Hydrogeochemical characteristics of Mahallat hot springs, central Iran

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Received: 19 July 2016 / Accepted: 01 November 2016 / Published online: 04 November 2016

Abstract

Mahallat hot springs located in the northeast of Mahallat, in central Iran. There are 6 main hot springs namely Shafa, Abejoush, Donbeh, Soleimanie, Hakim and Soda. In this research, geology, physico-chemical characteristics and petrography of basement rocks of these hot springs have been investigated. The results show that hot springs have an average temperature of 45°C and acidic to neutral pH. All sampled hot springs have calcic sulfate facies. The hydrogeochemistry of the samples show that the concentration of heavy metals is low and less harmful for the environment. In addition, the low changes of the discharge of hot springs; their temperature; and high partial pressure of CO_2, has led to the conclusion that the hot springs were located on faults and had deep aquifers. Hot springs, in terms of water quality, are better conditions than the other sources, and due to health their benefits, can play an important role in geo tourism of the area.

Keywords: Hydrogeochemistry; Hot Spring; Mahallat; Iran.

1- Introduction

Hydrothermal activity generates chemical interactions between hot water (hydrothermal fluid) and the host rocks, so that the composition of the fluid changes becomes enriched in many trace elements and REE (German and Von Damm, 2003). Type and origin of these springs have a major role in determining their physical and chemical properties, and hence different sources can have completely different properties: some are pathogenic and some healing to many factors such as the source of spring water. The composition of ground water that has passed, pressure, temperature, speed and time depends on the flow of water in the ground (Ghafouri, 2003). Some of these hot springs, because of having some chemical materials, hold a particular color, odor or taste and they are used enormously in the fields of health and tourism (Taheri *et al*., 2012, Esmaeili *et al*., 2015 and Modebberi, 2013).

Mahallat city is located in the Markazi province of Iran (Fig.1). Abe-Garm area of Mahallat district is a small part of Central Iran and is related to the volcanic belt of Orumieh-Dokhtar tectonic zone. These hot springs are used for swimming, bathing, and medical purposes. Visitors and local people use these resources and there is substantial room for expansion of use of this water as international and domestic touristic attractions in Iran (Erfurt-Cooper and Cooper, 2009; Navi *et al*., 2012). The natural contamination of local rivers and groundwater resources as a result of hot spring discharges is a global occurrence, yet the characteristics of toxic elements in hot spring waters have rarely been addressed. The purpose of this study was to establish the geochemical characteristics and possible adverse environmental impacts of the hot spring waters in the Abe-Garm geothermal field and surrounding areas.

