Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Monitoring of Surface and Ground Water Quality in Geothermal Exploration Drilling of Meshkinshahr Geothermal Field, NW-Iran

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Keywords: Geothermal energy, environmental impacts, water pollution, monitoring, exploration drilling and heavy metals.

ABSTRACT

In this report there are reported results of the monitoring of surface and ground water quality during and after finishing the drilling of three deep geothermal exploration wells in Meshkinshahr geothermal project, NW- Iran. This area has been investigated for geothermal resources by various researchers in the past few years for using geothermal energy to generating electricity. A preliminary review of possible environmental effects of proposed project has been carried out in Environmental Impact Assessment (EIA) project in last few years (Noorollahi and Yousefi, 2003).

During deep geothermal drilling different types of substances like Cement, Bentonite, Barite, Soda ash, Sodium chloride and ect. are used in drilling procedures and cement jobs. A large amount of pollutants may thus be discharged into shallow and deep aquifers and reservoirs that are feeding hot and cold springs and finally discharge into the Khyav River. In this study, an attempt has been made to identify the likely impact of drilling three geothermal exploration wells on Khyav River and several hot and cold springs in a study area about 132 km^2. The water quality of Khyav River is very important as it is not only used as the drinking water of Meshkinshahr city but also for the agricultural and aquiculture use of Meshkinshahr city and surrounding communities with a population of 200,000. Monitoring of possible quality change of hot and cold springs in area is very important because the permanent population of two villages (Moeil and Dizo) and many sheep grazer families during summer time use cold springs as a drinking water as well as several tourists that visit the area for site seeing and swimming in hot spots, which may be affected from possible quality change of these springs waters.

The results of study are shown that in during of 18 months monitoring of Khyav River drilling activities have great influence in quality of river and also hot and cold springs, but except some heavy metals, the concentration of all other elements are below drinking water standard levels.

1. INTRODUCTION

Geothermal activities in Iranian ministry of energy were started in 1975 with co-operation of Italian ENEL Company and Iranian Tehran Berkley Co. The aim of that study was to investigate of geothermal prospects in an area about 260,000 km^2 in northwestern part of the country. The result of that study, finalized in 1982 indicated four prospect areas in north western part of Iran and also further studies by Renewable Energy Organization of Iran (SUNA) have been defined 10 more prospect area in other parts of country [Fotouhi and Noorollahi, 2000].

In 1995, studies and development of Sabalan area (one of those 14 areas), which it was in first priority according to several studies, has been started. The aim of the project is to install the first Iranian geothermal power plant (100 MWe) and it is funding by Iranian Ministry of Energy.

The environmental effects of geothermal development are receiving increasing attention with the shift in attitudes towards the world's natural resources. There is a greater awareness of the effect of geothermal development on the surrounding ecosystems and landscape.

Geothermal power generation is often considered as a '***clean***' alternative of fossil fuel power plants, although geothermal power production is very clean methods, but it is necessary to survey the effect of geothermal contaminations on environment for to minimize it. Geothermal power generation using a standard steam cycle plant will result in the release of non-condensable gases, and fine solid particles into the atmosphere.

In recent years attention has been focused on the utilization of the geothermal energy as alternatives to hydropower, and fossil fuel power plants in Ardebil province with close to 1,200,000 populations as well as the 165,000 inhabitants of Meshkinshahr City. The Ministry of Energy and Renewable Energy Organization of Iran (SUNA) are trying to develop Meshkinshahr geothermal field to build up the first geothermal power plant. Before such projects are initiated environmental impact assessment (EIA) is necessary. As regards the Meshkinshahr area located in a formerly farmed area in NW-Iran, it is necessary to predict the environmental effects of geothermal development. In this report an attempt is made to describe the probable effects of three deep geothermal drilling in the Meshkinshahr area, and to give some recommendations or mitigation of project effects in surface waters (Khyav River) and deep and shallow ground waters.

Ground and surface waters are among the important natural resources. Through the course of history, we have not always protected our surface and ground waters and have not given them the importance that they deserve. As a result, the available waters have become contaminated or are in danger of becoming contaminated thus there is a need for a careful monitoring of possible contamination.

Geothermal project, The construction and drilling operation phase of geothermal development are not expected to have much adverse effect on water quality. Drilling fluids including drill mud and many chemicals are used to lubricate the drill bit, stabilize the hole, and remove drill cuttings. When the drill bit hits permeable rocks drilling

fluids may be lost into the rock formations. Excessive loss of fluids could result in localized changes to water quality. These changes would be adverse, but the proposed drilling fluids would be composed of non-toxic constituents that would cause minimal water quality degradation.
Also during drilling, liquid wastes that are returned from the drill column include water, non-toxic drilling additives, rock cuttings, and once the geothermal reservoir is intercepted – geothermal fluid. These liquid wastes would be directed to the well pad sump and could potentially leak from the sumps, infiltrate to the shallow groundwater and degrade the quality of the ground waters. The sumps would be constructed and maintained to have a permeability of less than 6 to 10cm/sec. Each liquid-holding sump would have a capacity adequate to hold the expected volumes of fluids to be produced during short-term flow tests and well start-up and work over operation.

Bentonite is a common drilling mud additive which would provide additional clay to the liner of the sumps and further reduce the potential for leakage from the sumps. For these reasons, it is unlikely that substantial leakage would occur from the well pad sumps to the shallow aquifers.

This study has been undertaken to determine the effects of drilling liquids during drilling of three deep geothermal exploration wells at the first phase of Maeshkinshahr geothermal project in surface and ground waters.

2. DRILLING FLUIDS AND ENVIRONMENT

Drilling fluids, including the various mixtures known as drilling mud, do the following essential jobs in geothermal wells:

- Lubricate the drill bit, bearings, mud pump and drill pipe, particularly as it wears against the sides of the well when drilling deviated wells around corners;
- Provide hydraulic pressure to the motor which drives the drill bit at the bottom of the hole;
- Clean and cool the drill bit as it cuts into the rock;
- Lift rock cuttings to the surface and allow cuttings to drop out in the mud pit or shakers to prevent them recalculating;
- Regulate the chemical and physical characteristics of the mixture arriving back at the drilling rig;
- Carry cement and other materials to where they are needed in the well;
- Provide information to the drillers about what is happening downhole - by monitoring the behavior, flow rate, pressure and composition of the drilling fluid;
- Maintain well pressure and lubricate the borehole wall to control cave-ins and wash-outs;
- Prevent well blow-outs - including very heavy minerals such as barites to counteract the pressure in the hole (Wills, 2000).

