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Environmental Impact by Spill of Geothermal Fluids at the Geothermal Field of Tuzla, Canakkale-Turkey

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ABSTRACT

Tuzla geothermal field is located in northwestern Anatolia 80 km south of Canakkale and 5 km from the Aegean Sea. Tuzla is an active geothermal area in northwest Turkey hosted by rhyolite lavas and pyroclastic deposits. Geothermal studies of the Tuzla field have been ongoing since 1966. Ten thermal gradient wells were drilled from 50 to 100 m depth in 1974, and two deep exploration wells (with a depth range of 814 m – 1020 m) were drilled in 1982 and 1983 by General Director of Mineral Research and Exploration (MTA). Temperatures up to 145°C were observed at 50 m depth in some of these wells. The reservoir depth is in the range of 333 to 553 m in volcanic rock with a temperature of 173°C.

This paper presents results from an environmental assessment study conducted on the subterranean and surface hydrological system of the geothermal field of Tuzla, Çanakkale. Monitoring of surface water and shallow aquifers inside and outside of the Tuzla geothermal field during the period August 2003 to May 2004 led to the detection of some contamination of surface water and shallow aquifers due to geothermal fluid. The study includes information about the main contamination sources within the geothermal field, the type of contaminants most abundant, the lateral and quantitative distribution of contaminants within and outside of the geothermal field, as well as an evaluation of the risk potential for the environment and some practical remediation proposals.

1. INTRODUCTION

Tuzla geothermal field is located in northwestern Anatolia 80 km south of Canakkale and 5 km from the Aegean Sea (Figure 1). Tuzla is an active geothermal area in northwest Turkey hosted by rhyolite lavas and pyroclastic deposits (Figure 2). Geothermal studies of the Tuzla field have been ongoing since 1966. The general geological and volcanological characteristics have been studied by Samilgil (1966); Erdogan (1966); Urgun (1971), Öngur (1973), Alpan (1975). Geophysical surveys were carried out by Demirörer (1971) and Ekingen (1972). Ten thermal gradient wells were drilled from 50 to 100 m depth in 1974 based on the result of geological and geophysical surveys. Temperatures up to 145 °C were observed at 50 m depth in some of these wells, and due to vigorous boiling within some were lost in blow-outs (Karamandersi and Öngur, 1974). Two deep exploration wells (with a depth range of 814 m- 1020 m) were drilled in 1982 and 1983. The reservoir depth is in the range 333 to 553 m in volcanic rock with a temperature of 173 °C, a production rate of 130 t/h and steam content of 13 %. The general characteristics of alteration were described by Gevrek and Sener (1985) in this field. Hydrothermal alteration mineral assemblages indicate that a geothermal fluid, with temperatures of 150-220 °C has been present (Sener and Gevrek, 2000). The nature and origin of the thermal springs in the Tuzla area have been described by Mutzenberg (1997). The environmental properties of the Tuzla Geothermal Fields were described by Baba (2003).

This paper presents results from an environmental assessment study conducted on the subterranean and surface hydrological system of the geothermal field of Tuzla, Çanakkale. The field study was carried out from August 2003 and May 2004.

