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Chemical Analyses of Hot Springs in Sabalan Geothermal Area, NW-Iran

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ABSTRACT

Sabalan geothermal area is located on the northwestern portion of Sabalan volcano, approximately 16 km southeastern of Meshkinshahr city, in the province of Ardebil, NW- Iran. Chemical analyses of hot springs waters from the Mouil Valley on the northwest flank of Mt. Sabalan are presented.

The chemical characteristics of the hot springs were evaluated using the Cl-SO_4-HCO_3, Cl-Li-B and Na-K-Mg triangular diagrams. According to these ternary diagrams the hot springs from Gheynarge, Ilando, Malek-su and Khosrov-su typical Cl-SO_4- waters, Mouil hot spring is acid SO_4 type. Waters from studied area are not equilibrated with rock. Monitoring of chemical composition (Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2) for Gheynarge and Ilando hot spring has been carried out since 1997 to 2008. The results shown that there are no changes or the changes are negligible.

1. INTRODUCTION

The Mt. Sabalan Geothermal field is located in the Mouil Valley on the northwest flank of Mt. Sabalan, close to the Meshkinshahr town (Khiyav) of Azerbaijan, Iran. The field is located between 38º 11′ 55″ and 38º 22′ 00″ North and 47º 38′ 30″ and 47º 48′ 20″ East.

Mouil hot springs are located on the northern slopes of Sabalan (Figure 1). Hot springs are important because they are used as swimming pools and hot spa both local residents and tourists. Their temperatures are in the range of 25-84ºC. From the many hot springs in the Sabalan geothermal area, five were selected in this study. The names of studied sites are Gheynarge, Ilando, Malek-su, Khosrov-su, and Mouil.

The aim of this study is interpretation of geochemical data for hot springs from the geothermal field of the Sabalan area.

2. SAMPLING AND ANALYSIS METHODS

Correct sampling techniques and sample treatment are needed for reliable analysis of components of water samples, as all subsequent steps depend upon it. When collecting samples from springs, water is free-flowing at the sampling spot. Containers are rinsed well before collecting the samples. Bottles are filled to the top to get rid of air bubbles. Samples for analysis filtered. Filtration is carried out using a 0.45 µm filter membrane.

All reagents were purchased from Merck (Germany) and used without any further purification.

The temperature (T), electrical conductivity (EC) and total dissolved solids (TDS) of the hot springs were measured in the field. The pH was determined in the laboratory in an hour. The T, pH and EC of the hot springs were measured by multi parameter (Horiba). The TDS of hot springs was determined by a digital TDS meter (HANNA). Chemical analysis of hot spring samples was conducted in the Water and Soil Laboratory of Mahab Ghodss Consulting Engineers Company, Tehran, Iran and in the laboratory of SUNA. Na^+, K^+, Li^+ and Ca^{2+} were measured by Flame Photometer (JENWAY, model PFP7), Cl^-, SO_4^{2-}, B^{3+} and SiO_2 were measured by Spectrophotometer (DR/4000U). Mg^{2+} and HCO_3^- were determined by acid titration. All of the other parameters (Cu^{2+}, Mn^{2+}, Hg^{2+}, Pb^{2+}, Cr^{6+}, Co^{2+}, Zn^{2+}, As_{total}, Cd^{2+}, Fe_{total} and Ni^{2+}) were determined using Polarography (797 Computrace, Metrohm, Switzerland) and Atomic Absorption Spectrometry.

3. CHEMICAL CHARACTERIZATION OF THE HOT SPRINGS

The chemical composition of hot springs components provides information on their types of waters and an evaluation of subsurface temperatures. In this order the concentration of main anions such as Cl^-, SO_4^{2-} and HCO_3^- and cations K^+, Na^+ and Mg^{2+} were used for interpretation of hot springs. The temperatures measured during collection of the samples ranged from 34ºC to 83ºC. The pH is generally slightly acidic (4.91-6.68). The TDS of the samples is in the range of 458.75-2456.75 ppm.