Drilling muds are made of Bentonite and other clays, and/or polymers, mixed with water to the desired viscosity. Mud transport the other components in drilling fluids down the drill pipe and bring cuttings back up the well. By far the largest ingredient of drilling fluids, by weight, is Barite ($BaSO_4$), a very heavy mineral of density 4.3 to 4.6. It is also used as inert filler in some foods and is more familiar in its medical use as the "barium meal" taken before X-raying the intestines (Wills, 2000).

Today the major challenge in choosing drilling fluids is to meet the increasingly demanding conditions of high temperature and pressure found in deep wells and horizontal wells while avoiding harm to the environment. The components of drilling fluids should be selected so that any discharge of mud or cuttings has the minimum possible environmental impact. Environmental concerns are a major driving force behind current drilling fluids research and development.

Although fluids are essential for the successful drilling of geothermal wells, they can also be one of the messier aspects of a drilling operation. Cuttings that are brought up out of the borehole have to be disposed of, as does any drilling fluid that remains attached to them and while the environmental footprint at a well site is relatively small, being confined to the vicinity of the drilling operation, the environmental impact near the rig can be significant. The degree of impact drilling fluids have on the environment depends on the type of mud used and the prevailing environmental conditions. Water-based mud is generally the least damaging compared to oil-based. With many pollutants the impact on the environment is influenced by the way the pollutant is discharged and subsequently dispersed throughout the environment. Surrounding the immediate area of the drill rig there is a recovery zone where there are plants and animals that are able to tolerate some degree of pollution.

Drilling fluids in the past were pure Bentonite mud, whereas modern mud are more complex and designed for a wide range of drilling conditions. Many factors must be carefully weighed and balanced, not the least of which is environmental safety. The environmental impact of cuttings contaminated with oil-based mud has resulted in severe restrictions of their use in many parts of the world and has led to the development of more environmentally friendly, synthetic-based drilling fluids that not only perform well but are less toxic and, in most cases, more biodegradable. Biodegradation is a key factor in reducing the long-term environmental impact of drilling fluids. Another consideration in drilling fluid design is reducing toxicity to plants, animals and aquatic life. But it is equally important to reduce the amount of waste generated from drilling activities. This is achieved by recycling drilling fluids as much as possible and by designing them in such a way as to make this easier to achieve. For example, on shale shaker screens low-viscosity fluids separate more readily from the cuttings. This improves the recovery of drilling fluid and reduces the amount of pollutants to the environment.

3. MESHKINSHAHR GEOTHERMAL PROJECT

The Meshkinshahr geothermal prospect lies in the Moil valley on the western slopes of Mt. Sabalan, approximately 16 km SE of the town of Meshkinshahr, in the province of Ardabil in northwest Iran. Mt. Sabalan has been previously explored for geothermal resources in 1978, with geological, geochemical and geophysical surveys being undertaken [4]. Renewed interest in the area resulted in further geophysical, geochemical and geological surveys being carried out in 1998. These have identified a number of prospects associated with Mt. Sabalan. The Meshkinshahr prospect has been identified as the best of these prospects.

The exploration phases of project including geological, geochemical, geophysical and hydrological studies with cooperation of Renewable Energy Organization of Iran and

Sinkler Night Merz (SKM) Co. from New Zealand have been finished in 1999. The preliminary results of investigations shown that the geothermal resources have been located in an area about 160 hectares. The location of three deep exploration wells for first stage of exploration has been defined in certain area.

3.1 Location and access

The study area is located in northern part of Iran which has located in south of Meshkinshahr city with 120 km distance to Ardabil major city. The area chosen for study is 132 km^2 and is the watershed for the major river called Khyav River within the study area.

The area is located between 38° 11' 55" and 38° 22' 00" North and 47° 38' 30" and 47° 48' 20" East and including the villages of Moeil, Valezir and Dizo. Those villages are located in the vicinity of the main road connecting the Meshkinshahr city to the biggest village, in area, Moeil village.

The study area is located in Sabalan Mountain that is the second highest mountain in Iran. Sabalan Mt. is a Quaternary volcanic complex that rises to a height of 4811 m, some 3800 m above the Ahar Chai valley to the north. The town of Meshkinshahr lies at an elevation of 1400 m, while the study area ranges from an elevation of 2200 m at Moil in the north, to 3700 m in the south, close to the peak of Kuh-e-Kasra (Mt. Kasra). Within the western section of the area examined, a wide valley in which several rivers and streams are situated, runs north from Kuh-e-Kasra, between the two villages of Moil (to the east) and Dizo (to the west), to Meshkinshahr. The largest and most deeply incised river is the Khyav River, located on the western side of the valley. The eastern part of the area is dominated by the lower slopes of Mt. Sabalan.

An asphalt road provides access to the area from Meshkinshahr to the village of Moil, then to the valley south of the village by an unpaved road. Other unpaved roads that proved useful in accessing the area are the roads through Dizo, and the more distant northern roads through Ghotur Suii, Hoshan Medani and Toas. The location of study area is shown in figure 1.

3.2 Climate and Weather Conditions

The study area is located in the northwestern part of Iran in mountainous area with good precipitation, which is mostly snow in the winter time. Most rain comes in October, November, March and April and snowing months are December to March.

3.2.1 Temperature

The temperature fluctuation in the study area is really high from -35 in January to +30 in June and July. This temperature variety induces very large fluctuations in river water temperatures during summer and winter times and inverses the importance of cold and hot springs during wintertime in the area. Average temperature variation in the study area is shown in figure 2 that has measured from 2000 to 2003 in study area.

3.2.2 Humidity

The humidity of the study area is not so high because of high elevation and cold condition. The yearly mean humidity is 59.5% according to measured data by geothermal project meteorological station in 2000-2003. Figure 3 shows the average monthly humidity in study area from 2000 to 2003. It shows that the maximum humidity is in June with 85 % and minimum has appeared in August and September with 13 %.

Figure 1: location of Meshkinshahr geothermal field in Northwestern Iran.

