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Environmental Monitoring of Air, Soil and Surface Water Resources; A Case Study on Meshkinshahr Geothermal Field Development

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ABSTRACT

Meshkinshahr Geothermal field is located in the north western part of Iran, in Meshkinshahr City in the northern flank of the Sabalan Mountains in Ardebil Province. This geothermal field is the first geothermal site developed in the Islamic Republic of Iran, and was selected for construction of the first geothermal power plant. The region is considered an ecologically sensitive area with a large number of springs and touristic resorts.

The developing plan consisting of 20 exploratory and production wells with approximately 2000 m depth started in year 2008. Accordingly, environmental monitoring and study of possible changes in the environment are in progress simultaneously with the civil works and drilling activities.

During drilling and discharge tests of geothermal wells, a large amount of geothermal brine and drilling mud discharged into the river, and shallow and deep aquifers. It will also affect reservoirs which are feeding hot and cold springs and finally drain into the river. Environmental monitoring studies will be continued for 6 years, consisting of monitoring and analyzing of air, soil and surface water resources. Field sampling of Khiyav-Chay River and hot springs is ongoing every 2 weeks, and air and soil will be sampled every 6 months. An appropriate model will be used to predict the probable impacts of different phases of the project and at last but not least an integrated management plan will be developed to reduce and control probable impacts.

The results of the study up to now show that during the 21 months of monitoring, drilling activities did not significantly change the water quality of the river and springs. And the concentrations of all physical, chemical and biological elements are less than drinking water standard levels. The only exception is the concentration of some heavy metals which were higher than drinking water standards. These were not high in pre-drilling baseline measurements studies but for conclusive interpretation more data points need to be observed.

INTRODUCTION

In the past three decades there was a noticeable improvement in the installation of geothermal plants in the world as a clean source of power generation. Power supply is independent of season time and continuously guaranteed during the project life time. So, in Iran after preliminary and feasibility studies, the construction of the first geothermal power plant was started. The development strategy was based on application of renewable energy and distributed generation, encouraging the establishment of a geothermal steam field development at Sabalan area.

The Sabalan protected area with its specific natural and geographical location is situated in Ardebil in the Northwest of Iran on the flank of 4800-meter heigh Sabalan Mountain. Also there is very high potential for ecotourism near the study area, which is located south of Meshkin Shahr city and on the banks of Khiavchy river. The hiking resorts, hot springs, small and big lakes, vast plains and fields and favorable condition of weather all are the natural characteristics of the study area. This area is reported to have nearly 830 species of plants, a considerable number of which are native to Sabalan Mountain . So regarding the sensitivity of the area, to prevent the irreparable damage to the nature of the area, exact and constant protection of the condition of the environment is necessary during the construction and operation period.

Therefore, studies related to protection and improvement of the environment of the Meshkin Shahr geothermal plant were applied, with the purpose of ensuring permanent protection of the area. The studies included investigation of the scope of the effects resulting from the construction and utilization of geothermal plant. Present techniques of reduction of the effects and management of the environmental program were defined. The studies began in March 2007.

This study has four scopes of environmental protection, investigation of the ecological condition of the area, erosion studies and control and social, economical and sanitary investigations, and at the end of the plan in addition to presenting techniques of reduction and mitigation of environmental impacts, presents an environmental protection plan.

In the water resources quality and quantity, air and soil monitoring plan with regard to potential presence and cycle of geothermal pollutants and different phases of execution and utilization of the project, necessary planning regarding regular sampling of the river water, cold and hot springs of the area and surface soil of the studying area and their analysis, in addition to qualitative protection of weather condition of the area and registration of parameters regarding weather forecasting were done, and during the registration of the current condition of the environment, any change in the qualitative and quantitative parameters of the environment were measured.