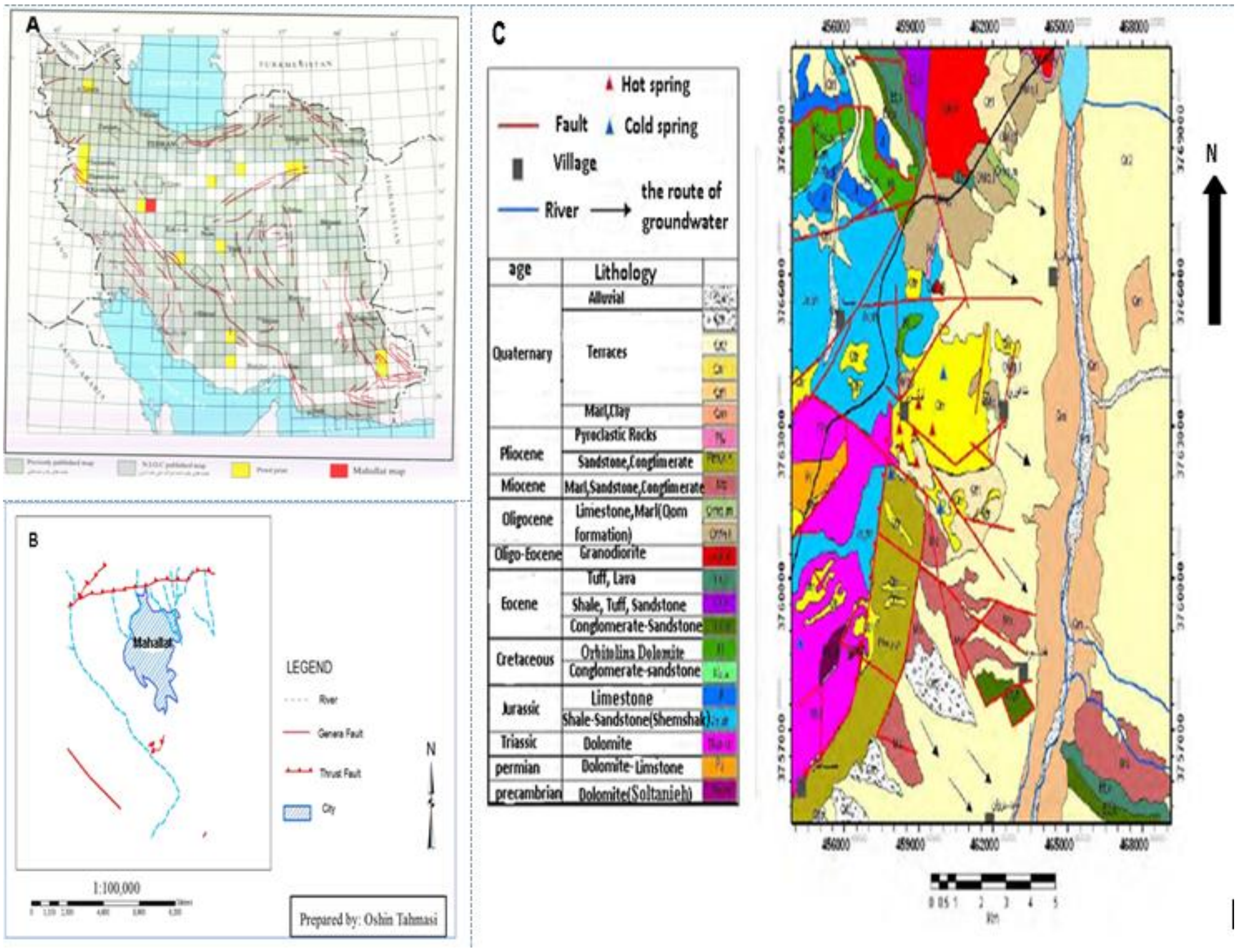


Figure 1) location and geological maps of Abe-Garm area.

There are six spring orifices by the names of Shafa, Abejoush, Donbeh, Soleimanie, Hakim and Soda in Mahallat. Shafa hot spring is the main spring and discharge from main fault. Other springs are related to fractures and secondary faults. The outcrop formations in the region under study are: Shemshak formation with shale and sandstone lithology, the unit of cretaceous lime containing Orbitolina and the unit of marl lime of Qom formation.

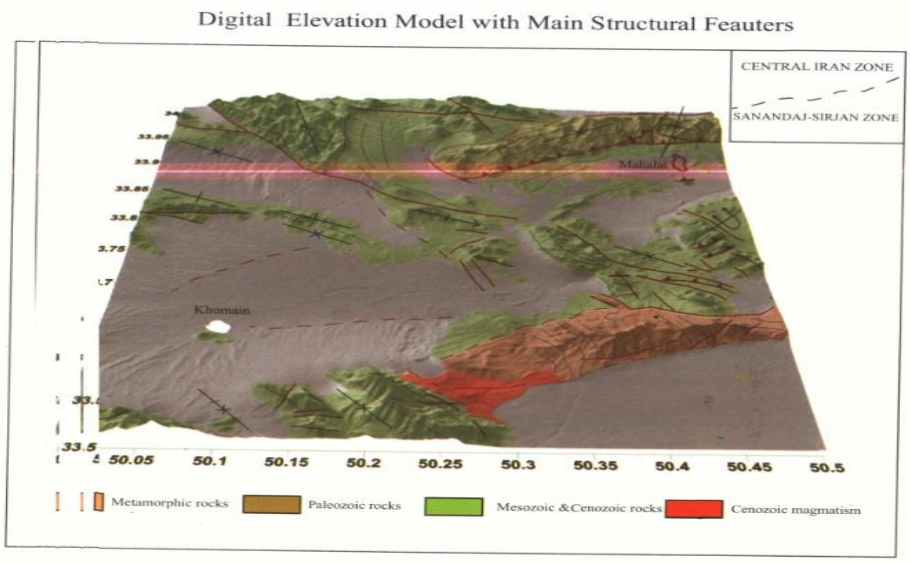


Figure 2: Three-dimensional model of the fault in the region.

Besides these sedimentary formations, there are outcrops of magmatic rocks including granodiorite, tuff and lava. There are lots of faults and fractures in the region (Fig. 2). Hot springs come out of travertine sediments and alluvium. On the base of geological and hydro geological studies, hot springs were recognized to be on faults, having a deep aquifer. They are confined and with hydrothermal karst building.

From geological point of view, the area is divided into three zones: northwest area- Paleozoic rocks, southeast area- Phanerozoic rocks, central area- sandstone, conglomerates, Eocene tuffaceous sediments. In this area volcanic rocks do not extend. The sediments of the area are known Mahallat Paleozoic Facies and respectively included: Soltanieh, Zaigun, Lalun and Mila. The oldest exposed rocks in the area is last Cambrian sediments (Soltanieh formation) consisting of sandstone and dolomite. The early Cambrian green and red Shale- Zaigun and sandstone- Lalun formation are underlain by the older Paleozoic sediments and overlain by the dark and white dolomites and also smelly corals. These formations transgressively overlie the Mila Dolomite and limestone complex. Permian sediments in Mahallat mostly are dolomitic and in some places sandstone is seen in the basal parts (Fig 1).