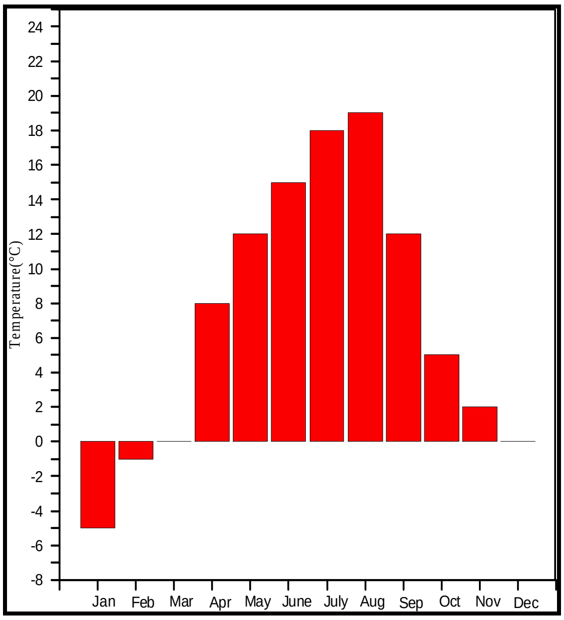

Figure 2: Average monthly temperature at Meshkinshahr geothermal area in 2002

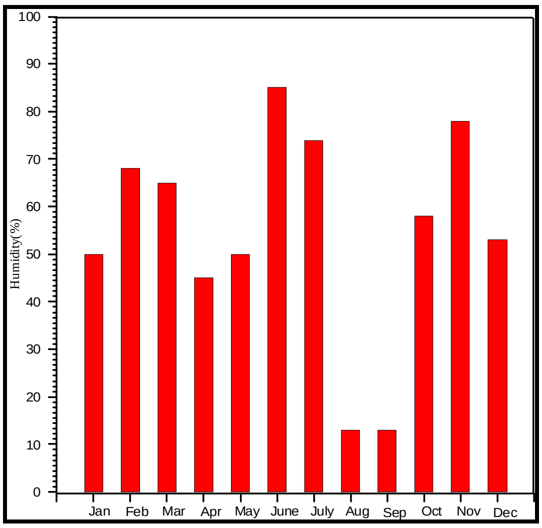

Figure 3: Average monthly humidity at Meshkinshahr geothermal area in 2002

3.2.3. Precipitation

Precipitations in this area fall as a rain during the fall and spring seasons and as snow in wintertime and mostly there is no precipitation during the summer months. The monthly averages for measured precipitation in geothermal project meteorological station from April 2000 to March 2003 are shown in figure 4.

According to recorded data yearly precipitation was 196 mm/year in 2000 and 300 mm/year in 2003, with maximum monthly average precipitation in December about 39 mm and a minimum of zero in June and July.

Variation of precipitation during the year affects the flow rate of Khyav River with higher flow rate in spring and lowest flow rate in summertime.

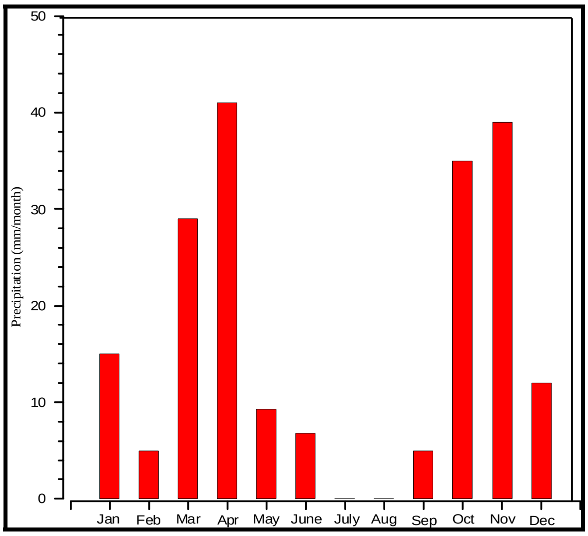

Figure 4: Average monthly precipitation at Meshkinshahr geothermal area in 2002

3.3 Exploration drilling

Drilling activities in Meshkinshahr geothermal field started in December 2002 for the drilling of 3 deep exploration wells and 3 injection wells. Exploration wells were designed to be drilled to 3200 m depth to reach into the expected geothermal reservoir and 3 injection wells at about 600 m depth for injecting of discharged geothermal fluid during well testing.

Drilling activities proceeded slowly due to cold weather (about -30ºC) in the winter time. The first geothermal exploration well reaching a depth of 3200 m and the first injection well 650 m depth were finally finished in June 2003.

The second well, at about 2 km distance from first well in northern part of field was finalized in late 2003. According to the condition of the well at final depth it was expected that there is no geothermal fluid in area so drilling of an injection well was terminated.

Drilling of the third well, located between two first wells started by directional drilling in January 2004 and gave satisfactory results. The well reached a depth of 2260 m and the subsequent injection well was drilled to about 600 m depth.

Results of preliminary measurements have shown that the bottom hole temperature is 240ºC at of 2260 m depth. It has thus prospects to be produced for electricity production..

Environmental investigations and monitoring are very important in project specially in during drilling of exploration wells, because the discharge of any drilling fluid and geothermal fluid into shallow ground waters and surface water specially Khyav river have great environmental and social effects in area, because the area is very susceptible and fragile for any changes. The Khyav river is close to well sites and any discharge of geothermal fluid and drilling fluids is expected to reach the river due to high slope of the region. Water quality in Khyav River is great important because the river is providing the drinking water of Meshkinshahr city with 65,000 population and also drinking water and irrigation waters for a further population of 200,000,people downstream. Any changes in chemistry of the water not only affects directly the residences of the area but also may also harm agricultural products distributed around Ardebil province and the whole country.

As well there are several hot and cold springs in area which are mainly used by local residences of three villages and nomad families as a drinking water, for swimming pools and bathing. Penetration of drilling mud and other chemicals used during drilling into shallow hot and cold aquifers affecting water flow from springs may have harmful effects on local residents. Therefore, the monitoring program for Khyav river and hot and cold spring as a part of main Environmental Impact Assessment of project was carried out by Iran Energy Efficiency Organization (SABA) during drilling and will be continued.

4. MONITORING PROGRAM

Ground water, in its natural state tends to be relatively free of contaminants in most areas. As described above pollution of surface- and groundwater can be a very serious problem as it is a widely used source of drinking water,. The aim of the monitoring program is to find out if any changes occur during the geothermal project development. The main water bodies in area are the Khyav river and several hot and cold springs and the monitoring of those are described.

4.1 Monitoring of Khyav River

Khyav river is a spring and snow based river which starts from the high elevation (3600 m a.s.l) parts of Sabalan Mt. This river flows about 50 Km after passing Meshkinshahr city and several villages before it finally joins the major Aras river on the border between Iran and Azerbaijan and discharges into Caspian Sea. The river’s water is not only used as a drinking water source for Meshkinshahr city but is also converted into several canals during the spring and summer seasons for irrigation use in agricultural and horticulture in the whole area.

The geothermal project drilling sites are located almost at the onset of the river and at higher elevation than the river base and also located between its two main branches. The area is harsh and mountainous and the average elevation difference between three well sites in Moeil plain and river base in Geynarjeh valley is about 300 m. Hydrological study shows that the groundwater flow in study area is from southeast to west and northwest where these waters are finally discharged into the river base through several cold and hot springs.

