Preliminary environmental impact assessment of a geothermal project in Meshkinshahr, NW-Iran

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Abstract

In this report, a preliminary environmental impact assessment is presented for a geothermal project on the western slopes of Mt. Sabalan, approximately 16 km SE of Meshkinshahr City, in the province of Ardabil in Northwest Iran. Various researchers have investigated this area's geothermal resources over the past few years for the possibility of using the geothermal energy to generate electricity. A preliminary review was carried out of the possible environmental effects of this proposed project as a precursor to an environmental impact assessment (EIA). In this study, an attempt has been made to identify the likely key impacts of geothermal exploration, drilling, and operation, and potential mitigation measures. The results of this study suggest that detailed studies be carried out on water supply for drilling; on how to properly dispose of effluent water; on the monitoring of gas emissions to the atmosphere during drilling and operation; and methods to reduce soil erosion. It is also recommended that a detailed assessment survey on the biology of the area be done, as well as the socio-economic effects of this project on the lives of residents of Meshkinshahr City and the nearby villages.

Keywords: *geothermal, environmental, renewable energy, Meshkinshahr, EIA.*

1 Introduction

The environmental aspects of geothermal development are receiving increased attention with the shift in attitudes towards the world's natural resources. Not only is there a greater awareness of the effect of geothermal development on the surrounding ecosystems and landscape, but also a greater effort is being made to use the resources in a sustainable manner. Geothermal power generation is often considered as a 'clean' alternative to fossil fuels or nuclear power plants but it is still necessary to survey its effects on the environment. Geothermal power generation results in the release of non-condensable gases, and fine solid particles into the atmosphere.

In recent years, attention has been focussed on the utilisation of geothermal energy as an alternative to hydropower, and fossil fuel power plants. The Ministry of Energy and Renewable Energy Organisation of Iran is considering the development of the Meshkinshahr geothermal field to construct the first geothermal power plant there. Before such a project is initiated, however, an environmental impact assessment is necessary. The Ardabil province has close to 1,200,000 inhabitants, including the 165,000 inhabitants of Meshkinshahr City. The Meshkinshahr area is located in a formerly farmed area in NW-Iran. In this report, probable environmental effects of a geothermal power plant project in the Meshkinshahr area are described, and some recommendations for mitigation of project effects in the geothermal field and the surrounding areas given (Armannsson and Kristmannsdottir, 1992).

2 Environmental impact of geothermal projects

Environmental impacts from geothermal development vary during the various phases of development. Geothermal development can be described as a three-part process:

1. Preliminary exploration, which has hardly any environmental effect.
2. Drilling. Each drill site is usually between 200 and 2,500 m^2 in area, and the soil in these areas is compacted and changed. There is also deposition of waste soil and drill mud. Construction of roads, well pads, and power plant sites result in cut and fill slopes that reshape the topography of the area, but the effect on the area's topography is not significant. Air pollution can result from gas emissions; smoke exhaust from generators, compressors and vehicles. During well testing, steam and spray can have an adverse effect on the local vegetation with trees and grass being scalded. Dust carried by wind blowing across exposed surfaces may also have a deleterious effect (Webster, 1995).
3. Production and utilization. Soil movement for the construction of pipelines, the power plant and other buildings may affect Land. During operation, subsidence and induced seismicity are the main possible effects

3 Existing environment of Meshkinshahr geothermal area

3.2 Meshkinshahr - brief history

The Meshkinshahr geothermal prospect lies in the Moil valley on the western slopes of Mt. Sabalan, approximately 16 km SE of Meshkinshahr City. Mt. Sabalan was previously explored for geothermal resources in 1974, with geological, geochemical, and geophysical surveys being undertaken (Foutohi, 1995). Renewed interest in the area resulted in further geophysical, geochemical and geological surveys being carried out in 1998. These studies have resulted in the identification of a number of prospects associated with Mt. Sabalan. The present study has been undertaken to find out what information is needed to establish baseline environmental conditions involving surveys of geology and land, weather conditions, noise conditions, ecology and socio-economic conditions.