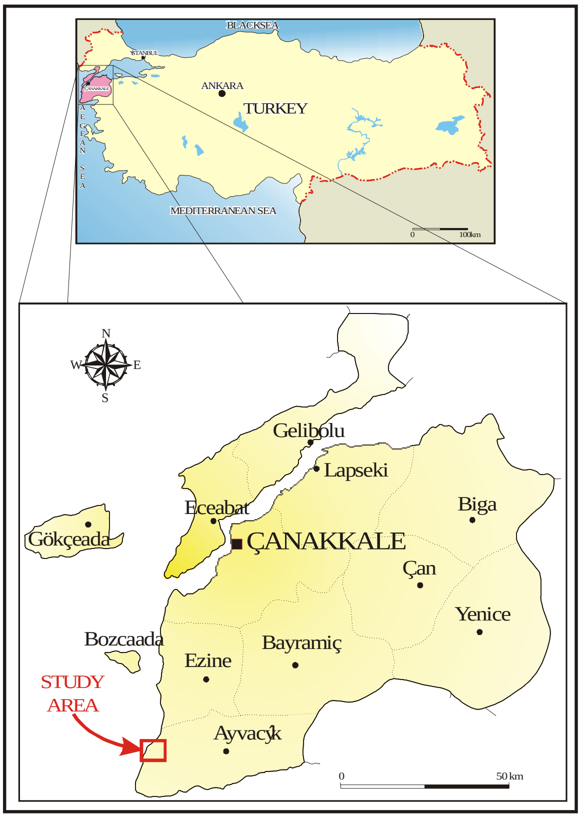

Figure 1: Location map of study area

2. METHODS

From August 2003 to May 2004, a total of 60 water samples were taken from cold and thermal springs, well, runoff, and from inflowing and outflowing geothermal geothermal brines of the evaporation ponds as well as brines from leaking sites. The locations of the sample site inside and adjacent to the geothermal field are shown in

Figure 3. The samples were filtered (0.45 µm filter size), acidified with HNO_3, and analysed for their major and trace elements concentration by ICP-AES method at the Canakkale Onsekiz Mart University, Canakkale, Turkey. The anions were measured by ion chromatography technique. EC, pH, temperature of the waters was measured in field by WTW Multi parameters 340i sets.

3. HYDROLOGIC AND GEOTHERMAL RESOURCES

The hydrologic and geothermal resources assessment considers the effects of the project on existing surface water and groundwater resources and the effects associated with geothermal heat extraction. Production or injection of shallow groundwater or geothermal fluid can affect the quality and quantity of cold groundwater. Most people abstract groundwater from alluvium for irrigation in the Tuzla area. The physical and chemical composition of the Tuzla geothermal water is very interesting from a hydrogeochemical viewpoint. At the surface, the waters reach temperatures between 34 °C and 80 °C. The total salinity reaches 49,700 mg/l, which is approximately twice the concentration of sea water. Water outflow from about 100 springs in the Tuzla field is estimated to be close to 50 l/s. The concentration of Na and Cl reaches 14800 mg/l and 49700 mg/l respectively (Figure 4 and 5).