The baseline studies to define the chemical characteristics of river water and spring discharges before any development had started in the area were done during the years 2000 to 2002 for 22 locations at the river where the river branches are joining together and for 19 major hot and cold springs in different seasons (high and low flow rate). The results of measurements and analysis are shown in Tables 1(Iran Energy Efficiency Organization, 2002).

Monitoring program during drilling was designed and carried out to control any chemical changes in water quality of river in January 2002 after starting the drilling activities. The program includes daily measurements of some chemical and physical characteristic and sampling and analysis of some major cations, anions and heavy metals every 15 days. Daily monitoring has been done in two major stations;

- **Pump station**; it is located in upper part of river in a place that before to introduction any expected pollution from project activities to river.

- **Meshkinshahr drinking water station**; the drinking water station located in lower part of river in study area and it is expecting that if the pollution from drilling activities goes to the river either from surface runoffs or ground water discharges.

In the above mentioned sampling stations the water quality monitoring has been done in two different states;

- **Daily measurements**; including the field measurement of Temperature, pH, T.D.S, Conductivity, Magnesium, Calcium and Total Hardness in both stations

- **Every 15 days measurements**; including the collection of samples in each station and analysis the samples for determine the concentration of anions and cations like NO_3, SO_4, K, Mg, Ca, Fe, Cu and Si.

The results of daily monitoring for TDS in river show that the concentration of TDS in upper part of river during the study period are almost constant and there are no considerable changes, only a small changes are displayed and they are because of seasonal fluctuations of river flow rate. But the concentration of TDS in lower part of river has considerable changes in during study period. After finishing the drilling in well A the concentration of TDS decreased and by the start of well C it increased again with some fluctuation during drilling of well C and B because of temporary stop of drilling or conducting of drilling with low permeable formations. Finally after finishing the all drilling activities the concentration of TDS decreased. Figure 5 shows the variation of TDS concentration in two sampling points in Khyav River.

Moreover the concentration of Ca and Total Hardness were monitored during drilling activities and the concentration variations of both of them have direct correlation with TDS concentration. Figure 6 and 7 show the changes in concentration of Ca and hardness in two sampling points in Khyav River.

Analyses of the samples were carried out by spectrophotometer methods in the environmental laboratory of the geothermal project at field site for Ca, K, Mg, TDS, pH, Fe, Cu, SO_4, NO_3 and Si. The results of the analysis had a very good correlation with those of daily measurements. The results confirm the interpretation of the daily measurements that the pollution from the drilling activities are affecting the river water. The result of laboratory analysis for K, TDS, total Hardness and SiO_2 are shown in figure 8.

To find out the pathways for the contamination to the river, three possibilities were considered i) flow from faults and features which associated from drill sites to river, ii) pollution from discharges of cold shallow recourses, which were polluted by drilling fluids, and iii) polluted by discharges from deep hot geothermal reservoirs which discharges through hot springs in along river canal.

The rapid change of element concentration in the river after finishing of drilling strongly indicate that the pollutants are at least partially discharged into the river by faults and features because the concentration of pollutants in Khyav river rapidly changes by drilling activities. The monitoring of the hot and cold springs described in the next section shows that pollutants have also been partially filtered by those sources.

4.2 Monitoring of cold springs

There are about 60 cold springs in the Meshkinshahr geothermal field. Most of the springs are used by local residents for drinking water and irrigation of farmlands.

Because of the importance of cold springs for the local community and the fact that all discharges go into Khyav river, any changes in composition of springs water not only affect the local residents but also residents in areas downstream using the river water for drinking and irrigation purposes. Two very important cold springs (Moeil drinking water and Moeil Usage water) were monitored and daily measurement of TDS, pH, Conductivity, Temperature, carried out during 18 months. The results show that in Moeil Usage spring there are no significant changes during the study period. This is probably due to the fact that the source area of this spring is located in far away from the geothermal area prospected. It originates from easternly mountains far from drilling sites, the elevation of the spring is higher than the drill sites and several faults are located between the spring source and the drill sites. The results of the monitoring of the drinking water of Moeil were quite different. Drinking water of Moeil Village is coming by a pipeline from an area between well site B and C. The TDS concentration in this spring, likewise as for the river water described in previous section, shows great changes during the period of drilling activities. After finishing the drilling in well at site A the amount of TDS in Moeil drinking water decreased rapidly and by the start of drilling in well C and continued by well B it increased again until the completion of drillings. Figure 9 shows the variation of TDS in Moeil usage water and Moeil drinking water. TDS concentration of Drinking water spring is variable because this spring is feeds from shallow aquifers inside the geothermal field between well sites B and C and any infiltration of drilling fluids into aquifers apparently affect the water quality of this spring.

4.3 Monitoring of hot springs

There are 10 hot and moderately temperate springs around Moeil. Hot springs are important because they are used as a swimming pools and hot spa both for local residents and tourists. The temperature range of the hot springs in area is about 25–85°C. They issue mainly from the gravels of Dizu Formation and 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 1500 ppm Cl and 442 ppm SO_4 and have significant concentrations of Mg (up to 24 ppm). They have a simple dilution trend indicating mixing with varying amounts of shallow groundwater. They exhibit a strong seasonal cyclic variation in flow rate but show very little seasonal variation in temperature or chemistry, which is indicative of storage behavior. Despite the elevated Cl concentration, stable isotope data show the waters to lie on the local meteoric water line.

The Moil, Moil 2, and Aghsu 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 have therefore formed by condensation and oxidation of H_2S, implying boiling at greater depths. The Moil springs have been slightly neutralized and are therefore further from the source of H_2S than the Moil 2 springs. Geochemical studies on storage behavior of the springs is indicative of them being fed by very large perched groundwater aquifers to be heated and to obtain a high Mg neutral Cl-SO_4 composition requires that magmatic volatiles have condensed and been neutralized 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).

The monitoring program for hot spring entailed to daily measurements of TDS, pH, Temperature, and Cl in Moeil, Ilando, Gheynarjeh and Maleksu, four socially important hot springs. The results of 18 months daily measurements show that the TDS in all springs change during drilling. As both the river and the cold springs the concentration of TDS have decreases after drilling of well A was finished and increases again by the start of drilling well C. . There is a good correlation between TDS concentration in the river, the cold spring and the hot springs. Figure 10 is shows the concentration of TDS in the 4 monitored hot springs.