3.3 Geology and land conditions

Mt. Sabalan is a large stratovolcano, consisting of an extensive central edifice built on a probable tectonic horst of underlying intrusive and effusive volcanic rocks. Enormous amounts of discharged magma caused the formation of a collapsed caldera about 12 km in diameter, and a depression of about 400 m. The lava flows in the Sabalan are mostly trachy andesite and dacite with alternating explosive phases. The schematic geological map (Figure 1) shows the volcanic formations from Eocene to Quaternary.

3.4 Geophysical surveys of Meshkinshahr

During the summer of 1998, a resistivity survey of the Mt. Sabalan geothermal area, in northwest Iran, was undertaken for SUNA (Renewable Energy Organisation of Iran). The primary objective of this survey was to carry out geothermal exploration of the Sabalan area to delineate any resistivity anomalies that may be associated with high-temperature geothermal resources. The subsurface resistivity structure was modelled to assess the size of the geothermal resources; to facilitate the choice of initial exploration of well sites; and to prepare conceptual models for the hydrology of the geothermal fluid reservoirs.

The planning of the resistivity survey called for a flexible approach for both method and site selection. The types of structures that the survey was designed to target included:

- Lateral resistivity boundaries - to assess resource extent;
- Vertical resistivity layers - to assist hydrological modelling and drillhole planning;
- Two-dimensional (or 3D) structure - to assist in locating fault zones, caldera and graben structures or intrusives.

The scope of the project involved a total of 212 resistivity stations in an area of about 860 km^2 on the slopes of Mt. Sabalan, near Meshkinshahr and Sareyn (Ardabil). Three complementary resistivity methods were chosen to achieve the desired accuracy and penetration depth range for practical drilling target purposes:

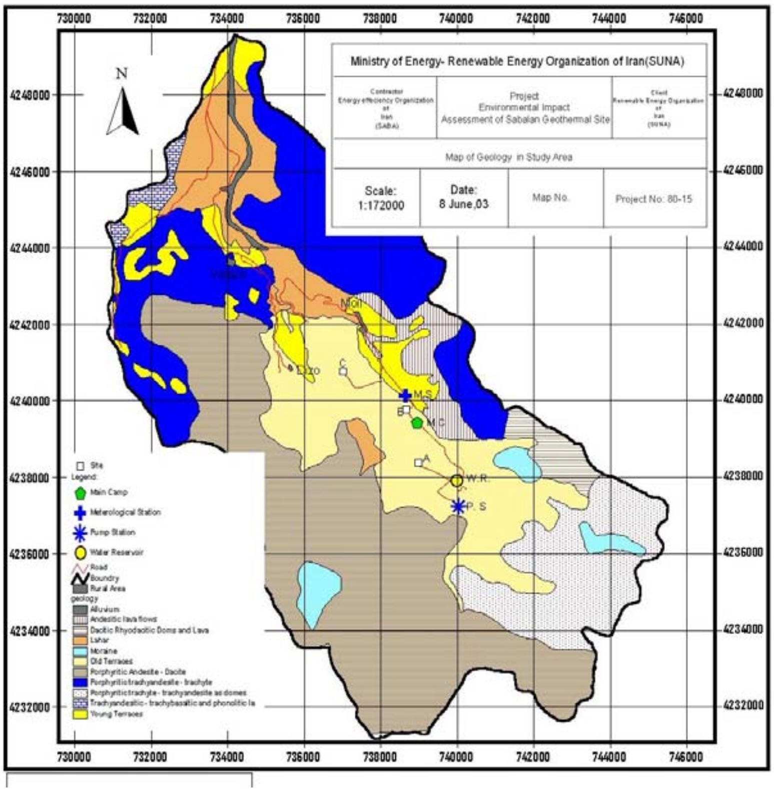

Figure 1: Schematic geological map of the Meshkinshahr area.