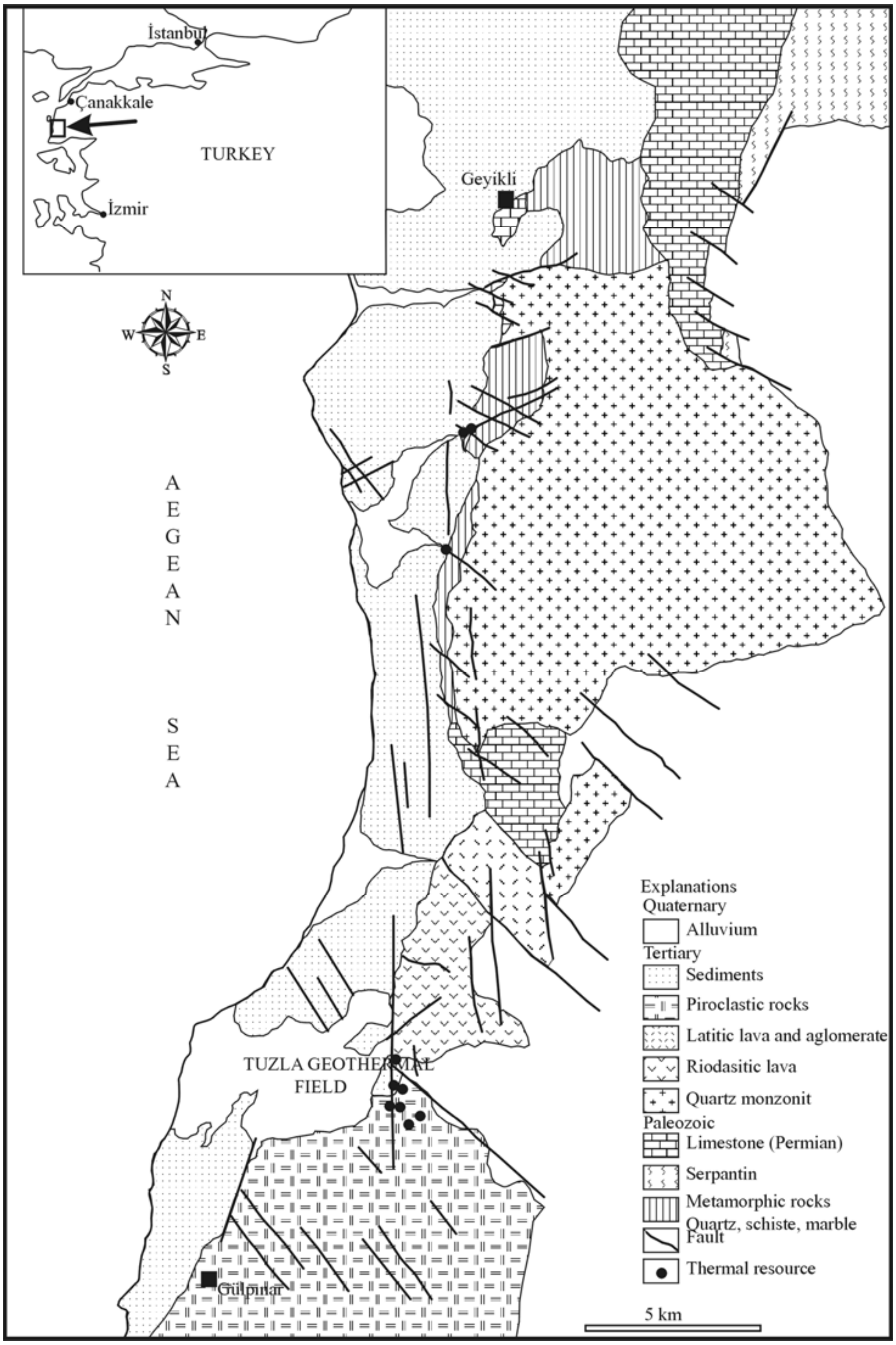

Figure 2: Geological map of study area (from Mutzenberg, 1997)

