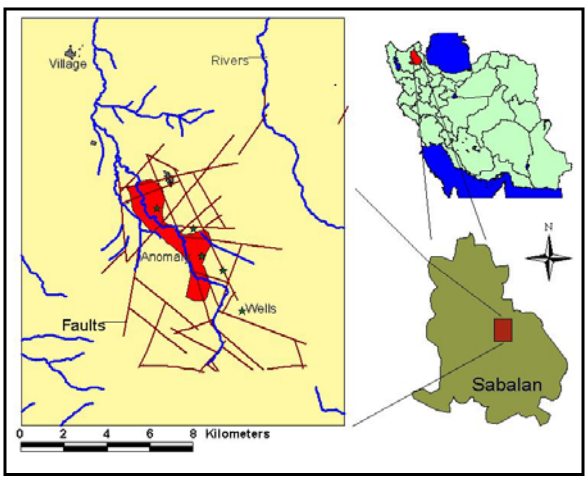


Figure1.Study area

HYDROGEN SULPHIDE (H_2S)

H_2S is one of environmental concerns which appear to be universally present in geothermal fields. The impact of H_2S discharge will depend on local topography, wind patterns and land use, but the effects include an unpleasant odour, corrosion, eye irritation and respiratory damage in humans. Detection by smell is possible at a concentration of about 0.3 ppm. As the concentration increases, the odour becomes sweeter and disappears at around 150 ppb, thus smell is not a reliable indicator of concentration. H_2S occurs near gas exhausters in power stations and in fumaroles and monitoring is required continuously. H_2S can react with oxygen to form more oxidised sulphur compounds.

OVERVIEW OF THE DISPERSION MODEL

The pollution mapping section of the ISC3View program allows the user to perform H_2S dispersion calculations using a simple Gaussian Plume model to predict the level of concentrations downwind from the source. The user can input the following variables: wind speed, direction, atmospheric stability, H_2S flow rate, and one of two terrain roughness classes. The terrain classes represent a facility surrounded by a flat, open field with crop stubble, or surrounded by elevated barriers. The output of the model is a color-coded map of the H_2S plume. The map indicates estimates of the plume length.

GIS IN AIR QUALITY MANAGMENT

By doing air quality modeling in a GIS environment, the output of the pollutant records can be obtained in the form of spatial records.
GIS science and technology is capable of supporting the development of geospatial air quality models. For modelling in GIS environment, AQMS (Air Quality Management System) may consider as be thought of comprising three phases namely, monitoring, development of DSS (Decision Support System) and execution. The milestone capabilities of GIS for AQMS are as fallow (Hussain, 2003):

a) To locate the monitoring stations

b) To develop geospatial air quality models

c) To develop spatial decision support system

GAUSSIAN DIFFUSION EQUATIONS

This study is based on the Gaussian diffusion model by using the *ISC3view* software. The model for stacks uses the steady-state Gaussian plume equation for a continuous elevated source. For each source and each hour, the origin of the source's coordinate system was placed at ground surface at the base of the stack. The X-axis is positive in the downwind direction; the axis is crosswind (normal) to the Y-axis and the Z-axis extends vertically. The fixed receptor locations are converted to each source's co-ordinate system for each hourly concentration calculation. The hourly concentration that calculated for each source at each receptor is summed up to obtain the total concentration produced at each receptor by the combined source emissions.

For the steady-state Gaussian plume, the hourly concentration at downwind distance X (m) and crosswind distance Y (m) was given by:

$$C = \frac{QKVD}{2\pi u_s \sigma_y \sigma_z} \times \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where;

Q=Pollutant emission rate,
K= Scaling coefficient,
(default value for *Q* of 1×10^6 g/s and concentration in $\mu g/m^3$),
V= Vertical term,
D= Decay term,
σ_X, σ_y= Standard deviation of lateral and vertical concentration distribution (m), and
Us= wind speed at release height (m/s).