- DC (direct current, AB/2=25 m Schlumberger array),
- TEM (transient electromagnetic, 50 or 100 m central loop array), and
- MT (magneto-telluric, frequency range 8 kHz - 0.02 Hz).

Station locations were selected by the survey crew to fulfil the exploration objectives of the survey while taking into account considerations of terrain (to minimise topographic distortions in the data), and site accessibility. A resistivity map of the Meshkinshahr area is shown in Figure 2 (Bogie et al., 2000).

3.5 Hot springs

In the Meshkinshahr geothermal area, there are several hot springs with a temperature in the range of 25–85°C, originating in Mt. Sabalan. The springs in the Meshkinshahr prospect issue mainly from the gravels of the Dizu Formation. There are no springs reported downstream at lower elevations. The Gheynarge, Khosraw-su, Malek-su and Ilando springs produce neutral-Cl-SO_4 waters with up to 1,500 ppm Cl and 442 ppm SO_4, with significant concentrations of Mg (up to 24 ppm). They exhibit a simple dilution trend indicating mixing with varying amounts of shallow groundwater and a strong seasonal cyclic variation in flow rate but very little seasonal variation in temperature or chemistry, which is indicative of storage behaviour. Despite the elevated Cl concentration, isotopic ratios for the waters plot on the local meteoric water line.

The Moil, Moil 2, Aghsu and Romy springs are acid (pH 4.28, 3.20, 3.53 and 2.76 respectively). The Moil 2 and Aghsu springs are typical acid-SO_4 waters and therefore have formed by condensation and oxidation of H_2S, implying boiling at greater depths. The Moil springs have beenslightly neutralised, and are therefore further from the source of H_2S than the Moil 2 springs. The Romy spring waters contain significant Cl (119 ppm). It is difficult to derive water of this temperature and chemistry by mixing other spring chemistries, and so it is possible that the Romy spring waters may represent a diluted but acid equivalent of the neutral Cl-SO_4 waters. The storage