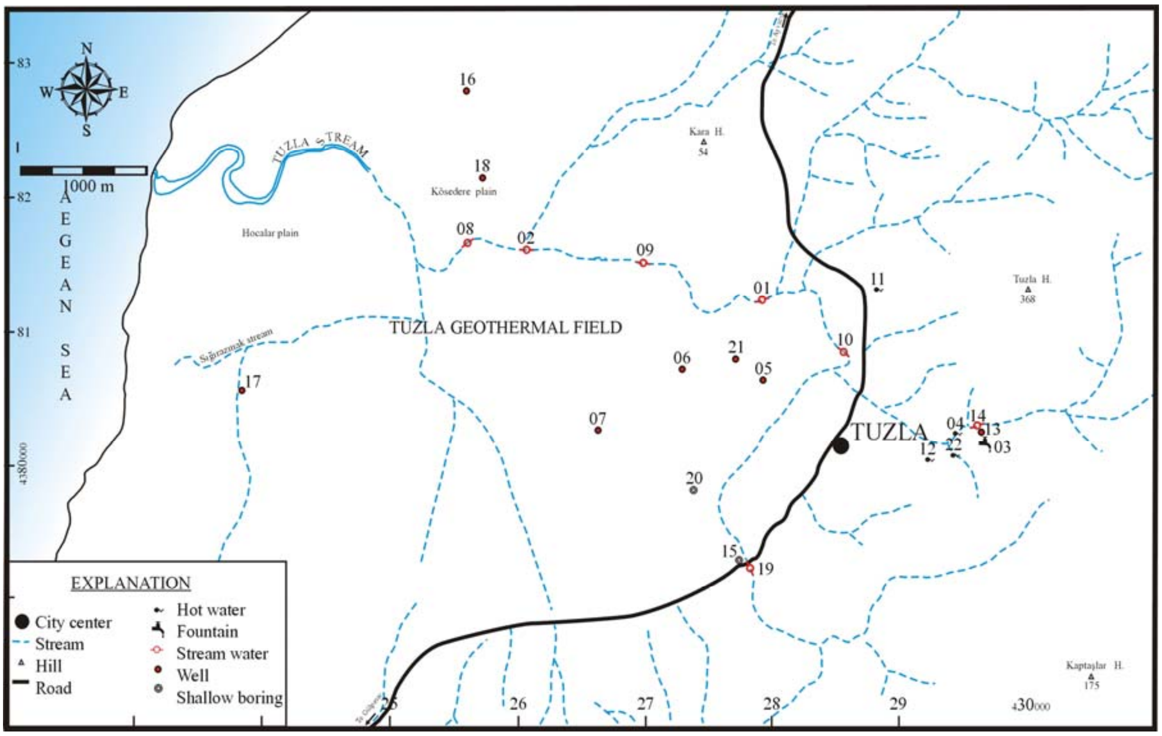

Figure 3: Sample Location Map

4. CHEMICAL COMPOSITION AND RISK POTENTIAL OF GEOTHERMAL FLUID

The chemical composition of groundwater changes either due to water-rock interaction or mixing with different waters. To follow the whole process from original groundwater to geothermal water and back to mixing of the geothermal water with the original groundwater is quite a complex process with involving complex thermodynamic calculations with assumptions about thermodynamic data and underground conditions. Each possible effect and concern should be considered in the EIA.

The average of some trace element composition of the geothermal brine the spring, wells, stream and pond is illustrated in Table I. Beside increased salt concentration of the NaCl-type brine, the fluids from the Tuzla reservoir are considerable enriched in B and Sr. With values up to 83 ppm and 134 ppm respectively, the elements B and Sr exceed the international drinking water standards. Considering the characteristic of both, cold and hot springs, the minor elements Cr, Cd, Pb and Zn are very useful as trace for detection of hydrological surface systems, that are contaminated by geothermal brines. Table 1 shows that concentration of heavy metals such as Pb, Zn and Sr in hot water higher than cold water. Also, the concentrations of heavy metals such as Sr in stream are higher than wells water samples. Tuzla stream have been affected by spill of hot water. Therefore, concentration of heavy metals higher than wells water.

4.1. Leaking Evaporation Ponds

Based on site observation and chemical analysis, the man-made evaporation ponds represent the major contamination source for the spreading of contaminants from the geothermal production cycle into discharging, proximal and distal surface runoff systems. The ponds, which are used for the storage of geothermal water, are surrounded by man-made walls (Figure 6). Discharging oxidised brines and salt crust at the external part of the pond walls are obvious indicators for active seepage processes.

4.2 Metal Concentrations

Residents in Tuzla use groundwater which is abstracted from alluvium aquifers. Geothermal fluid generally contains more heavy metals than cold groundwater. Some metals were analyzed for in open spring pools in Tuzla (Table 2). The most outstanding feature is high contents of Zn, Pb, As and Sb. Of these trace metals; Zn and Pb are known to build stable chloride complexes at high temperatures (White, 1968). As and Sb can be used, in addition to NH_4 and B, to give a qualitative indication of the age of a geothermal system (Giggenbach and Gougel, 1989). Since these volatile constituents evaporate at an early stage of a geothermal system, the relatively high concentrations in the present hydrothermal system of the Tuzla area may indicate a young age for this system, with a sufficient supply of fresh thermal water (Mutzenberg, 1997).