2- Sampling and analytical methods

Considering the topographical and hydrological conditions, climate, and rainfall time, samples were taken. The sampling was done in the fall of 2012-dry season. To investigate the chemical parameters and trace element concentrations, 6 water samples by ICP-OES would be evaluated. The locations of the water samples are shown in Figure 1. Temperature, pH and electrical conductivity (EC) of the water samples were measured on-site. Water samples were collected into 250 ml polyethylene containers. All water samples were collected as two filtered batches. 2.5-ml ultrapure Merck HNO_3 was added into one of the batches for cation analyses.

Table 1) Basic information of hot spring waters from the Abe-Garm of Mahallat.

EC	PH	T (C°)	Springs
2100	6.7	47.7	Shafa
2100	6.47	47.3	Abjush
2100	6.6	46.1	Suda
2160	6.8	35	Ab Hakim
2090	6.6	46.9	Ab Dambe
2030	6.4	46.9	Ab Soleimanie

The other batch taken for anion analyses was untreated. Water analyses were performed using standard methods in the ‘‘Geological Survey of Iran’’ Laboratories. Bicarbonate and chloride analyses were measured by titration methods, sulfate concentration by spectrophotometry and cations by flame photometry. Acidified samples were analyzed for major and trace elements with an ICP-OES method.

Table 2) Geothermometry results of the hot springs reservoir temperature (C°) based on chemical composition.

Hakim	Abjush	Dambe	Suda	Soleimanie	Shafa	Geothermometer
184.37	168.5	160.65	161.72	169.56	171.21	Na-K
43.39	41	39.9	39.76	45.36	42.53	Na-K-Ca
≤350	≤350	≤350	≤350	≤350	≤350	Na-K-Ca-Mg
-	-	130.09	121.73	131.4	128.76	QUARTZ
-	-	102.64	93.47	104.08	101.18	Chalcedony

Different Geo-thermometers indicate temperature for the geothermal reservoir is between 76.39 to over 350 (Table 2). Due to Carbonate reservoirs of hot springs and chemical agents, the concentration of calcium and magnesium ions in the depths is different so specific temperatures through Geo thermometers containing Ca are unreliable. And because of high silica (quartz and chalcedony) content in the samples, the temperatures determined by chalcedony geo-thermometry are reliable.