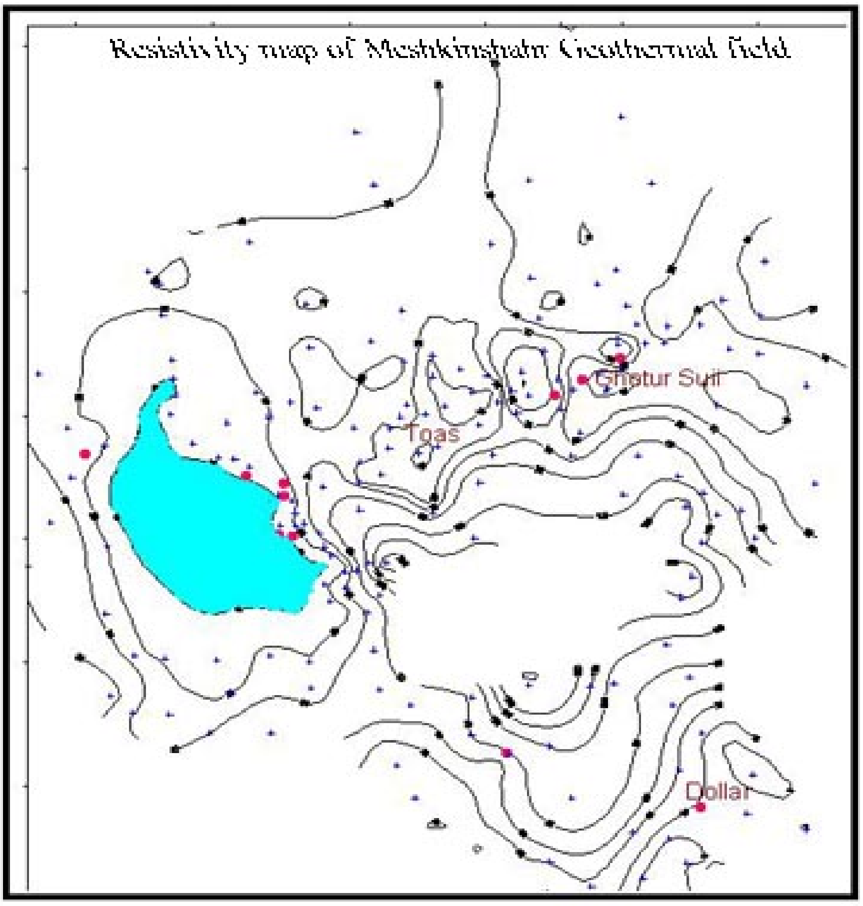

Figure 2: A resistivity map of Meshkinshshr area (Bogie et al. 2000).

behaviour of the springs is indicative of them being fed by very large perched groundwater aquifers, and to obtain a high Mg neutral Cl-SO_4 composition requires that magmatic volatiles have condensed and been neutralised within these aquifers. A degassing, shallow intrusive and possible heat source is therefore inferred which is consistent with a similar conclusion from the geology (Bogie et al., 2000).

3.6 Weather conditions

Measurement of weather conditions in this geothermal field started with the installation of the Moeil meteorological station at the site in April 2000. At this meteorological station, data is continuously collected for temperature, humidity, wind speed, wind direction, solar radiation and air effluent such as SOx, and NOx. Data is recorded automatically every half hour.

Precipitation in this area has been measured from April 2000 to the present at this meteorological station. Yearly precipitation is 196 mm. Maximum precipitation in December is about 39 mm and the minimum in June and July is zero. Temperature data for the Moeil meteorological station for 2002 are shown in Figure 3. The maximum temperature is recorded in July at about 31°C, and the minimum in January is about -19°C.

Humidity data for this area was collected in 2002 at the Moeil meteorological station. Maximum humidity is recorded in December, at about 78%; and the minimum is recorded for August, about 13%.

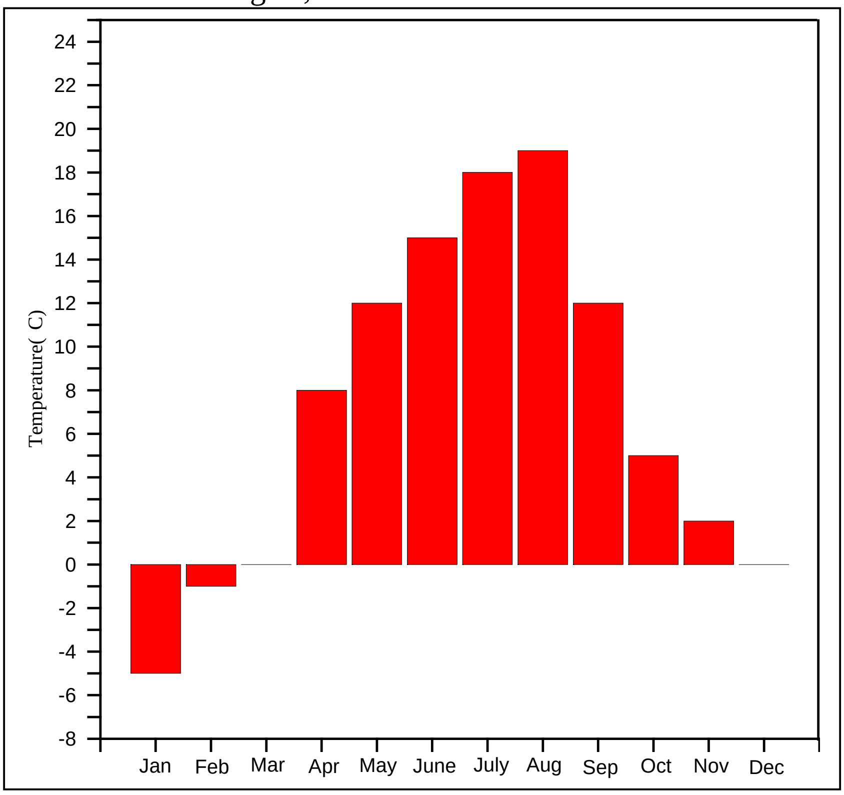

Figure 3. Temperature in Moeil Meteorological station for 2002.