Deposits from present thermal springs in Tuzla contain some heavy metals, such as Pb and Zn. The analysis of the hot water samples also indicate high heavy metal compositions when compared to cold water (see Table 1). Therefore, the heavy metals in hot water were accumulated in the eastern part of the Tuzla River in the alluvium aquifers (see Figure 6 and 8).

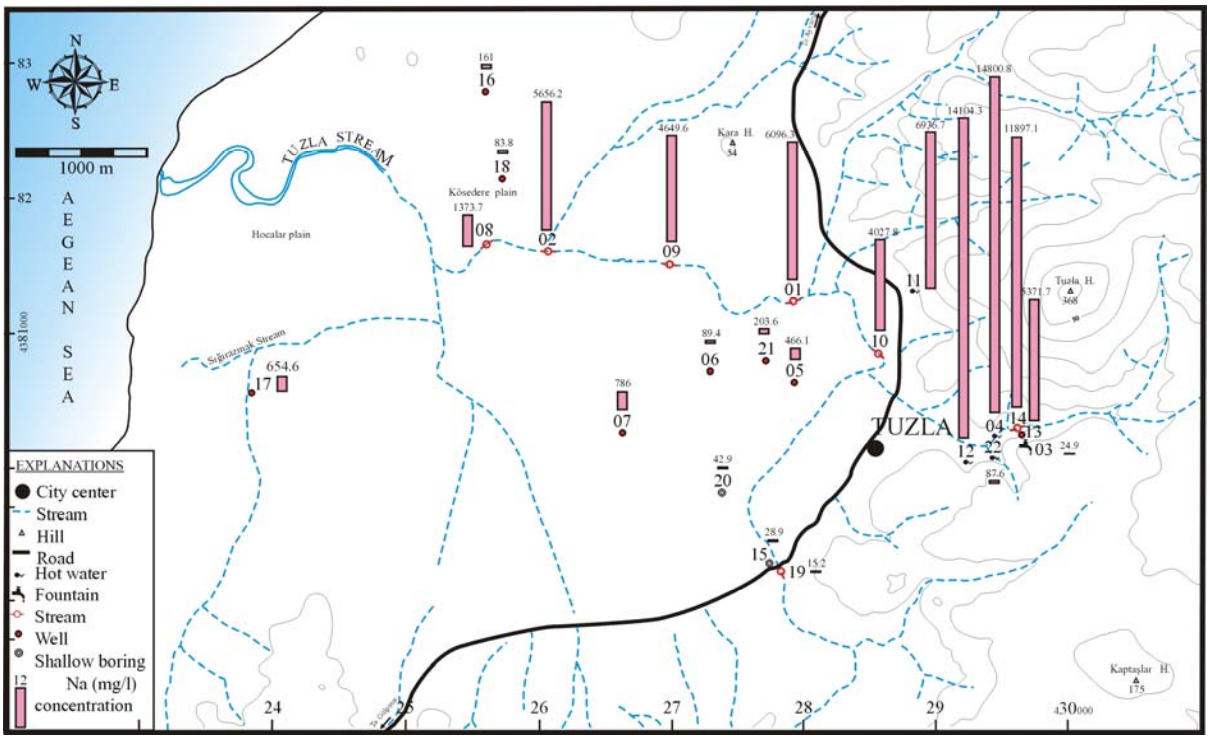

Figure 4: Distribution of Sodium (Na) in water sample

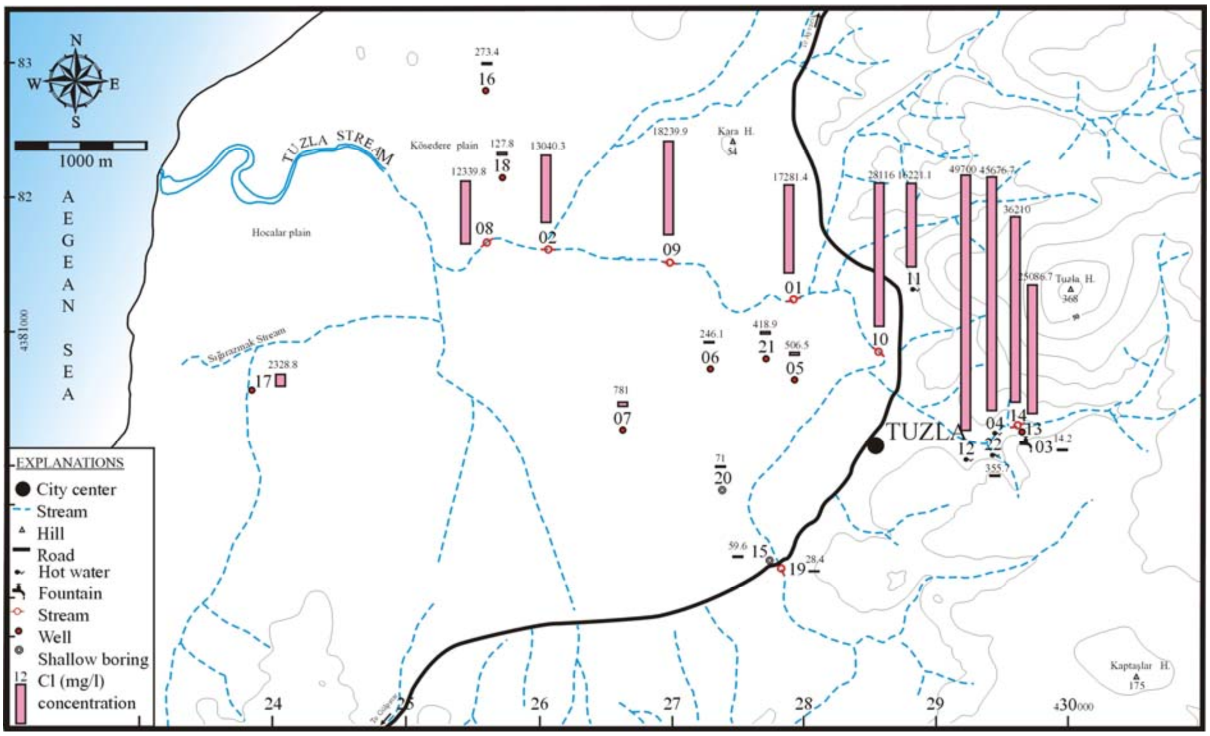

Figure 5: Distribution of Chlorine (Cl) in water sample

Table 1: Water analysis interval of some major and trace element concentrations

Sample Number	LOCATION	Mn (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	Cu (ppm)	Zn (ppm)	Sr (ppm)
01	Tuzla Stream	0,007-0,698	0,001	0,001	0,011-0,020	0,001-0,003	0,003-0,010	2,25-10,51
02		0,019-0,611	0,001-0,015	0.001	0,014-0,238	0,001-0,027	0,002-0,025	2,09-12,40
08		0,006-0,661	0,001-0,029	0,001-0,086	0,004-0,148	0,001	0,002	2,06-12,36