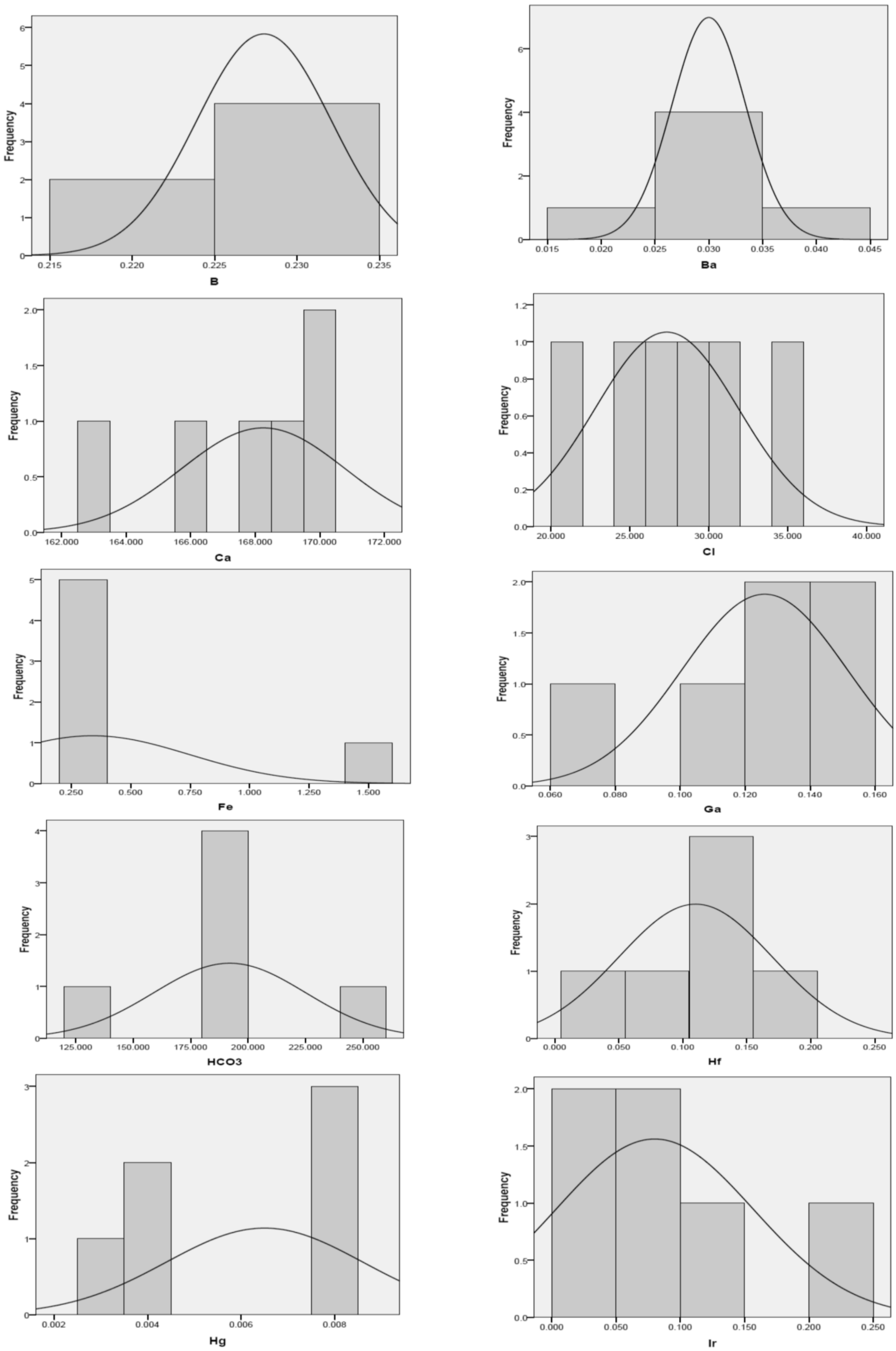
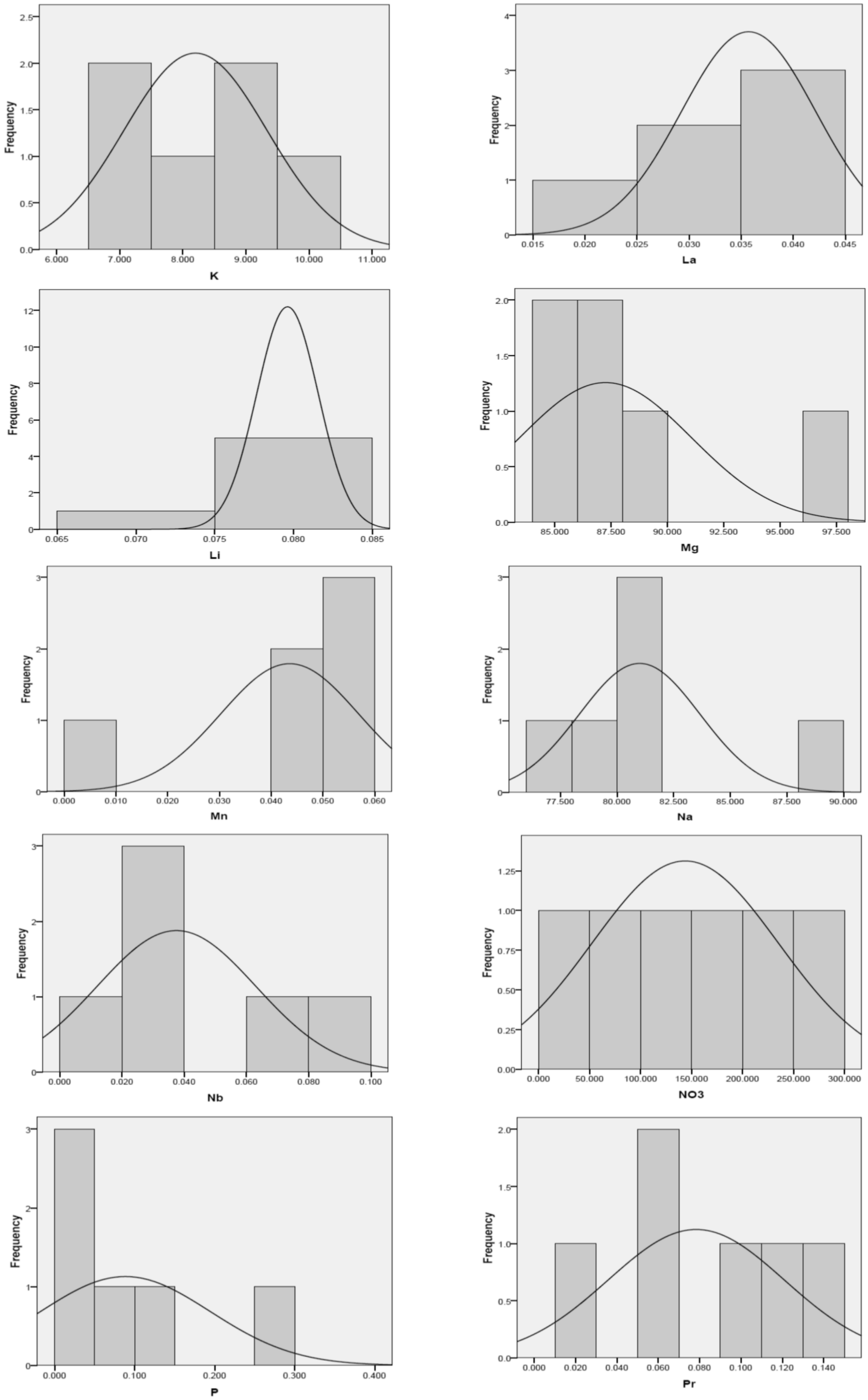


Figure 3) Histogram of different elements in the hot springs of the Ab-Garm area.