April 2002, at 30 points to cover the whole area. The results show that the noise level in the whole area is less than average.

3.7 Air quality

Meshkinshahr geothermal field is an unexploited natural area without any industrial or other air polluting activities. Only some gases from geothermal manifestations escape to the atmosphere. The concentrations of H_2S are higher than of other gases in geothermal manifestations, and it seems necessary to monitor this in the area. H_2S concentrations have been monitored over the whole area, about 132 km^2, where most of the geothermal manifestations are located. The concentrations of gases in the north-western part of the area are greater than in the other parts, because most of the gases are released to the atmosphere from this area.

3.8 Wind patterns

Wind conditions were measured during the year 2002 at the Moeil meteorological station. Hourly wind direction and wind speeds have been used to make a wind rose plot, and it is seen that the most common wind directions are northeasterly and west/south-westerly. Figure 4 shows the yearly wind pattern at the Meshkinshahr area for 2002.

3.9 Noise conditions

Most geothermal developments are in remote areas where the natural level of noise is low and a slight change in noise level is detectable. The Meshkinshahr area is without any industrial activities; thus there is no noise pollution there at present. The base noise level was measured in April 2002, at 30 points to cover the whole area. The results show that the noise level in the whole area is less than average.

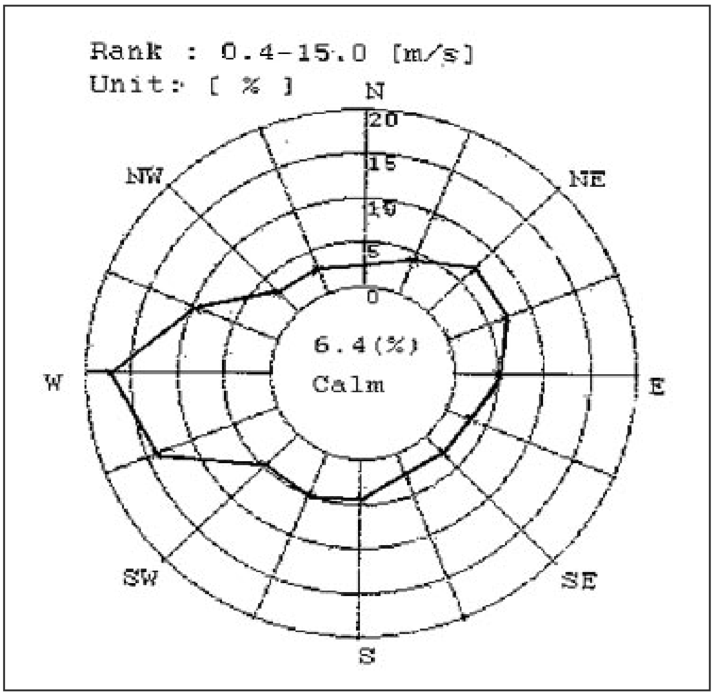

Figure 4: The yearly wind pattern at the Meshkinshahr area in 2002.