Cox and Sheppard (1980) and Cox and Sandalls (1974) have estimated average removal rates of hydrogen sulphide. Using an average reaction rate 5×10^{-12} cm^3/s and an average hydroxyl concentration of 3×10^6 molecules/m^3, an average removal rate of hydrogen sulphide was estimated to be approximately 5 % per hour. This will give an exponential decay rate of 1.425×10^{-5} s^{-1} when used in the ISC3View model.In the present study a similar removal rate of 5% hour was used. (Noorollahi, 1999)

METEOROLOGICAL PARAMETERS

In this research the monitored environmental data from meteorological station in the site, were collected, and then the accuracy of the data was assessed by using statistical analysis to detect and remove errorly recorded data. The required meteorological parameters by the model are surface and upper observation data in ASCII meteorological format. The required surface data are temperature, cloud cover percent, cloud height, wind speed and direction. The upper air data is the mixing layer height. ICS3View can estimate the mixing layer height from the surface data.

There is a meteorological station in Sabalan geothermal field. In this study the data for the year 2001 were used to analyze and modeling to predict and compare the condition of ambient air before and after utilization of power plant were conducted.

Atmospheric stability

Together with distance from source, the atmospheric stability affected the dispersion parameters (σ_x, σ_y). It is often defined by the Pasquill stability categories, which ran from category A for a stable atmosphere to E for an unstable atmosphere. In the model the default wind speed parameter ranging from 1.54 m/s to 10.18 m/s is used in place of the discrete stability categories, and also wind speeds that are changeable by user. The relationship between the Pasquill stability categories and the wind speed parameters used in the model are shown in Table 1.To define the stability parameter, the model employs one of two methods, using wind speed or using the standard deviation of the wind direction to define the stability parameter.

Table1.The relationship between the Pasquill stability categories (SC) and the wind speed (m/s) parameters (WS)

SC	A	B	C	D	E
WS	1.54	3.09	5.14	8.23	10.18

Wind patterns

Wind data analysis was carried out for the whole year 2001. It is evident that the dominant wind pattern is one of the important requirements for the model. The dominant wind directions were east and northeast; this means that maybe transport of H_2S in the area will be towards east and northeast. Annually wind rose diagrams of the field are shown in Figure2.

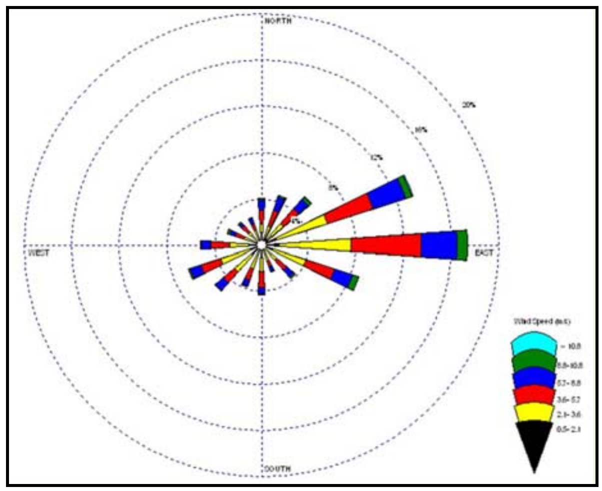


Figure.2. Wind rose diagram of NW Sabalan (2001)

Temperature

The temperature fluctuations in the study area are large from -35 in January to +30 in June and July. The average temperature variation in the study area from 2000 to 2003 is shown in Figure 3.

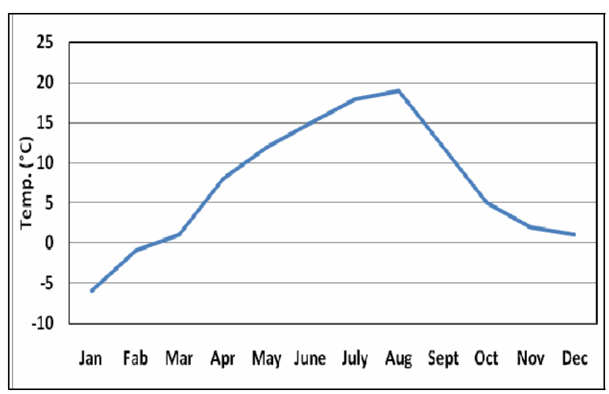


Figure.3. Temperature variation in the study area

Humidity

The humidity in the area is not very high because of high elevation. Average annual humidity in the study area is 59.5%. The maximum humidity is in May with 85 % and the minimum is in June, 13%.

