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Environmental Impact Of The Utilization Of A Geothermal Area

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Abstract

Geothermal energy is generally accepted as being an environmentally benign energy source. Geothermal development over the last 40 years in world, has shown that it is not completely free of impacts on the environment. Environmental impacts are projected to limit the use of this needed energy resource. Most of high temperature of geothermal waters in the World are highly mineralized with elevated levels of arsenic (As), boron (B), cadmium (Cd) and lead (Pb) resulting in scaling and corrosion. Since they are not reinjected, geothermal discharges also result in observed contamination of soil and waterways. Reinjection is recommended to be installed as a standard procedure to avoid these adverse impacts.

Keywords: *Environmental impact; geothermal; reinjection; trace elements;*

Özet

Jeotermal enerji genel olarak çevreye karşı iyi huylu enerji kaynağı olarak kabul edilir. Dünyada son 40 yılda jeotermal gelişmeler, bu kaynakların çevreye etkilerinin tamamen yok olmadığını göstermiştir. Bu enerji kaynaklarının sınır değerde kullanımlarının çevresel etkileri projelendirilmektedir. Dünyada yüksek sıcaklıklı jeotermal sular arsenik (As), bor (B), kadmiyum (Cd) ve kurşun (Pb) gibi minerallerce zenginleşmiştir. Yüksek minerlizasyon sonucu bu alanlarda kabuklasma ve korozyon oluşmaktadır. Reenjeksiyonun yapılmadığı sahalarda jeotermal kaynakların deşarjı toprak ve suların kirlenmesine neden olmaktadır. Bu nedenle standartlara uygun reenjeksiyonların yapılması, önemli derecede çevresel etkilerin giderimini sağlayacaktır.

Anahtar kelimeler: *Çevresel Etki, jeotermal, reenjeksiyon, iz elementler.*

1. Introduction

The world primary energy consumption is about 400 EJ/year. It is provided by fossil fuels (80%), renewables (14%), and nuclear energy (6%). The world Energy Council expects it to have grown by 50-275% in 2050 depending on different scenarios. Renewable energy sources are expected to provide 20-40% of the primary energy in 2050 and 30-80% in 2100 [1]. Geothermal energy has been produced commercially for over four decades on the scale of hundeds of MW both for electricity generation and direct use. Geothermal resources have been identified in over 80 countries and there are qualified records of geothermal utilization in 58 countries. [2] Huttrer (2001) expects the world electrical installed capacity to have grown by 43% in 2005. Assuming a continuing growth of 20% per five years (which is the average growth during 1980-2000), the electrical production may reach about 80 TWh in 2010 and 120 TWh in 2020. Assuming the worldwide direct use growth of 44% during 1995-2000 reported by Lund and Freeston (2001) [3] to continue, the direct use energy production may be about 100 TWh in 2010 and 200 TWh in 2020.

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Geothermal is one of the important renewable energy sources in Turkey being the 7th richest country in the world in geothermal potential. Most of its development has been achieved in geothermal direct-use applications with the equivalent of 61,000 residences heated with geothermal energy (665 MWt) including district heating, thermal facilities and 565,000 m^2 geothermal greenhouse heating. There are 194 spas which are used for balneological purposes (327 MWt). Engineering design of geothermal district heating for more than 300,000 residences has been completed. The total installed capacity is 992 MWt for direct-use and 20.4 MWe for power production. A liquid carbon dioxide and dry ice production factory is connected the power plant ([4, 5, 6]).

Turkey has extensive geothermal resources of 4,000 to 4,500 MWe of power generation potential and 32,000 MWe of low enthalpy direct use resources, enough to heat five million homes [7]. Making greater use of Turkey's high and low enthalpy geothermal resources could significantly help combat serious pollution problems resulting from the use of fossil fuels for heating in many cities, and save foreign currency on natural gas imports.

With increasing awareness of the detrimental effects of the burning of fossils fuels on the environment, there has been an increasing interest world wide in the use of clean and renewable energy sources. Geothermal energy is generally accepted as being an environmentally benign energy source, particularly when compared to fossil fuel energy sources. However, some application have shown geothermal energy is not completely free of adverse impacts on the environment. This paper presents some results from an environmental impact of geothermal energy in different parts of World, observed environmental impacts of geothermal power generation, the distribution of contaminants in the geothermal field in different parts of World, as well as an evaluation of the risk potential for the environment and some practical remediation proposal.