3.10 Social and economic conditions

The region of Meshkinshahr in northwestern Iran has a population of approximately 165,000. Its principal town, Meshkinshahr, has 65,000 inhabitants. The main industries are community service such as teaching, health care, banking, trading, farming, fish farming and ranching. Industrial activities include slaughtering, meat processing, cannery and wood industry. For several decades, this region has suffered a brain drain because there have been few jobs for highly educated people. The percentage of highly educated people in the Meshkinshahr region is very much lower than the national average. For many years, the local government of Meshkinshahr has been trying to improve the economy of this area by creating some permanent and provisional jobs. In the last few years though, there were very low amounts of precipitation in the whole of Iran, and also in the Meshkinshahr area, causing most of the farmers to have economic problems. The government has been trying to install some industrial manufacturing to help the people. Most of the sectors that have been developed are tourism-related activities, but others that are in line include food production (fish and farm produce), mining of minerals, the utilisation of high-temperature geothermal fields, the direct use of geothermal energy (swimming pool, fish farming), and construction of a dam for electricity production and irrigation. In recent years, attention has been focussed on the utilization of the high-temperature geothermal field to produce 100 MW of electricity in Meshkinshahr.

3.11 Vegetation

In the spring of 2002, with the aid of plant biologists, a vegetation map of the study area was made (Figure 5) which shows the entire area is covered by vegetation. The density of coverage is 15% at high elevations (above 3,200 m); 45% coverage from 2,400 m to 3,200 m; and 30% coverage for elevations below 2,400 m. The recorded permanent flora of Meshkinshahr consists of 369 species.

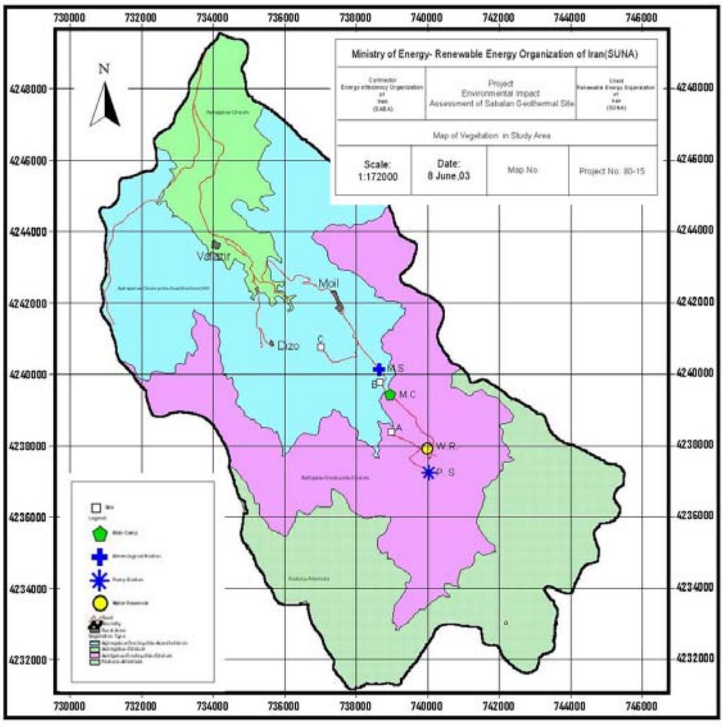

Figure 5: Vegetation map of the project area.

Most of the resident activity in the Meshkinshahr area is sheep farming, and protection of vegetation is very important for the local government.

3.12 Fauna

The Meshkinshahr area is a mountainous area, and the fauna is rich. Sheep farming in summer time is the most important activity of the residents, but they leave the area in wintertime because this area gets very cold. Due to this movement, the number and types of species in winter and summertime are quite different. The permanent fauna of the Meshkinshahr area has been recorded as consisting of 250 species. Some species like Phasianus, Mergus albelus, Aaudial chrysaetos and sturnus vulgaris are overabundant.

3.13 Tourism

In a general report on tourism in Iran that was published by the Ministry of Society and Culture, it was recommended that geothermal areas be given high priority in the development of tourism, especially in the Ardabil province due to Mt. Sabalan. Also in the Meshkinshahr area, many hot springs with different temperatures are found, and very nice landscape in all seasons. Opening up the area by way of new roads would change conditions drastically, and might bring in a greatly increased number of tourists and also change the most common route for climbing the Sabalan peak, because when the road to the Meshkinshahr geothermal field is finished, this will be the shortest way to the Sabalan peak.