Precipitation

The measurements from April 2000 to March 2005 show the average annual precipitation in the area is around 358 mm/year, with maximum precipitation in December about 89 mm and the minimum is zero in June and July.

BACKGROUND AIR QUALITY

A network of thirty sampling point and a meteorological station for air quality monitoring were erected in the study area (Figurer 4).

In the meteorological stations data for temperature, humidity, wind speed, precipitations, wind directions, solar radiation and air pollutions such as SO_2 and NO_x are continually recorded in the installed computer every half an hour.

In the 30 air quality sampling point H_2S, CO_2, No_x, SO_2 and PM (Particulate Matter) were measured once a season from July 2000 to May 2001 and then H_2S related to its importance were measured once a month from June 2001 to April 2002.

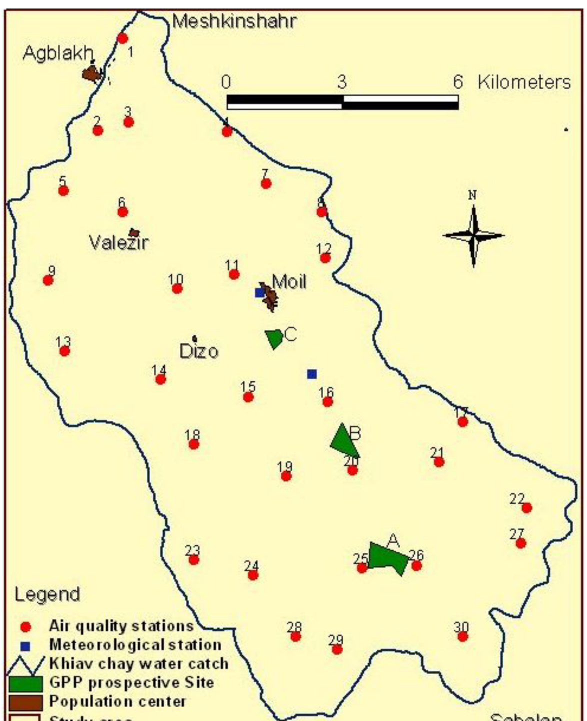
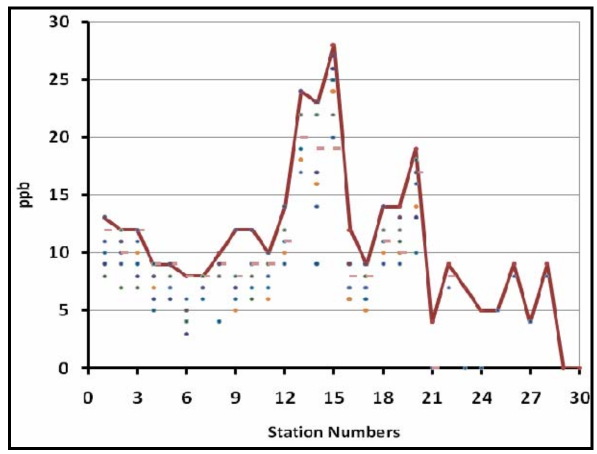


Figure.4. Location of air quality sampling points and meteorological station

Sabalan geothermal field is an unexploited natural area without any industrial or other air polluting activities. Only gases from geothermal manifestations and transportation vehicle escape to the atmosphere. The mentioned air quality parameter concentrations have been monitored in the whole Khiav river watershed about 132 km^2 where most of the geothermal manifestations are located. Comparisons between the standards (30 ppb) and result of the measurements show that the concentrations value of all data are below standard or in the other hand there is no air pollution related to H2S in the study area.