CONCLUSION

There is found to be a direct correlation between results of daily field measurements and laboratory analysis for concentration of some components in river monitoring. There is also a good correlation between measured data for Khyav river, hot springs and cold springs. Considerable changes in concentrations of elements occur and concurrent decreases and increases in concentration are observed in the sampling sites at the river, cold spring and hot springs. .

To reduce the harmful effects of project development on human and agricultural resources in the future drillings, the project developer is responsible to increase attention on:

- Meshkinshahr drinking water resources should be changed from river based to other resources or it should be taken from upper part of the river, where there is no effect by the project activities.

- Moeil Village drinking water is affected by project activities and it is needed to change the source and provide for other clean drinking water for Moeil residents.

- There is not any monitoring of the drinking water spring of Dizu Village, which is located in the geothermal field. The monitoring of that spring is necessary.

- The monitoring program for Khyav River, cold springs and hot springs should be continued with some more elements added with attention to contaminants in drilling fluids and geothermal fluids.

- A water quality monitoring program is required downstream of the river where the most part of water is canalized for irrigation purposes.

Depending on local environmental sensitivity and conditions like as biological considerations, water depth, circulation and human use of river water, additional controls on drilling fluid discharges might be considered. These include discharge prohibition or limits on discharge rates and volumes, and where appropriate, the use of a "closed-loop" solid control system minimizing discharge volumes of drilling fluids.

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Table 1: Chemical characteristics of Khyav River water and spring discharges before to starts any development activities in Meshkinshahr area.

Station NO	X	Y	pH	EC (mV)	TDS	Hardnes (ppm)	SO4 (ppm)	NH3 (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Cl (ppm)	SiO2 (ppm)	Cr (ppb)	Co (ppb)	Pb (ppb)	Ni (ppb)	Zn (ppb)	Mn (ppb)	Hg (ppb)
1	734073	4248716	7	4	37996	96	86	49	6.25	68.7	33	6	43	45	0	5	0	0	5	5	0
21	735194	4243322	8.6	26	169	84	96	33	6.25	8.4	35	4	47	44	0	5	0	0	5	6	0
22	735150	4243215	7.7	10	640	264	116	14	88	56.1	168	26	277	N.D	0	6	0	10	9	6	0
23	735201	4243244	7	22	160	84	90	29	4.22	72.6	40	9	41	N.D	0	0	0	0	17	63	0
31	736000	4242321	5.5	113	190	92	110	39	2.27	76.5	42	9	43	N.D	0	8	0	10	34	95	0
32	736100	4242268	15.7	4	121	52	38	7	4.14	84.3	30	5	31	N.D	0	0	0	0	11	28	0
33	736115	4242330	4.3	208	425	176	380	42	4.46	4.14	81	20	76	N.D	0	22	0	40	59	340	0
41	735312	4241050	4.6	51	490	128	54	9	8.36	64.8	125	18	157	N.D	0	0	0	0	11	54	0
42	735315	4240945	12.7	10	86	84	10	13	8.2	68.7	14	2	14	N.D	0	0	0	0	9	11	0
43	735388	4240970	8.6	29	80	80	18	1	8.2	72.6	12	2	10	N.D	0	0	0	0	5	8	0
50	737520	4242150	5.7	2	430	264	330	1	6.73	2.19	56	30	10	N.D	0	9	0	0	24	433	0
51	736660	4242280	2.3	255	390	N.D	416	61	N.D	N.D	28	14	8	N.D	0	22	0	40	60	397	0
52	736766	4242284	4.2	260	420	128	455	31	4.3	48.12	18	11	4	N.D	6	36	0	70	58	298	0
53	736721	4242357	4	180	321	192	335	45	8.52	4.14	33	19	8	N.D	0	19	0	40	97	449	0
60	737703	4241625	8.2	250	340	184	340	5	6.49	4.14	28	18	5	N.D	0	12	0	30	500	316	0
71	737228	4241600	5.2	270	515	N.D	461	44	N.D	N.D	18	11	4	N.D	7	23	0	50	42	180	0
72	737295	4241360	6.2	255	452	N.D	430	61	N.D	N.D	18	10	4	N.D	9	30	0	70	59	180	0
73	737360	4241500	4.2	266	662	88	482	32	6.25	76.5	18	11	4	N.D	12	28	0	90	58	162	0
81	738192	4239412	6	65	40	36	17	5	6.9	88.2	6	1	7	N.D	0	0	0	0	11	5	0
82	738290	4239281	7	24	38	36	15	5	6.9	88.2	5	1	6	N.D	0	0	0	0	4	3	0
83	738327	4239350	6	70	53	44	21	13	2.11	84.3	10	2	10	N.D	0	0	10	0	40	23	0
90	740122	4237165	5.6	41	27	44	9	1	6.9	8.4	3	1	4	N.D	0	0	0	0	7	2	0