4 Environmental impact assessment

Baseline environmental conditions have been estimated, with suggested further analysis, to determine the impacts of a geothermal project for all relevant phases of development, and to propose mitigating measures to reduce environmental impacts.

The objective of an environmental impact assessment is to determine the potential environmental, social and health effects of a proposed development project. An EIA attempts to assess the physical, biological and socio-economic effects of the proposed project in a form that permits logical and rational decisions to be made. Attempts can be made to reduce or mitigate any potential adverse impacts through the identification of possible alternative sites and/or processes.

4.1 Geology and land

During exploration, there is no significant impact on geology and land, only in geophysical exploration such as the drilling of shallow wells to obtain a geothermal gradient map, during which there are some effects on land and soil from disposal.

During drilling, 10 km of road construction and preparation of 3 drill sites can cause unstable earth conditions and changes in geological substructure. During well testing, care should be taken not to discharge the wastewater directly to steep areas, but sumps should be made to contain this waste water, as failure to do this can cause serious gullying.

Each drill site in Iran is on average about 20,000 m^2 in land area. In this project, 3 wells are drilled during the first phase. About 60,000 m^2 of land in this area, mainly used for sheep farming, will be affected during drilling and many years after that. The soil in these areas will become compacted and changed, and close to the drill site there will be some deposition of waste soils. The construction of a 10 km access road, camping facilities, storage areas, buildings, pipelines, powerhouse and worker’s quarters will affect about 860,000 m^2 of land.

During operation, subsidence and induced seismicity are the main possible effects on the land around the power plant and the surrounding areas. A monitoring program for subsidence in this area is recommended. The base level of the geothermal field was recorded in summer 2001.

4.2 Effects on air

Gas emission to the air would take place during all phases of the proposed project. During the construction and decommissioning phases, dust would result from surface disturbances and vehicle travel on unpaved roads. Non-condensable gases, including hydrogen sulphide (H_2S) and carbon dioxide (CO_2), will be released from the geothermal fluid during well drilling and testing, and during power plant operations. Oxides of nitrogen, carbon monoxide, and oxides of sulphur emitted from internal combustion engines will be released during all phases of the project. A summary of the effects on air during such a project follows:

- Small quantities of critical air pollutants will be released from mobile construction equipment and other vehicles, but this impact will be below the level of significance.
- Large quantities of critical air pollutants, in particular oxides of nitrogen (NO_x), will be released from drilling rig engines during well drilling operations, but this impact will not be significant if wells are drilled one by one, and only one active drill rig is operated at any one time.
- Hydrogen sulphide will be released during well flow testing from well pads, and it is necessary to control the concentration of H_2S in the atmosphere and keep it below levels specified in international standards.
- Hydrogen sulphide will be released to the atmosphere during power plant operation. H_2S concentrations measured in steam samples from the area are not dangerously high.
- The project will release “greenhouse gases” which will contribute to global warming. These gases consist mainly of carbon dioxide (CO_2) and some methane (CH_4). But a prediction of the amount of carbon dioxide released to the atmosphere per kilowatt of electricity shows it to be approximately 20 times smaller than the amount of “greenhouse gases” released from a fossil-fuel power plant for an equivalent amount of electricity.
- The main residential area in the Meshkinshahr geothermal field is in the eastern part, and the wind pattern is mainly from west to east. According to wind direction, , the power plant should be installed in the southern part of the field to minimize the effects from air pollutants.

4.3 Effects on water

The wells, which will be drilled in this area for high-temperature geothermal fluid will be deep and may require up to 50 l/s of water for periods of several months, depending on the number of wells to be drilled. The amount of water used as drilling fluid is enormous and should be discharged with utmost care into well-designed sumps, or possibly re-injected as this can affect the quality of the groundwater in the area.

Hydrological studies show that the groundwater flow in the study area is from southeast to northwest, and these waters finally discharge into the Khyav River. Drinking water for Meshkinshahr City, and agricultural water for more than 20,000 residents in the northern part of Meshkinshahr comes from the Khyav River, so it is necessary to survey the effects of the geothermal effluent on the river.