To make the background dispersion model for H_2S in the study area pessimistically between the 16 measured values for each station, the maximum concentrations were chosen for the stations (Figure5).



Figurer.5.The maximum value for each station were chosen for background H2S concentration

Table 2 shows these data which were used to make the background dispersion model in GIS by Interpolating Gaussian operator.

Table.2. Maximum H_2S value in the stations

Sampling Points	H_2S (ppb)	Sampling Points	H_2S (ppb)	Sampling Points	H_2S (ppb)
1	13	11	10	21	4
2	12	12	14	22	9
3	12	13	24	23	7
4	9	14	23	24	5
5	9	15	28	25	5
6	8	16	12	26	9
7	8	17	9	27	4
8	10	18	14	28	9
9	12	19	14	29	0
10	12	20	19	30	0

Figure 6 shows the model which was made in GIS environment by using the background data.

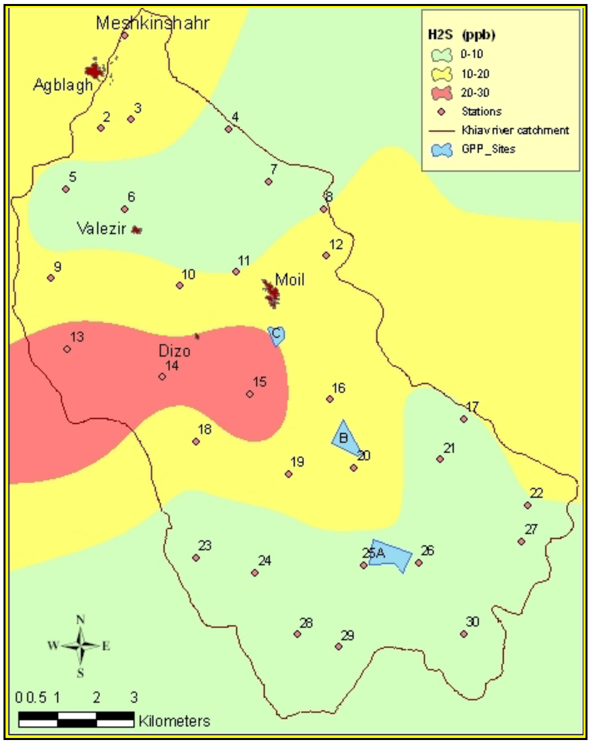


Figure.6. Background dispersion model of H_2S in the ambient air of study area

The prepared background dispersion model shows that the concentration of H_2S in the western part of the field is greater than the other parts. This part of the study area consists of the biggest and highest geothermal manifestations such as Gheynarge hot spring which only can cause such condition in the model.

SABALAN GEOTHERMAL POWER PLANT

A schematic flow diagram of 50 MW Sabalan geothermal power plants is presented in Figure 7.

Conventional geothermal power plant development in high temperature water dominated field would require at least the following main systems with the related equipments:

- Steam piping
- Silencer /Separator
- Steam turbine/Generator
- Condenser
- Cooling towers

Basically H_2S, CO_2 and other gases may release to the atmosphere from separator and condenser.
In the current study the specifications of these systems were applied in the H_2S prediction dispersion model as a possible pollutant point source.

Based on the Sabalan reservoir steam specifications and using Engineering Equations Solver (EES) program, steam consumption was calculated for 50MW electricity. It will be around 380 ton/hour.

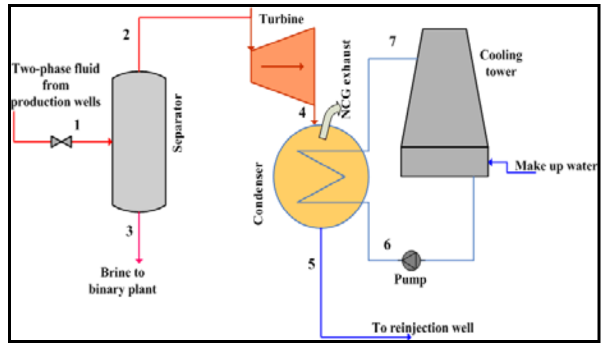


Figure.7. Flow diagram of a geothermal power plant

The model was set to predict average of annually gas concentrations in the area. In the ISC3View model which is based on the Gaussian diffusion system the required emission parameters and power generation specifications were calculated. These parameters are shown in Table 3.