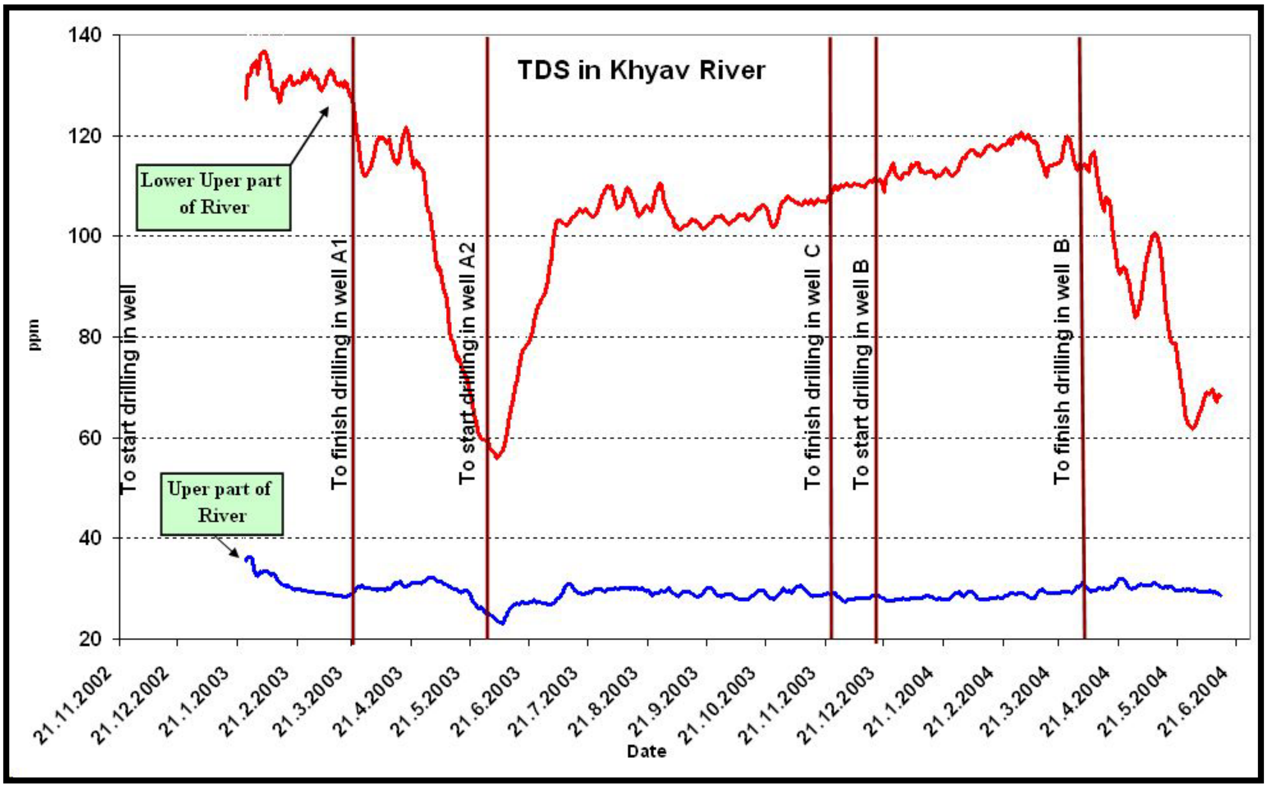

Figure 5: Variation of TDS concentration in two sampling points in Khyav River

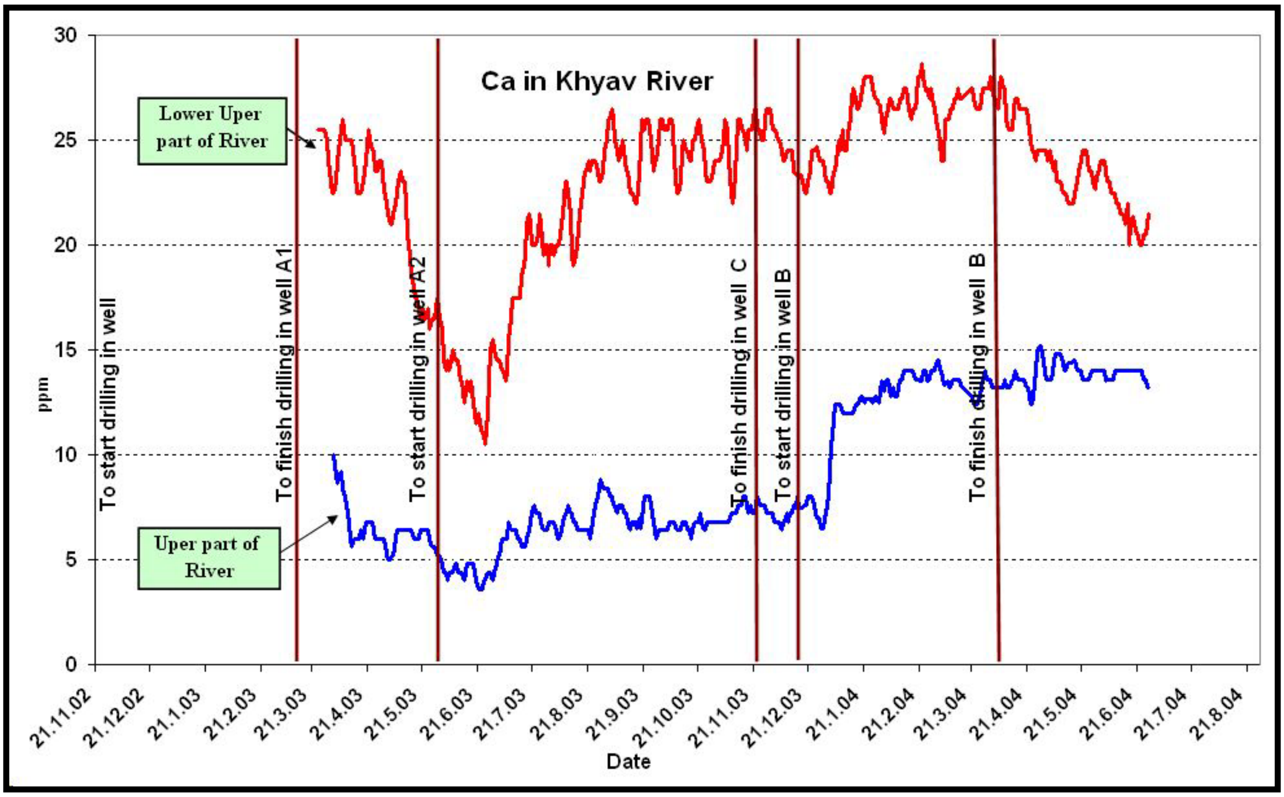

Figure 6: Variation of Ca concentration in Khyav River.