2. Environmental impacts of geothermal generation

Geothermal energy is generally accepted as an environmentally benign energy source, particularly when compared to fossil fuel energy sources. Geothermal development in the last forty (40) years, however, has been observed not to be completely free of impacts on the environment. These impacts are becoming of increasing concern, and to an extent, may now be limiting development. History shows that ignoring such problems can be counterproductive to development of an industry by the public, regulatory authorities and financial institutions. If our aim is to further the use of geothermal energy, then all possible environmental effects should be clearly identified, and countermeasures devised and adopted to avoid or minimize their impacts [8]. The most important environmental effects of geothermal utilization have been reviewed by [8, 9, 10, 11, 12]. Geothermal utilization can cause surface disturbances, physical effects due to fluid withdrawal, noise, thermal effects and emission of chemicals as well as affect the communities concerned socially and economically [11].

2.1. Surface disturbances

A drilling site is usually between 200-2500 m^2 in area [11]. With the advent of directional drilling it has become possible to drill many wells from the same drill pad [13]. In Krafla, Iceland, wells have been drilled on the same pad with a distance of 30-60 m between them. Assuming that wells are drilled from each drill pad, involving land use of the order of 1000-1500 m^2 per well [14]. The construction of road access to drilling sites can involve destruction of forests and vegetation which particularly in tropical areas with high rainfall (Indonesia, Philippines), can result in erosion [8]. As geothermal areas tend to be associated with soft rocks such as pumices or in hydrothermal altered rock, development can cause land erosion and slips if care is not exercised [10].

2.2. Physical changes due to fluid withdrawal

Fluid withdrawal may cause subsidence and lowering of groundwater table. In the Travale-Radicondoli geothermal field in North Italy, a maximum subsidence rate of 2.5 cm/year was detected from 1973 to 1983 [15]. A maximum rate of 45 cm/year and total subsidence of 15 m were observed in a geothermal field of the Wairakei (New Zealand), representing the highest measured subsidence values worldwide [8]. Generally low and high-temperature geothermal systems are overlain by cold groundwater. When the geothermal system is produced, a large pressure drop occurs in the reservoir. Because of the pressure change, groundwater may be drawn down into the upper part of the reservoir. For example; at Wairakei, a localized drop of more than 30 m in groundwater level has occurred associated with a cold downflow [8]. The lowering of the groundwater table may cause the mixing of fluids between aquifers, and cause difficulties such as the deterioration of piped water, a danger that has needed watching in Seltjarnarnes (Iceland) [16].

2.3. Noise

The development of a geothermal field creates considerable noise, particularly during drilling and well-testing which can disturb animals and humans living nearby. Drilling operation noise exceeds 90 dB and the noise from the discharge of boreholes may exceed 120 dB, the pain threshold at 2-4000 Hz [11]. But noise during discharge can be reduced to about 85 dB using a traditional silencer and to 65-70 dB with a rock muffler [14].

2.4. Ground temperature changes

Steam is much more mobile than water. The generation and movement of steam can increase ground temperatures so that vegetation becomes stressed or killed. If excess heat enters the environment via geothermal steam it may affect cloud formation and even cause changes in the local weather. Where waste water is piped into a stream, a river, a lake or local groundwater it may seriously affect the biota in the local environment and eventually the whole ecological system [11]. For example; Nesjavellir Plant (Iceland) is located near Lake Thingvallvatn, approximately 6 km from the power plant. The warm water of the power plant is discharged into parts of Lake Thingvallvatn. The water temperature in the lake is about 4-5 °C. But after the start of electricity generation at the Nesjavellir Power Plant increased discharge of hot water has lead to a marked temperature rise, from 13-20-26 °C in geothermally affected lakeside springs [17].

2.5. Fluid Composition

Gas discharges from low-temperature systems do not usually cause significant environmental impacts. In high-temperature geothermal fields, power generation using a standard steam-cycle plant may result in the release of non-condensable gases and fine solid particles into the atmosphere [18].

Gas concentration and composition covers a wide range, but the predominant gases are carbon dioxide (CO_2) and hydrogen sulphide (H_2S).

Carbon dioxide (CO_2) occurs in all geothermal fluids but is most prevalent in fields where the reservoir contains sedimentary rocks, and particularly those with limestones. The process can be expressed as following reaction:

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$$

In the acidic region, CO_2 can accelerate the uniform corrosion of carbon steels. The pH of geothermal fluids and process steams is largely controlled by CO_2 [19].

Hydrogen sulphide (H_2S) is characterized by a "rotten egg odour" detectable by humans at very low concentrations of about 0.3 ppm. The process can be expressed in the following reaction:

$$CaSO_4 + FeS_2 + 3H_2O + CO_2 = CaCO_3 + \frac{1}{3}Fe_3O_4 + 3H_2S + \frac{7}{3}O_2$$

In vapour-dominated fields such as Larderello (Italy) and The Geysers (USA), and fields in which all waste fluids are reinjected, gas in steam will be the most important discharge from an environmental perspective. The most significant ongoing gas emissions will be from the gas exhausters of the power station, often discharged through a cooling tower. Although gas and particulate discharge will also occur during well drilling, bleeding, cleanouts and testing as well as from line valves and waste bore water degassing, this is usually insignificant by comparison [18].