09		0,005-1,066	0,001-0,020	0,001-0,132	0,004-0,322	0,001	0,001	2,06-21,23
10		0,001-0,406	0,001-0,034	0,001-0.138	0,004-0,405	0,001-0,030	0,001-0,014	3,57-116,82
11	Hot water	0,758-3,902	0,001-0,027	0.069-0,329	0,058-0,311	0,001-0,016	0,047-0,292	34,19-110,77
12		1,306-5,073	0,013-0,015	0,086-0,174	0,061-0,243	0,005-0,008	0,110-0,132	49,05-51,79
13		0,001-1,306	0,014-0,026	0,050-0,289	0,127-0,428	0,001	0,008-0,148	41,53-122,33
04		0,001-1,319	0,013-0,041	0,027-0,150	0,155-0,443	0,001-0,023	0,053-0,151	123,37-134,63
22		0,001-0,003	0.001	0.001-0,002	0,007-0,011	0,001-0,003	0,002-0,003	0,10-0,13
05	Well	<0,001	0,001-0,002	0,001	0,007-0,008	0,001-0,003	0,001-0,009	0,24-2,85
06		0,001-0,005	<0,001	0,001-0,002	0,006-0,011	0,001-0,002	0,003-0,025	0,25-1,30
07		0,001-0,008	<0,001	0,001	0,003-0,013	0,001-0,005	0,007-0,028	0,13-2,00
16		<0,001	<0,001	0,001-0,002	0,009-0,012	<0,001	0,008-0,020	0,68-1,99
17		0,001-0,669	0,001-0,019	0,001-0,024	0,001-0,213	<0,001	0,001-0,020	0,001-4,04