Table3.Emission parameters used for modeling

Parameter	Silencer	Condenser
Stack height	25 m	25 m
Stack exit diameter	2 m	0.3 m
Gas exit temperature	192 °C	55 °C
Gas exit velocity	3 m/s	4 m/s
Pressure	2 bar	1.5 bar
H_2S flow rate	7 g/s	32 g/s

STEAM GEOCHEMISTRY

To estimate the potential emission rate of specific gases from planned flashed-steam power plant, needs to characterize the concentrations of these gases in the steam field of geothermal system which will be condense in the condenser after electricity generator.

The steam geochemistry analysis calculations show that the almost 2% of the steam which will be use for power generation (380 ton/h) will be gases. Between these gases 98% is CO_2, 1.8% H_2S and 0.2 % others which are the non condensable gases (SKM., 2005).

In this study for calculation of H_2S flow rate pessimistically all amount of non condensable gases which is included in the required steam for power generation were considered as exhausted gas that will be released to the local climate without any abatement controls.

The ISC3View dispersion modeling software was used to make prediction dispersion model of H_2S gas from the future power generation. The program takes in account the calculated amount of gas (32g/s) which most probably will be released to the local atmosphere from the power generation (Table 3).

PREDICTION MODEL

The selected sources type for geothermal power plant in the current study is point pollutant which is located in 739480 and 4238380 in the Zone 38 of UTM coordinate system.

After running the ISC3View model the results surfer gird digital data and dispersion map were opened in the GIS environment by using AQMS. The data were edited and drawn again to achieve better visualized maps.

Figure 8 shows the prediction dispersion model map of H_2S in the Sabalan geothermal area if the power plant is located in site B which is one of the suitable sites to install the power plant (Figure 4).

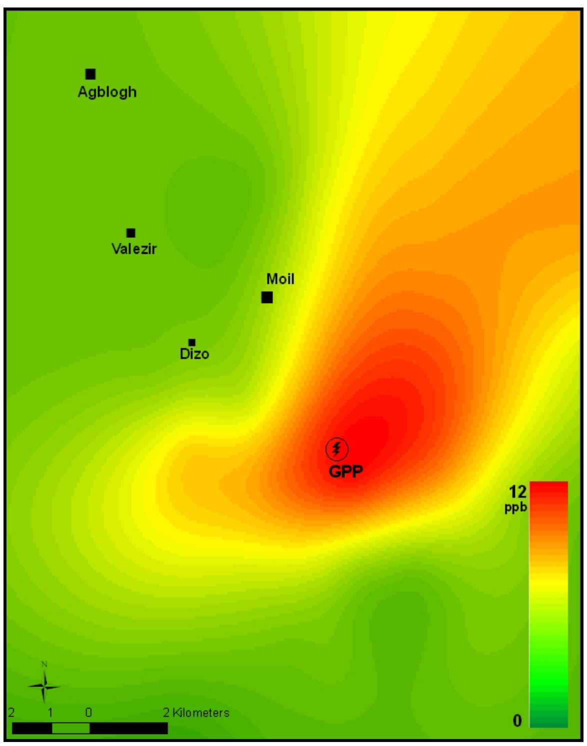


Figure.8. Prediction dispersion model of H_2S, from 50 MW GPP, NW Sabalan

AIR QUALITY IMPACT PREDICTIONS

To predict the impacts of planned power generation on air quality of Sabalan area needs to resort to atmospheric transport modeling.
To predict the air quality impacts from the planned 50 MW geothermal power plant and to define the area under the risk, the background concentration dispersion model (Figure 6) and prediction calculated dispersion model (Figure 8) of the study area were combined cell by cell in the raster format by using GIS map calculation operator. The results of this function are shown in Figure 9.