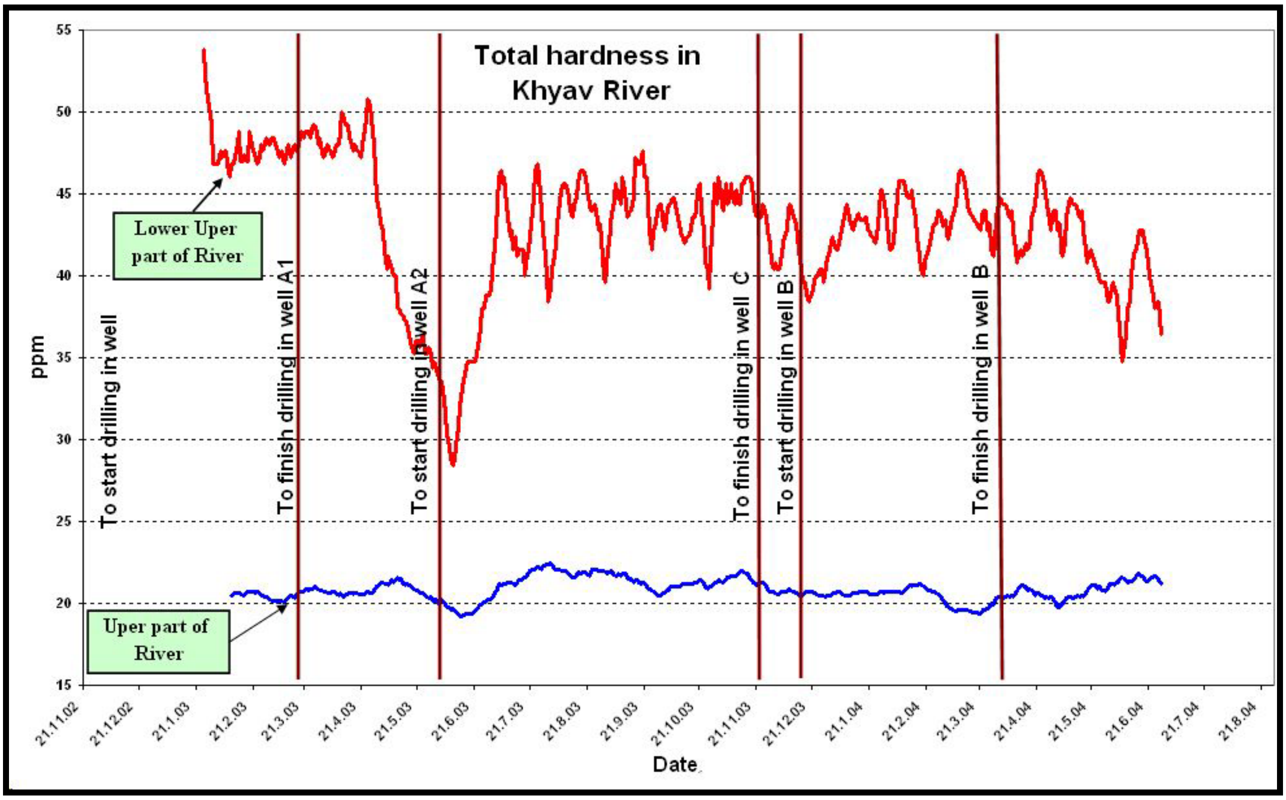

Figure 7: Concentration of Hardness in Khyav River water at upper and lower parts

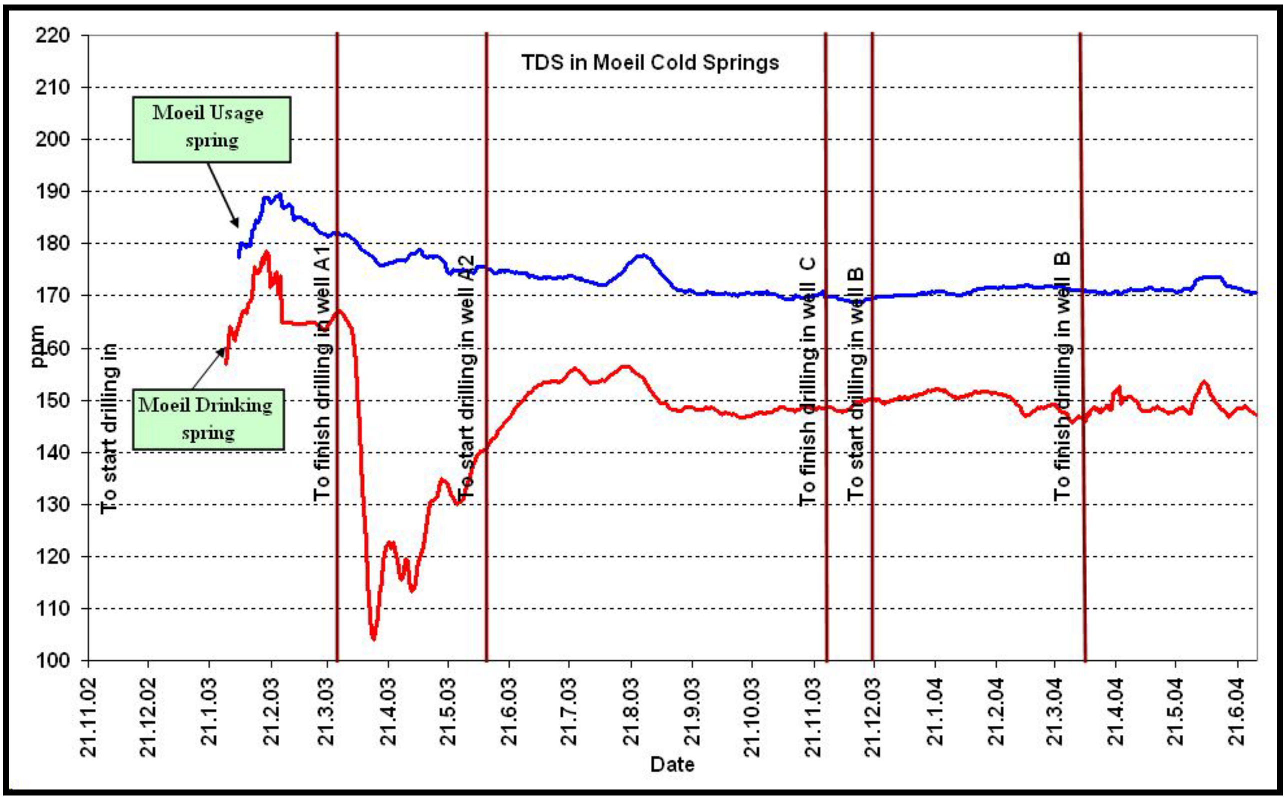

Figure 9: Variation of TDS in Moeil Usage spring water and Moeil drinking spring water.