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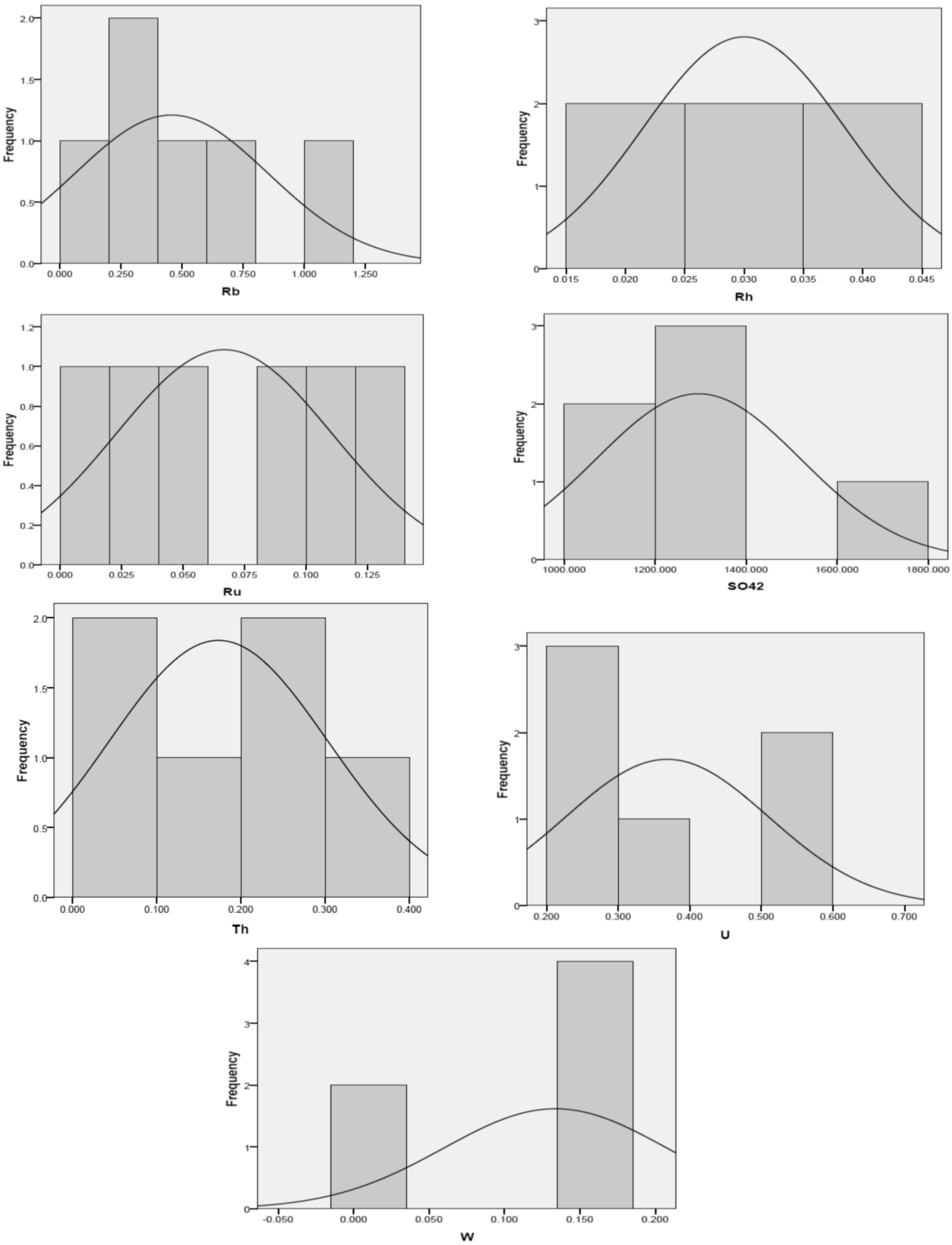