Results of the chemical analyses of hot springs (Gheynarge, Ilando, Malek-su, Khosrov-su, and Mouil) are presented in Table 1.

Cl-SO4-HCO3 triangular diagram was used to classify geothermal waters on the basis of major anions (Giggenbach, 1991). According to this diagram (Figure 2) all samples plots to area of Cl field and can be classified as Cl-rich geothermal, except the hot spring from Mouil which fall to area of steam heated water. The high concentration of SO_4 and low pH can be explained by atmospheric oxidation of H_2S near the surface (Bogie, 2000).

A plot of the relative concentrations of chloride, lithium and boron is shown in fig. 3. Data points close to the Cl^- in the area of low absorption of B/Cl steam that suggests that they are from old geothermal system, except the Mouil hot spring water which plot near the Li-B tie line showing high Li-B content.

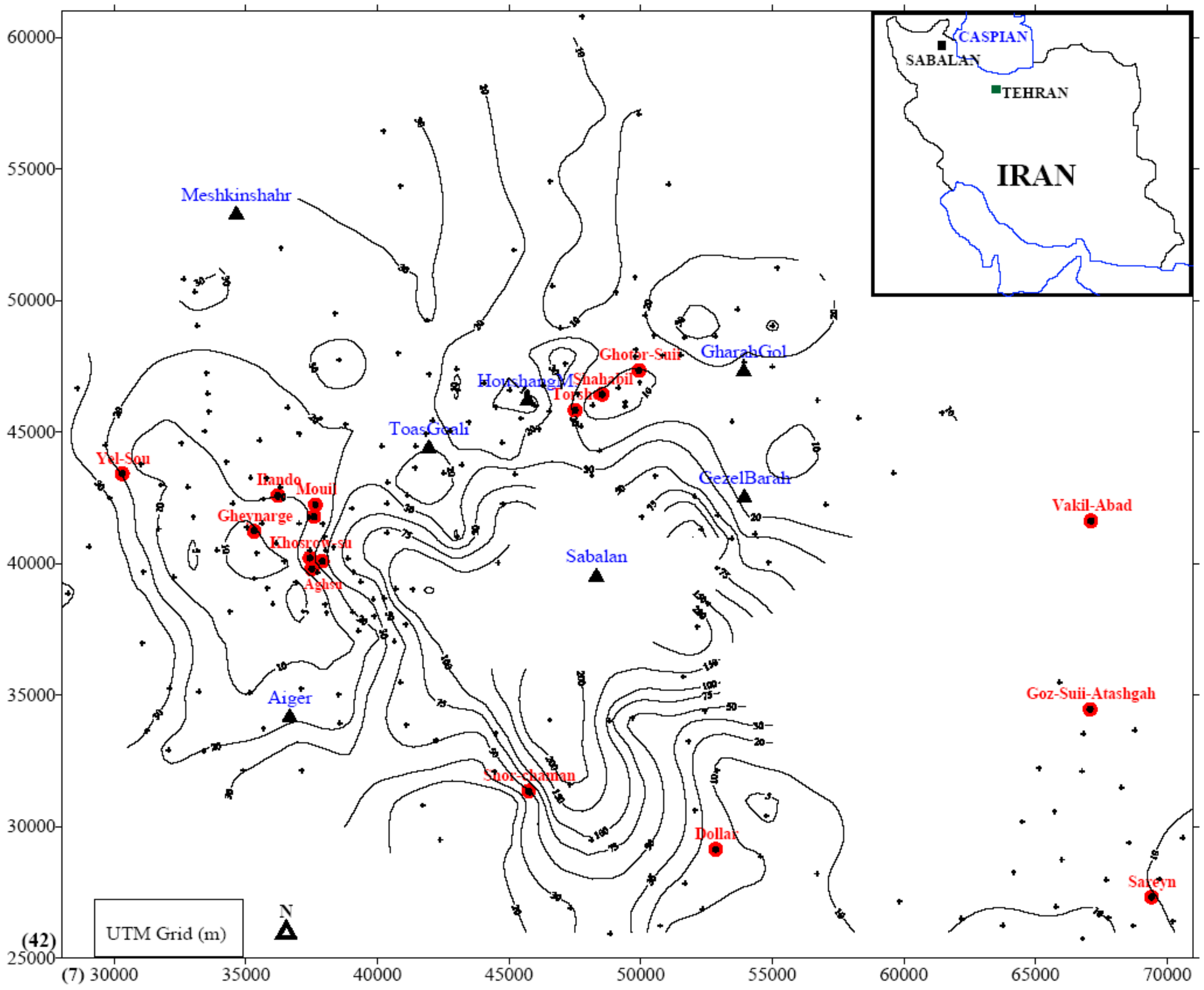