Although mainly CO_2, the geothermal gases may include high concentrations of H_2S gas. For example H_2S in Geysers (USA) steam has been recorded as 222 ppm, Cerro Prieto (Mexico) steam 350 ppm and Wairakei (New Zeland) steam 400 ppm [18].

The main potential pollutants in the liquid effluent are: hydrogen sulphide (H_2S), arsenic (As), boron (B), mercury (Hg) and other trace metals (e.g. lead (Pb) and cadmium (Cd)) [11]. Most high temperature geothermal bore waters include high concentrations of at least one of the following toxic chemicals: lithium (Li), B, As, H_2S, Hg, and sometimes ammonia (NH_3). Arsenic is preferentially retained (>99 %) by the water phase in steam/water separation, and the measured levels of arsenic in geothermal steam are usually less than 40 μg/kg. However, the arsenic concentrations in geothermal water do present a disposal problem [10]. Environmental impact by spill of geothermal fluids in the geothermal filed of Los Azufres, Michoacán (Mexico) was observed by [20]. Increased trace element concentrations, especially of Fe, Mn, F, B, and As in surface waters within the geothermal field and up to 10 km outside it were observed. Maximum values of 125 and 8 mg/l were observed for B and As, respectively. The concentrations of arsenic in Salton Sea (USA), Cerro Prieto (Mexico) and Wairakei (New Zealand) have been recorded as 12, 2.3 and 4,7 ppm respectively [18].

The waters with greatest pollution potential are those with very high deep temperatures and/or high salinities. As pointed out by [10] the concentrations of heavy metals tend to rise in proportion to the square of the water salinity so that brines that may have associated with them pose a heavy metal contamination problem. For example, fluids from the Salton Sea field (USA), which is hosted by evaporate deposits, are acidic and highly saline ($pH<5$, $Cl= 155\ 000$ ppm). At the other extreme, those of the Nesjavellir field (Iceland) are alkaline and of very low salinity ($pH>9$, $Cl \sim 100$ ppm). The disposal of highly saline bore waters can have an adverse affect on water quality [18].

Generally, boron is high in thermal water in Turkey. Its concentration is related to volcanic and sedimentary rocks, but may also be controlled by degassing of magma intrusives. The geothermal fields of western Turkey provide a unique setting for extremely high enthalpy combined with a large variation in chemical composition. For example; effluents from the power plant in Denizli-Kizildere where boron concentrations are greater than 20 mg/l are released into adjacent creeks and endanger natural biota that are sensitive to boron ([21, 22]). High B concentrations of thermal water cause environmental problems in soil and water in different parts of Turkey. West Anatolia has a particularly important role in agriculture in Turkey and most of the high temperature thermal water is located in this part. Most grape fields are located in West Anatolia. Grapes and other fruits are sensitive to boron. Recently it has not been possible to use highly B contaminated areas for agricultural purposes in Turkey. A part of the irrigation water demand is supplied by drilled wells. This is another reason for boron contamination in groundwater. The Tuzla (Canakkale) and Kursunlu-Salihli (Manisa) geothermal fields are other areas where thermal fluids cause boron contamination in soil and groundwater. Similar problems are known in other parts of Turkey, e.g. the boron concentration in Kursunlu-Cavundur (Cankiri) (63,8 mg/l), Duzce-Derdin (Sakarya) (50,6 mg/l), Germencik (Aydin) (69 mg/l) and Kursunlu-Salihli (Manisa) (65 mg/l) thermal fluid is extremely high.

3. Conclusions and Recommendations

Geothermal development in the last 40 years, has shown that it is not completely free of adverse impacts on the environment. These impacts are causing an increasing concern, and to an extent which may now be limiting developments. High alteration zones are observed in most geothermal fields in the World. Due to high mineralization , trace elements, such as B, As, Cd and Pb affect soil and water. Therefore, all possible environmental effects should be clearly identified, and mitigation devised and adopted to avoid or minimize their impact.

Reinjection should be considered an integral part of any modern, sustainable and environmentally friendly geothermal utilization, both as a method of waste-water disposal and to counteract pressure draw-down by providing continued water recharge. Reinjection is essential for sustainable utilization of geothermal systems, which are virtually closed and with limited recharge. Therefore, reinjection should be used in geothermal fields in Turkey, where heavy metal concentrations of the fluids may be high.

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