Figure 6: Geothermal brine discharged over the rim of the evaporation pond in Tzla

Table 2: Metal concentrations in upper Miocene ferromanganese crusts and deposits from present thermal springs in Tuzla (all in ppm) (Mutzenberg, 1997).

Sample Number	1ExhR	2 T6/1	3 T3/1
Si	$1.5x10^5$ - $2x10^5$	$6x10^4 – 10^5$	105 – $1.5x10^5$
Ca	7,000 – 10,000	$10^5 – 1.5x10^5$	$2x10^4 – 4x10^4$
Mn	700 – 900	2,000 – 3,000	1,000 – 3,000
Fe	$4x10^5 – 5x10^5$	$4x10^5 – 5x10^5$	$4x10^5 – 5x10^5$
Zn	700 – 900	3,000 – 5,000	2,000 – 4,000
As	500 – 700	3,000 – 4,000	3,000 – 5,000
Sb	n.d	1,000 – 2,000	500 – 600
Ba	1,000 - 2,000	500 – 800	500 – 800
Pb	150 – 200	3,000 – 4,000	4,000 – 6,000
U	300 – 500	n.d.	n.d.

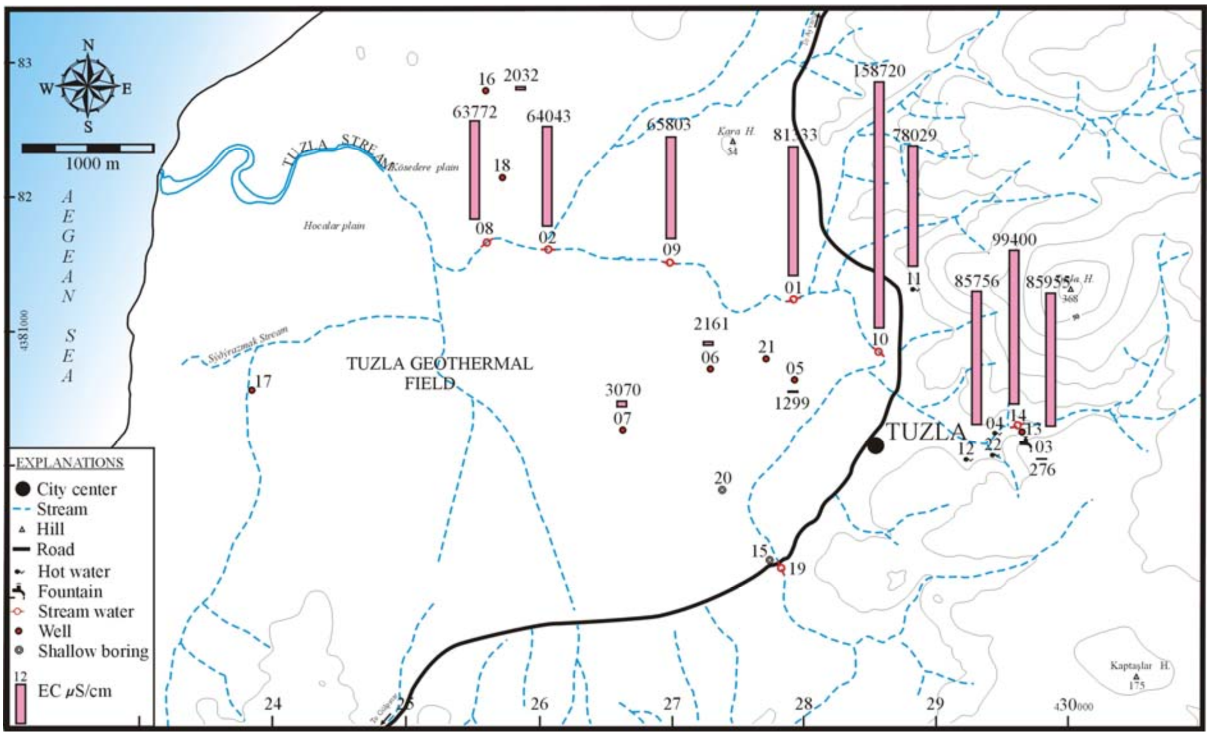

Figure 7: Distribution of Electrical Conductivity (EC) in water samples

4.3. Discharge of Geothermal Brine in Stream

Tuzla River is one of the important surface water for agriculture purpose in this area. This river has its origin at the East of Tuzla Plain (see Figure 7), subsequently passing close to a geothermal brine spring. Its recharge is derived from several small springs composed of Quaternary alluvial fillings of the Tuzla plain. In the discharge area, N-S trending Tuzla stream forms a natural barrier for contamination. The reason is that since the mentioned stream lacks tributaries to the south of the study area, it carries the contaminated water to the Aegean Sea. Figure 7 shows that electrical conductivity differences and high values are observed in the Tuzla Stream running E-W.

Figure 8: Discharge of geothermal brine in east part of study area

4.4 Contamination of groundwater System

Andesitic flow and rhyolitic domes from the volcanic stratigraphy of the Tuzla Geothermal area. The common fracturing of the volcanic rocks cause the deep infiltration of meteoric water and the lack of shallow piezometric water levels around study area. An exception is this plain where quaternary alluvium has built a shallow, porous aquifer with restricted extension.