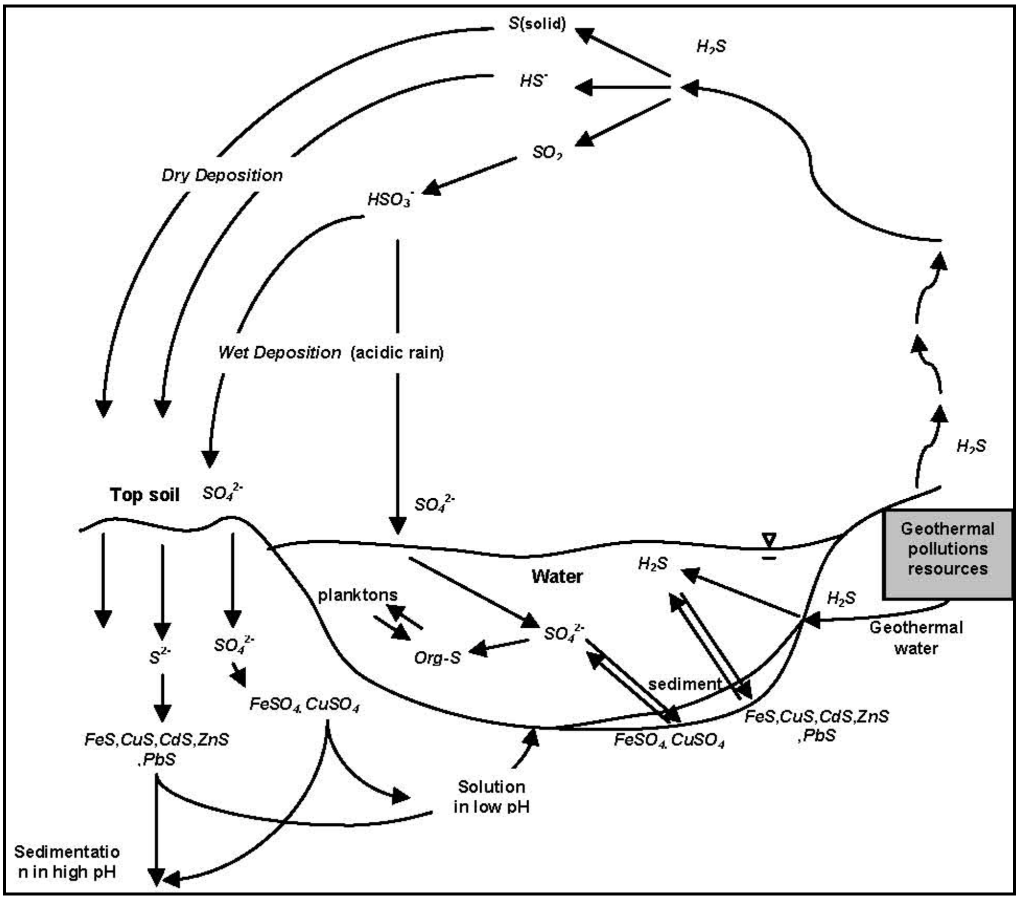

Figure 1: Cycle of transmission and different forms of Hydrogen Sulfate (H_2S) in the pollutants-receptive environments

Figure 1 shows a diagram of one of the common pollutants in geothermal projects in three environments of water, soil and air regarding to its cycle in the environment.

The source of pollution in the surface water in geothermal projects, in addition to discharge of spring water and waste water which could happen primarily during drilling action, probable outflow of drilling mud on the surface or flow of geothermal fluid are usually the source of pollution in sub-surface water. The penetration of pollution of drilling mud and geothermal brine to the sub-surface aquifers during drilling and exploration in case of same reservoir for springs, consequently will pollutes springs too. So with regards to the importance and extensiveness of the subject, in this article in addition to examining the river and springs sampling results, meanwhile of project execution, results were compared and the process of the changes and methods of controlling the results were examined, especially about the springs that are connected to the geothermal reservoir.

METHODOLOGY OF MONITORING OF RIVERS AND SPRINGS

After investigation along the river and identifying the probable sources of pollution and considering the qualitative and quantitative effect of the branches of the river, in order to specify the location of sampling from the river, the location of the entrance of the pollutants to the river was studied and finally four points were chosen for water sampling and monitoring of river water quality as shown in Table 1.

Sampling locations of the springs is considered also as the sign of qualitative changes of sub-surface deep and shallow waters in the study area. As the resources of the springs can not easily be indefinite, determination of the springs which are affected by geothermal projects and should be included in the periodic sampling program is not possible before the completion of the studies.