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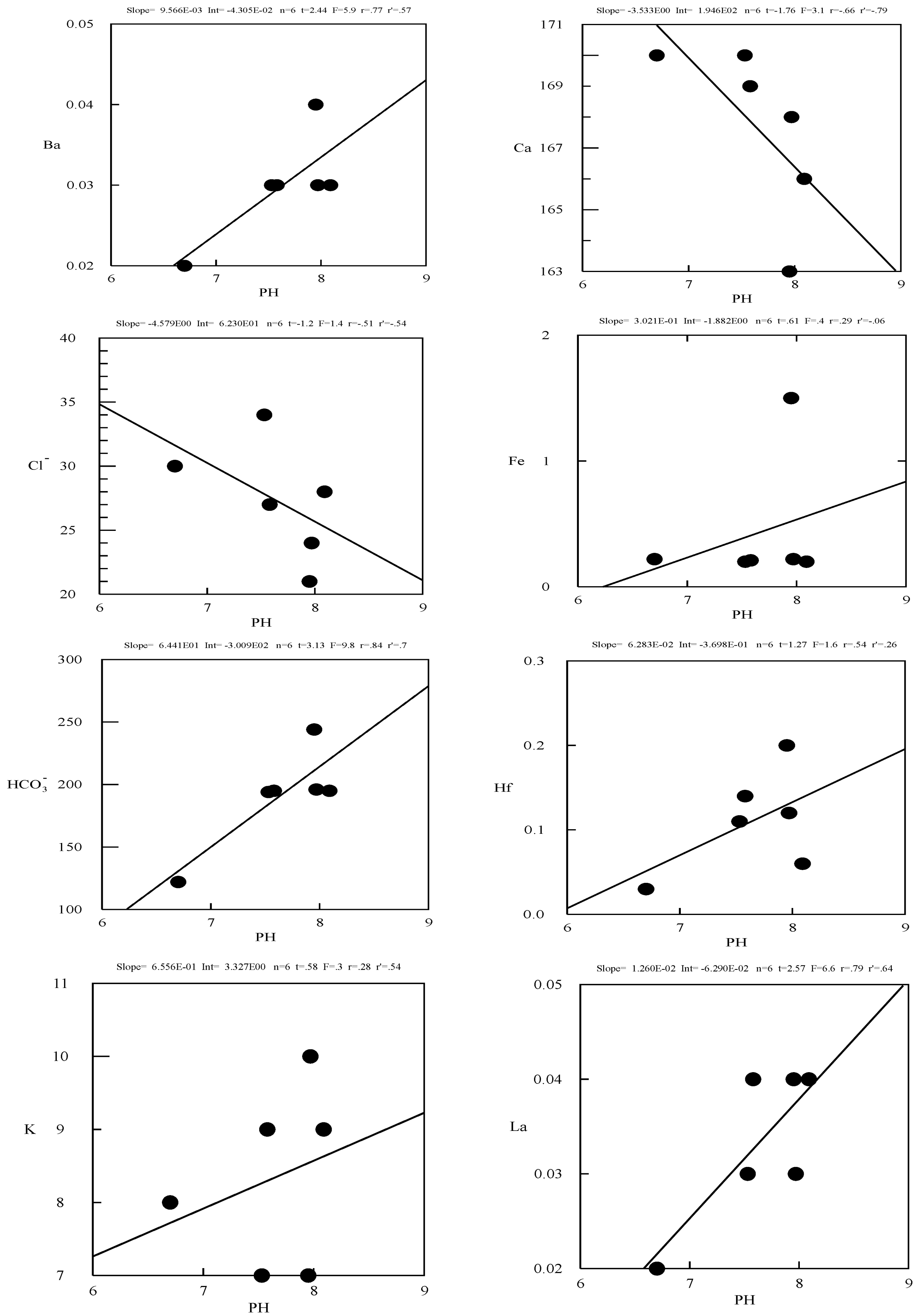

Figure 4) Dual graphic of elements relative to PH in the hot springs of the Ab-Garm area.