Results for H_2S distribution prediction model show the gases from power plant, will be transferred to northeast and east. The maximum concentration of H_2S about 31 ppb will be in the areas close to the powerhouse. The concentration of H_2S will be close to the DOE’s standard level for ambient air quality.

In the 282 km^2 study area will be only small impacted parts of the areas close to the production wells in site A and C. The concentrations of H_2S in these areas will be 28-31 ppb which can be defined as areas under risk (Figure 9). These mean at least one time per year in these areas the concentration of H_2S will be exceed than air quality standard. Therefore monitoring of H_2S periodically is recommended to the developer after utilization. The areas under risk are 5.8 km^2 which is around 2% of the study area. The location of these areas and the concentrations relieved that there is no need for health risk assessment project.

CONCLUSIONS

The experiences of other geothermal power plants show that the principle gases of concern in their surrounded environment are H_2S and CO_2 and other constituents are less likely to have a significant adverse effect on the local environment.

The potential flow rate of these gases depends on the steam chemistry and geothermal power plant technology. The dispersion type of gases and average removal rate depends on the meteorological conditions such as wind directions, wind speed, precipitations, atmospheric stability and surface roughness and topography. Determination of the effects on air quality, the affected area and the area under risk depends on the background concentrations of the gases, national standard and morphology of the ground surface.

H_2S distribution prediction model was prepared in this study to find the impacts on local air quality from planned 50 MW geothermal power plants in the NW Sabalan geothermal field.

The results show that there is no adverse effect of H_2S concentrations in 98% of the area and only 2% will be impacted close to the wells in site A and C. The concentrations of H_2S in the under risk areas will be 28-31 ppb and at least once a year the concentration of H_2S will be exceed than national air quality standard. Therefore monitoring of H_2S periodically and development of air quality management system is recommended.

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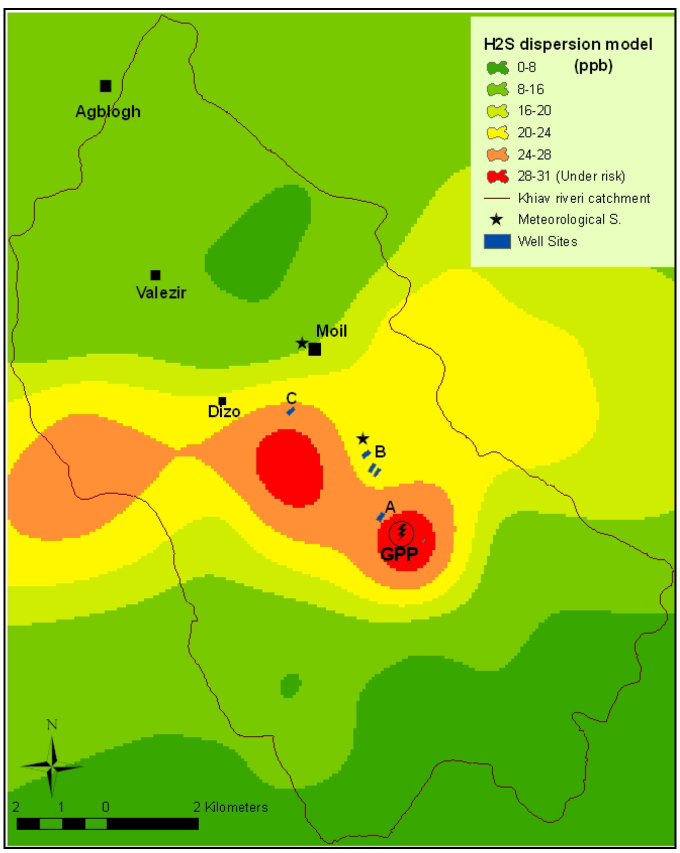

Figure.9. Final prediction dispersion model of H2S and the area under risk, NW Sabalan