Table No. 1: Sampling Location of the River

Station Name	Characteristics of the Station
R1	Upstream condition, upper than the Site E
R2	Pumping Station of the Site
R4	Meshkin Shahr drinking water intake
R5	Lowest point of Khiyav-Chay after the junction of the branches

In order to better choosing the springs, first with regard to physical characteristics of the springs such as flow, temperature, pH and the utilization of the springs, 79 springs of the area were examined especially by their temperature and discharge and 9 springs among them (Table 2) were chosen for sampling. Also for more examination of the association between springs and geothermal reservoir and identification of the springs affected by geothermal activities, by using the primary results from the analysis of the spring waters, preliminary examination was done on these studies by the method which will be explained in the next part.

Of course by the advancement of the studies and supplementary studies on the examination of the association of the springs and the geothermal reservoir, this list can be re-examined by progress in monitoring plan. In Figure 2 the location of sampling from the rivers and springs of the area were specified.

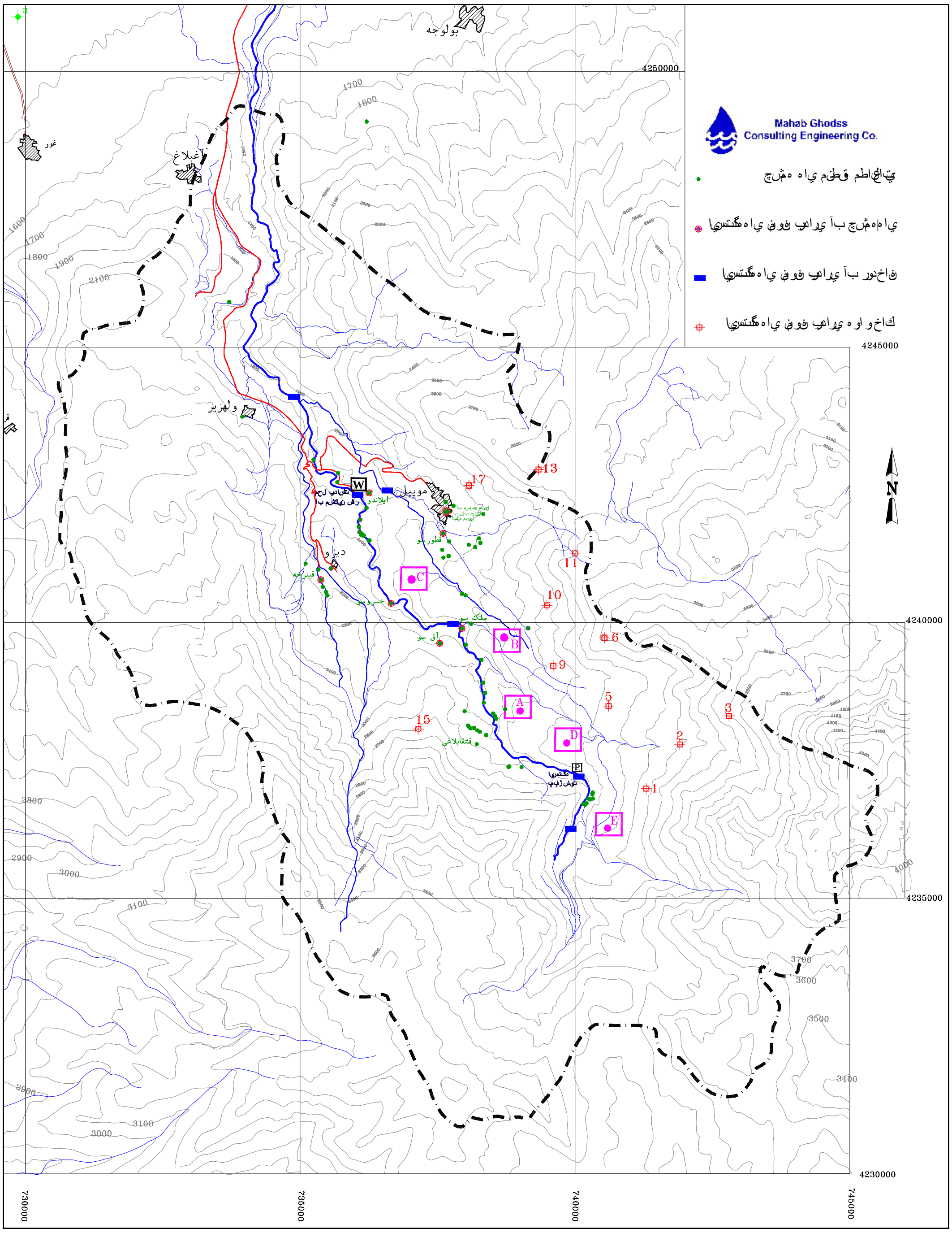

Figure 2: location of sampling stations from rivers, springs, soil and air

Table 2: Location of sampling from springs

Station	Names of the Stations	Temp.* (◦C)	flow* (Lit/S)
M1	Aghsoo Spring	32	0.28
M2	Maleksoo Spring	45	2
M3	Khosrosoo Hot Spring	64	0.2
M4	Gheinarjeh Hot Spring	85	8
M5	Moeil Hot Spring 2	30	14
M6	Moeil Hot Spring	45	1.8
M7	Moeil water consumption	13	0.3
M8	Moeil Drinking water	9	0.2
M9	Ilandoo Spring	34	4.5

In the samples of the rivers and springs in addition to measurement of the Debi theses parameters were analyzed; Physical and chemical parameters such as temperature, pH, EC, TDS were measured in the sampling stations by flied equipments. Also parameters such as Chloride, sulfate, Nitrate, Nitrite, Phosphate, Ammonium, Aluminum, boron, Br and silicate were measured by DR4000 with spectrophotometer method. Concentration of calcium, magnesium, bicarbonate and general solidity measured by titration and lithium, sodium, potassium and barium with phelimphotometer JENWAY model PFP7 and standard methods.

In these studies, concentration of heavy metals such as Fe, Mg, Cu, Zn, Cd, Ni, Co, Arsenic, mercury, chrome$^{(VI)}$ and sulfide combination were measured by polarograph voltmeter Model VA797 using polarography method.