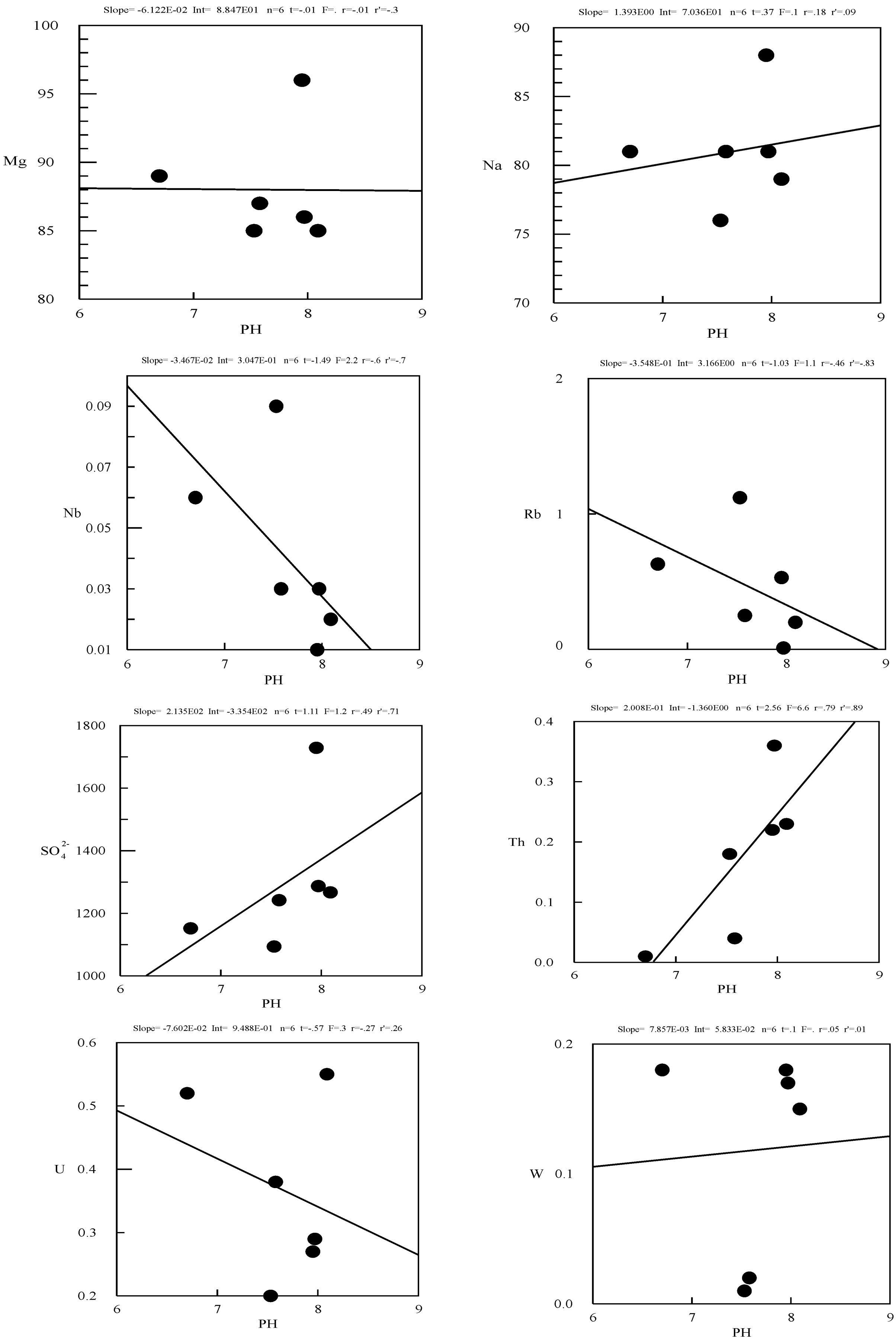

Figure 4) Continued.

As well as, mixing hot water with cold water in shallow parts generates variety between temperatures via different geo-thermometers.

Table 3) Saturation index of minerals in the cold springs.

Luran	Absard	Kolahi	Nakht	mineral
1.74-	0.58-	0.92-	0.69-	Anhydrite
0.61	0.39	0.1	0.45	Aragonite
0.75	0.54	0.24	0.6	Calcite
1.49	0.63	0.18	0.79	Dolomite
1.51-	0.34-	0.69-	0.46-	Gypsum
6.81-	6.53-	6.4-	6.73-	Halite

After reviewing the results obtained from the geo-thermometer, the reservoir temperature of Mahallat was estimated about 165 C° (Rezai M. *et al.*, 2010). 4 cold springs called Nakht, Kolahi, Absard, and Luran are located in this area (Fig. 1). These cold springs are oversaturated than calcite, aragonite and dolomite (table 3). All hot and cold springs of the area are calcic sulfate type (Table 4).

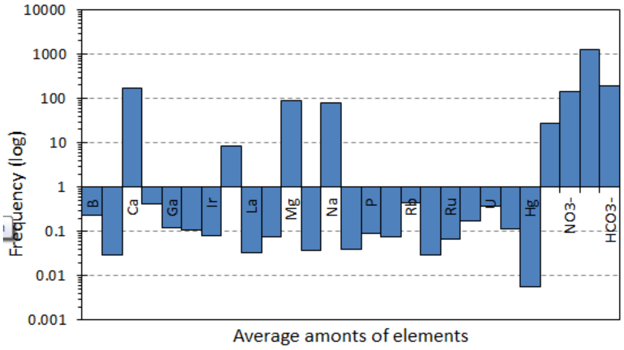

Figure 5) Average amount of elements in the hot springs of the Ab-Garm area.

Table 4) Chemical characteristics of the cold springs.