Spent geothermal fluid from the power plant will be injected into an injection well that is located behind the exploration wells. The concentration of dissolved solids and gases in geothermal water and steam are greater than in shallow ground water. Therefore, it is necessary to monitor the effect of geothermal fluid on surface water and shallow groundwater after the installation of a power plant.

4.4 Noise effects

In the Meshkinshahr geothermal field, there will not be serious noise impacts during geothermal project activities such as drilling, well testing and operation. Only during well testing will there be some temporary noise, which will affect wildlife in the vicinity of the drill rig. Workers on-site will need to wear appropriate hearing protection as a necessary safety precaution. The greatest noise effects during power plant operation are from the cooling tower, transformer, and turbine-generator building. When power plant operation starts, noise mufflers must be used to keep the environmental noise level below the 65 dB limit set by the U.S. Geological Survey (Kestin et al., 1980). With a reduced level of noise, workers, tourists and wildlife will not be seriously affected.

4.5 Flora

The vegetation will be destroyed during drill site preparation with the construction of buildings, pipelines, transmission lines, and roads, but this effect is not significant because the drill site can be re-vegetated with the same species after drilling and well testing are completed. During operation, a monitoring programme including the monitoring of pollutant gases such as H_2S in the atmosphere should be carried out, and if the concentrations of these gases become higher than limits set by standards, measures must be taken to reduce their amounts in the atmosphere.

Sheep are in this area and graze extensively on the surrounding vegetation. During drilling and well testing, care should be taken to avoid damage to vegetation when disposing of drilling effluents and operational wastewaters to avoid damage to vegetation that might be consumed by sheep. A detailed study should also include the potential effect of changes in the thermal area, such as increased steam flow due to exploration, to changes in the distribution of the thermally adapted plants, and to whether some of the species could be rendered extinct.

4.6 Fauna

During exploration for geothermal energy in this area, damage to animals is unlikely. During construction of roads, preparation of drill sites and drilling, the effect of noise from the drill rig and well testing will cause most of the animals to move from the vicinity of the drill rig. The most significant effect of geothermal power plant operation on the environment is air pollution. The sensibility threshold of animals to the smell of gas is the same as for humans. A detailed study on the identification of all animals, and a survey of the probable effects of long-term geothermal operation on animals is required. The stocks of some species like Phasianus, Mergus albelus, Aaudial chrysaetos and sturnus vulgaris may collapse and have to be watched carefully.

5 Conclusions and recommendations

- Hydrological studies show that the groundwater flow in the study area is from southeast to northwest, and these waters are finally discharged into the Khyav River. Drinking water for Meshkinshahr City and agricultural water for more than 20,000 residents in the northern part of Meshkinshahr comes from the Khyav River, so it is necessary to survey the effects of geothermal effluent on the river.
- The extreme permeability of the lava formations suggests that it should not be difficult to dispose of effluent water. As there is always a danger of over-exploitation of the fluid, the best solution economically and environmentally is re-injection.
- The greatest damage to the vegetation of the area has up to now been due to sheep grazing, and limiting this activity would improve

the flora of the area. A careful recording of rare plants, especially those that normally only grow near hot springs should be undertaken.

- Building of a power plant in this area would increase access by way of new roads. Thus, increased tourism would be expected and might even call for some tourism-related services in the area. Due to the dense populations of some species like Phasianus, Mergus albelus, Aaudial chrysaetos and sturnus vulgaris, have to be watched carefully as their stocks may collapse. The greatest noise effects during power plant operation are from the cooling tower, transformer, and turbine-generator building. When power plant operation starts, noise mufflers must be used to keep the environmental noise level below 65 dB.
- Hydrogen sulphide will be released to the atmosphere during power plant operation. H_2S concentrations in steam samples from the area are not dangerously high.

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