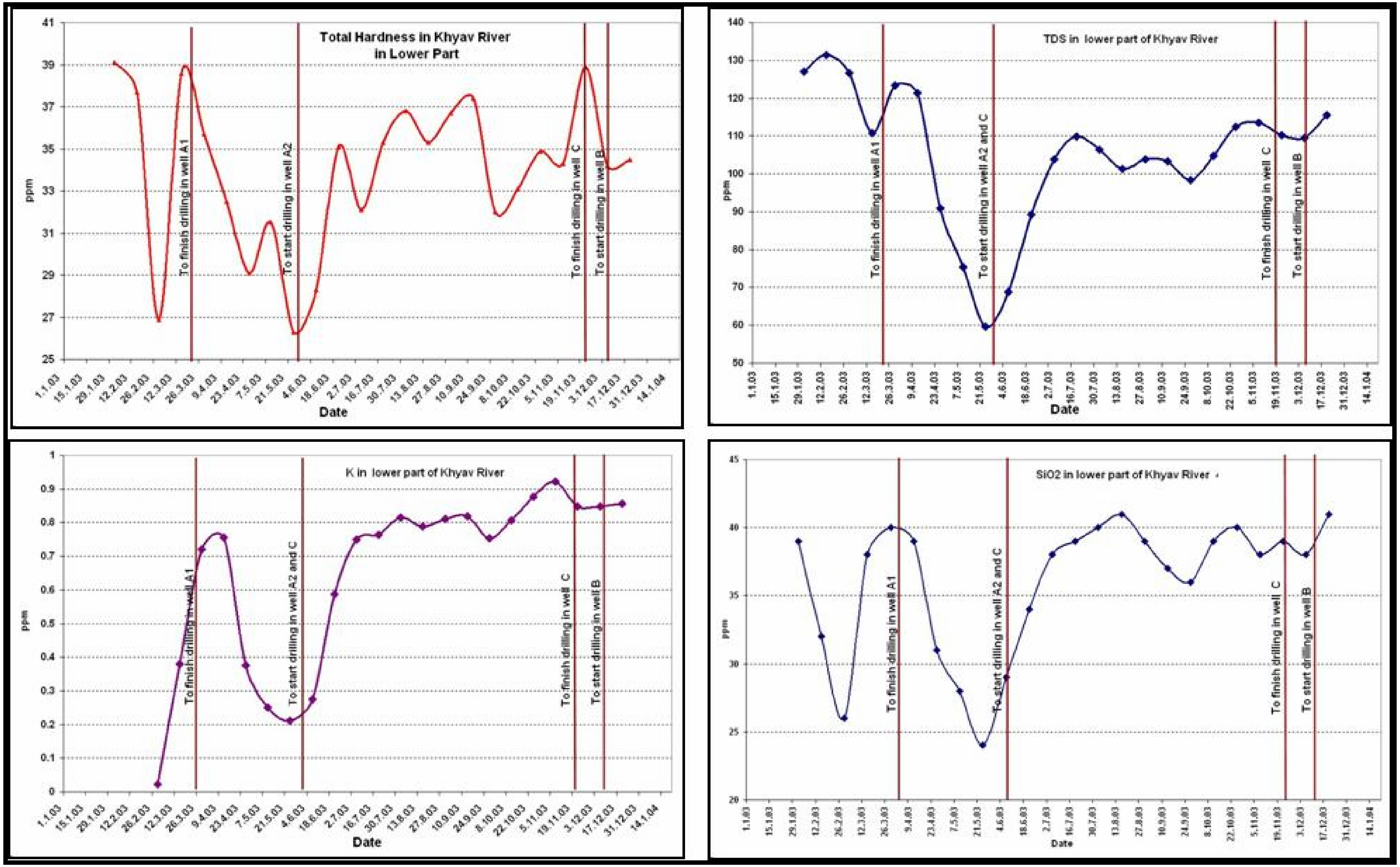

Figure 8: The result of laboratory analysis for total Hardness, TDS, K and SiO_2 in lower part of Khyav river (Drinking water station of Meshkinshahr City)

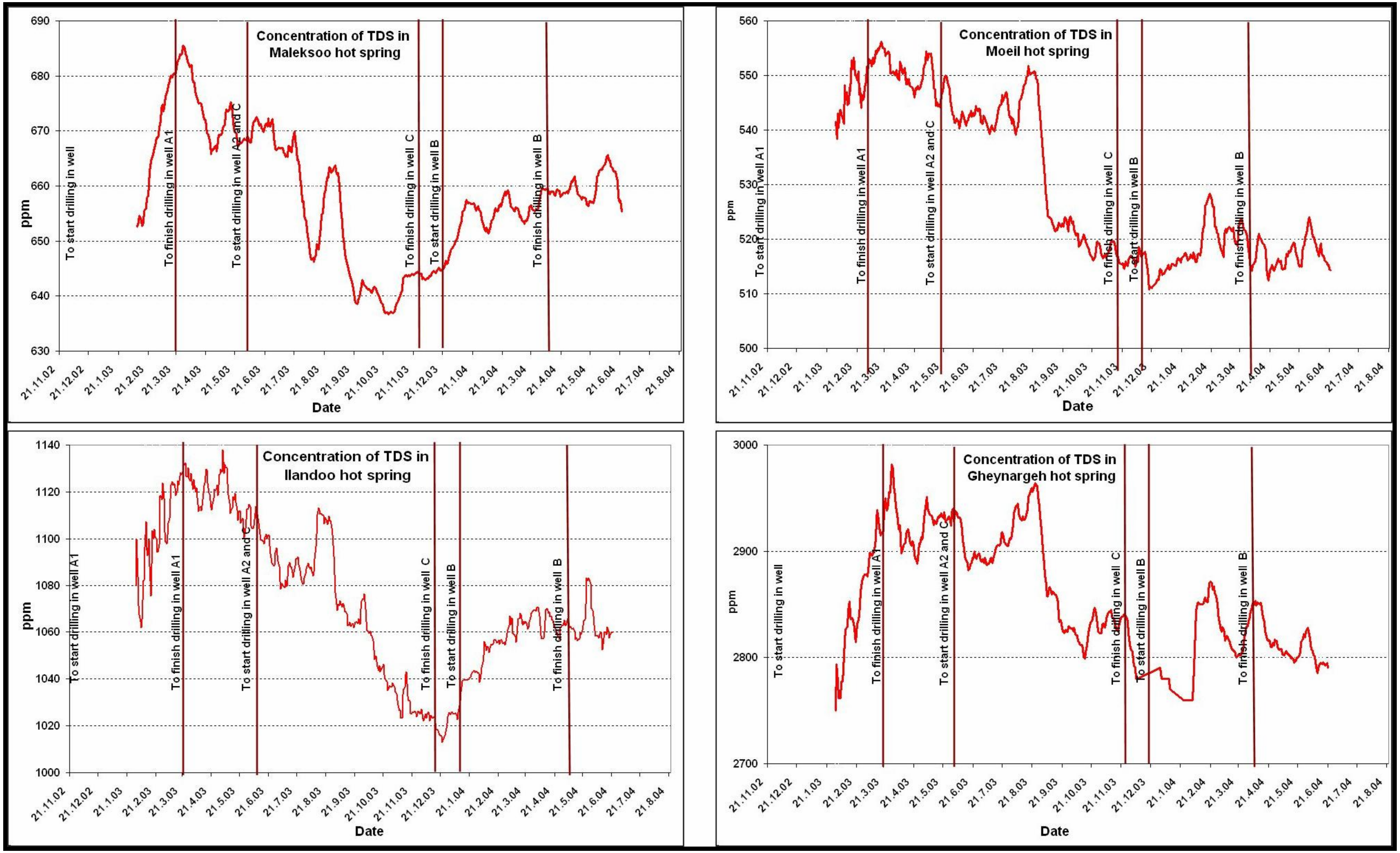

Figure 10: Concentration of TDS in Malek su, Moeil, Ilando and Gheynargeh hot spring