K	Na	Mg	Ca	HCO_3^-	SO_4^{2-}	Cl	TDS	PH	EC	T	
2.34	71.4	31.8	64.2	173.8	164.2	53	500	7.5	890	20	**Min**
9.75	165.6	58.2	314	205.6	1104.9	109	1829	8.3	2690	21	**Max**
7.02	136.1	46.8	204.4	192.9	713.6	80.5	1298	7.78	1974	20.5	**Mean**

3- Results and discussion

After sampling the hot springs and sending them to laboratory, 74 elements were analyzed by ICP method. The histograms of elements show that the elements value variations in the analyzed samples. They show that the chemistry of springs are calcic sulfate type, amount of Ca, Mg, Na, SO_4, NO_3 are more than the other elements.

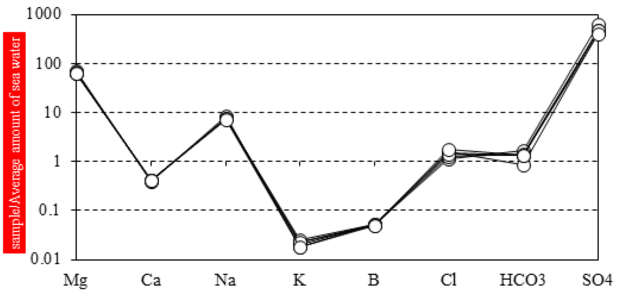

Figure 6) Spider diagram elements according to the average amount of sea Meybeck, M. (1979), Ernst, W G (ed.) (2000).

The dual graphics of elements with PH indicate that the relationship between elements and PH. Increase in PH value causes to decrease in elements content like Ca, Cl^-, Rb, Nb and U and increase in Ba, Fe, Hf, HCO_3^-, La, K, Na, Th, SO_4^-, and W. In high PH condition, the environment is alkali and elements which have direct correlation with PH and their concentration is relatively high.

4- Environmental impacts of hot spring

Due to the importance of pollution environment of hot springs in Mahallat and the hazards of excessive amounts of dangerous elements, in this study, after measuring the elements of the hot springs and comparing the values obtained with international standards, it was found that none of these elements are more than the standard values. But Arsenic value in Shafa spring is a little more than the other. The hot springs of Mahallat are calcic sulfate type and have high Radon. These springs have been used traditionally in the treatment of rheumatic, skin diseases, gout, etc. also, today, they are used for swimming, bathing, and medical purposes.

Table 5) Sulfate and calcic value in the hot springs of Mahallat.

Dambe	Hakim	Abjoosh	Soleimanie	Shafa	Suda	Spring
1244	1152	1267	1094	1729	1287	SO_4 (ppm)
169	170	166	170	163	168	Ca (ppm)

Shafa spring has the highest sulfate value and Soleimanie spring has the lowest. Finally, inasmuch as sulfate concentration in all the springs is almost close together so they have same health benefits. As well, amount of Radon in the baths (487 Bq/m^3) is more than EPA (148 Bq/m^3) and it Can cause health risks.

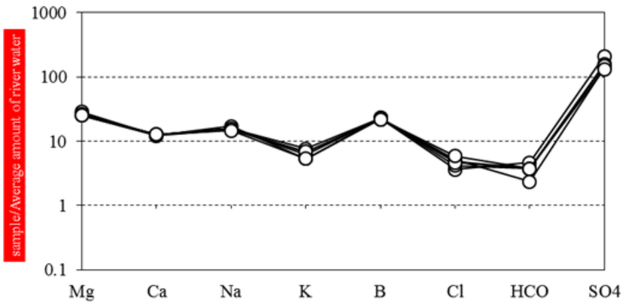

Figure 7) Spider diagram elements according to the average amount of river water Meybeck, M. (1979), Ernst, W G (ed.) (2000).

5- Conclusions

According to the geological and hydrological results, it seems that the Cretaceous and Eocene limestones and dolomites constitute the reservoir for the springs and that magma has probably penetrated into these lithologies. Because of little changes in discharge of the hot springs; the temperature of their water; and high partial pressure of CO_2, the aquifer of the hot springs must be deep. The temperature of hydrothermal system related to hot springs is not sufficient enough to generate electricity. But because of having high temperature and discharge, that is necessary that their potential would be evaluated for using hydrothermal energy. On the base of geological and hydro geological studies, hot springs were recognized to be on faults, having a deep aquifer. They are confined and with hydrothermal karst building. In addition, all sampled hot springs have the type and facies of calcic sulfate. In Hakim spring, in old alluvial deposits, there is some evidence of mixing with shallow and more salty water which reduces temperature and increases TDS of its water. It seems that the effect of Ca^{2+} common ion of dissolution of gypsum or anhydrite with effusion of CO_2 to be the most important hydro geochemical factor in forming travertine of the region. In this research, Sulfate and radon geochemical characteristics have been investigated and their effect in curative properties of the springs has been evaluated. Hot springs in terms of quality of the water sources are better condition than the other resource, especially alluvial, and also because of having health benefits they are an important role in attracting geo tourism of the area.

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Geological maps of Abe-Garm area. Adapted from the map 1/100000 Kahak and Moote.

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