Taking into account the specific geological conditions, it was difficult to prove the environmental impact of geothermal spills on the shallow aquifer system. In the case of the MTA wells and some spring, the unsealed evaporation basin probably caused the vertical infiltration of geothermal brine into the shallow plain aquifer. Approximately 50m below the well, the mineralised water discharges at the surface as a small spring. The saline spring water composition from August, 2003, comprising a mixture of meteoric water with geothermal fluids. As a consequence of the high salt content of the geothermal component, evaporation process and low discharge rate of the spring, the surrounding dark-grey to black soil covered by white salt crust with an areal extension of ca. 1 km^2 (Figure 8).

In countries with favourable hydrogeological and volcanological condition having high and low geothermal gradient the use of non conventional types of energy sources, such as geothermal energy, represent a very economic and environmental-friendly alternative in comparison with conventional types of energy sources. On the other hand, the present study indicates possible environmental impacts in the Tuzla Geothermal Field. Especially, western part of the study area is affected by geothermal fluids containing high concentration of Cl, Na and EC. Also, geothermal fluids discharge the Tuzla River, where concentration of some elements such as Na and Cl are very high.

CONCLUSION

Some of the possible potential impacts and measures to reduce the adverse effects of the impacts are summarized below.

- During well drilling, permeable groundwater aquifers can be penetrated resulting in a loss of drilling fluids into the reservoirs

- There is some possibility that geothermal fluid could mix with shallow groundwater downhole through damaged well casing or from the surface following an accident such as well blowout, sump overflow or pipeline rupture. Monitoring should be conducted throughout the construction, operation and decommissioning phases of the project.

- Geothermal reinjection should be considered an essential part of any modern, sustainable, environmentally friendly geothermal utilization.

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