Figure 1. Resistivity anomaly map of the Sabalan region. Showing locations of hot springs ●, major geographic features ▲ and resistivity stations +. The grid is simplified from UTM (metres), oriented north. Contours show average MT apparent resistivity (Ω-m) at 3 Hz frequency. Elevations range from 4800m (Sabalan peak) to about 1500m (Meshkinshahr and Sareyn) (Bromley, et al. 2000).

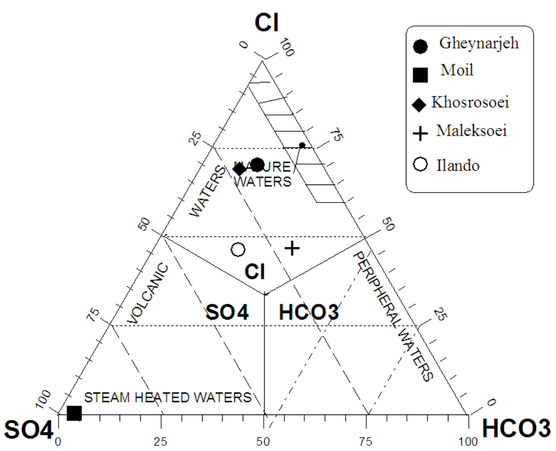

Figure 2: The classification of hot springs from the Sabalan geothermal area according to the Cl-SO4-HCO3 triangular diagram of Giggenbach (1991).

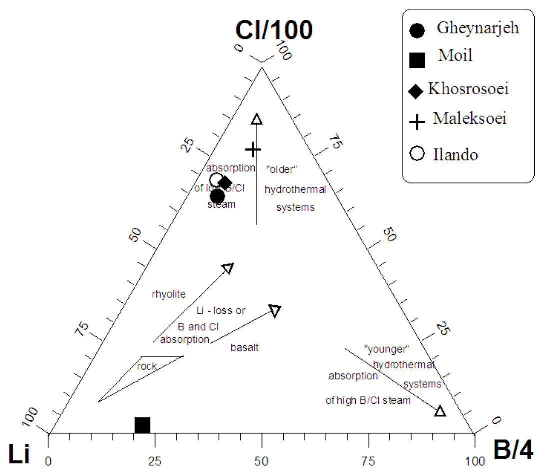

Figure 3: The Cl-Li-B triangular diagram of hot springs from the Sabalan geothermal area according to Giggenbach (1991).

The diagram using the Na-K equation (Arnórsson et al., 1983) and the K/Mg equation (Giggenbach, 1988) was used for interpretation of original of hot spring and equilibrium state. From figure 4 seen that hot springs from Gheynarge, Khorosoei and Ilando plot close to boundary line with partial equilibrium field and samples from Malek-su and Mouil close to the √Mg corner. It means that waters have not attained equilibrium.

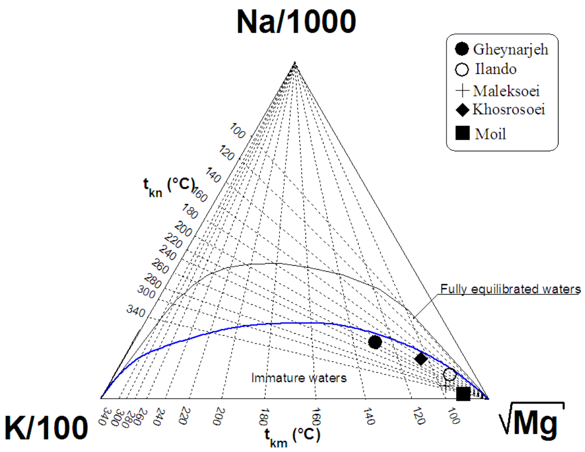

Figure 4: The Na-K-Mg triangular diagram for hot springs from the Sabalan geothermal area according to Giggenbach (1988)

4. CHEMICAL MONITORING

The chemical data of the Sabalan geothermal field is available over tens of years. The variation in Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2 concentrations with time (from 1977 to 2008) in the hot spring from Gheynarge and Ilando shown in Figure 5 and 6 and also presented in Table 2. In the years from 1998 to 2007 concentrations of Cl^- and Na^+ in hot spring from Gheynarge increased from 957 mg/l up to 1755.6 mg/l and from 690 mg/l to 1045 mg/l respectively. It can be due to boiling processes and mixing. There are no significant changes in concentrations of Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2 for Ilando hot spring.

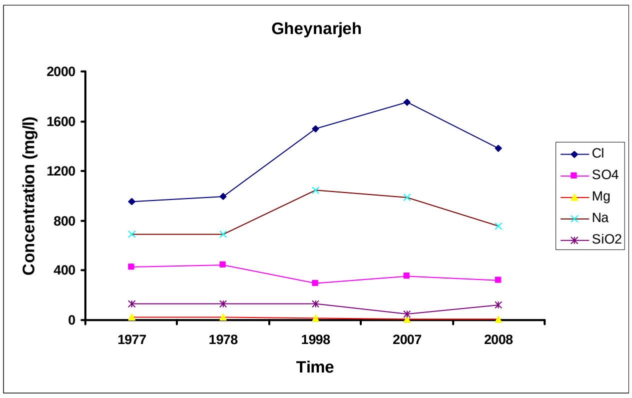

Figure 5: Changes in Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2 concentrations with time in the Gheynarge hot spring in the Sabalan geothermal field from 1977 to 2008.

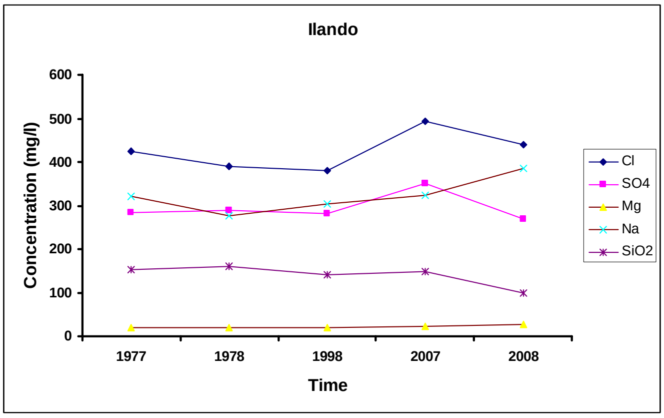

Figure 6: Changes in Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2 concentrations with time in the Ilando hot spring in the Sabalan geothermal field from 1977 to 2008.

5. CONCLUSIONS

The main conclusions in the case of studied hot springs can be summarized as follows: The Gheynarge, Ilando, Malek-su and Khosrov-su are Cl-SO_4 type except hot spring from Mouil which is aside SO_4 water. All of the waters are from old geothermal system, except the Mouil hot spring water. The hot springs from studied area have not attained equilibrium.

Variation of Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2 concentrations in the Gheynarge hot spring show that content of Cl^- and Na^+ were increased from 957 mg/l up to 1755.6 mg/l and from 690 mg/l to 1045 mg/l respectively during 1998-2007. It can be due to rock dissolution. There are very little changes or the changes are negligible in the Ilando hot spring.

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Table1. Chemical composition of the hot springs (Gheynarge, Ilando, Malek-su, Khosrov-su, and Mouil) in the Sabalan geothermal area. (N.D = Not detected).

Sample ID and parameters	Gheynarge	Ilando	Malek-su	Khosrov-su	Mouil
Elevation (m)	2126	1959	2262	2297	2065
Temperature (ºC)	82.6	34.8	43.7	62.68	39.65
pH	6.61	5.92	5.98	6.68	4.91
Electrical Conductivity (µS/cm)	5.01	1.95	1.18	2.87	0.95
TDS (mg/l)	2456.75	918	559.75	1398.25	458.75
Li^+ (mg/l)	5.99	1.45	0.48	2.97	0.28
Na^+ (mg/l)	0.88	0.33	0.21	0.51	0.064
K^+ (mg/l)	1.17	0.37	0.43	0.499	0.288
Mg^{2+} (mg/l)	3.37	4.46	4.04	3.33	4.88
Cl^- (mg/l)	1336.93	390.82	264.02	836.1	1.196
SO_4^{2-} (mg/l)	309.46	283.03	89.92	249.56	560.89
HCO_3^- (mg/l)	261.22	176.65	174.95	127.22	22.9
B^{3+} (mg/l)	6	1.03	1.23	3.83	0.3
Cu^{2+}(µg/l)	7.7	5	5.3	8.3	27
Mn^{2+}(µg/l)	403.25	30.67	155.3	263	363.5
Hg^{2+}(µg/l)	N.D	1.4	1.07	2	0.7
Pb^{2+}(µg/l)	10	7.5	10.5	9.5	12.75
Cr^{6+}(µg/l)	N.D	0.13	N.D	N.D	N.D
Co^{2+}(µg/l)	0.02	0.06	0.055	0.3	0.055
Zn^{2+}(µg/l)	26.75	38.75	1.05	45	84.25
As_{total}(µg/l)	895	162.25	134.75	279	8.5
Cd^{2+}(µg/l)	23	31	1	56	23
Fe_{total}(µg/l)	69	91	397	79	729
Ni^{2+}(µg/l)	125.5	226.5	467	147	433.7

Table 2. The variation of Cl^-, SO_4^{2-}, Mg^{2+}, Na^+ and SiO_2 concentrations with time in the Gheynarge and Ilando hot springs in the Sabalan geothermal field from 1977 to 2008.

sample ID	Date	Cl^-(mg/l)	SO_4^{2-}(mg/l)	Mg^{2+}(mg/l)	Na^+(mg/l)	SiO_2(mg/l)	Reference
Gheynarge	20-Aug.-77	957	432	21.9	690	128	TBCE(1979)
Gheynarge	24-May-78	993	442	24.3	690	130	TBCE(1979)
Gheynarge	10-Sep.-98	1541	300	15.6	1045	134	Bogie et al. (2000)
Gheynarge	08-Oct.-07	1755.6	351.5	10.6	985.8	46	This study
Gheynarge	29-Jun.-08	1380	325	12.1	760	126	This study
Ilando	20-Aug.-77	425	283	19.4	322	154	TBCE(1979)
Ilando	24-May-78	390	288	20.7	276	160	TBCE(1979)
Ilando	10-Sep.-98	381	281	20.3	304	141	Bogie et al. (2000)
Ilando	08-Oct.-07	493.53	350	21.3	324	148	This study
Ilando	29-Jun.-08	438.8	270	28.3	385	100	This study