Regarding the succession of the sampling of water, after preliminary technical examination, sampling was done twice a month in the drilling period and every month when there is no drilling.

IDENTIFICATION OF THE SPRINGS AFFECTED BY THE GEOTHERMAL RESERVOIR

In general in geothermal reservoir the temperature is high and water and solute and insoluble parameters comes out of the springs connected to it with pressure. In this regard, recognition of the effective and important parameters in the geothermal studies and also identification of the springs affected by reservoir and prediction of the temperature of the geothermal reservoir is important. Chemical components in the spring fluids are divided into two categories:

Tracer Elements: Inert parameters once added to the fluid remain unchanged and in the course of the flow of the fluid their concentration and chemical composition do not change. And they can be used for identification of the geothermal flow. Chlorine and Br are the examples of these parameters.

Indicator: parameters which are chemically reactive and reflect in environments of equilibrium and based on the condition of the environment are reactive. Sodium and potassium are among the parameters which are used as indicators for the geothermometry. Where fluids reach the surface by way of hot springs or fumaroles, their chemical composition percentage may often be used to deduce sub-surface temperature.

For the indicators used for geothermometry the following assumptions work:

1. fluid-mineral equilibrium at depth
2. a temperature dependent equilibrium reaction at the depth
3. an adequate supply of solid phases to permit the fluid to become saturated with respect to the constituents used for geothermometry
4. negligible re-equilibration as the water flows to the surface
5. no dilution or mixing of hot and cold waters

Chloride water is one of the main fluids that come out of many thermal reservoirs the steam which comes out is used to produce energy. The main anion in this fluid is chlorine which in geothermal waters constitute of 0.1 to 1 percent of the fluid water. Main cations in this fluid are Na^+, K^+, Ca^{2+}, Mg^{2+}. In addition, this fluid has high concentration of SiO_2, and noticeable amount of $SO4^{-2}$ and HCO^{-3}. Other common constituents of the water are B, Li, Rb, Cs, F, NH_3. Because of some restrictions of the environment As and Hg were also identified. CO_2 and H_2S are the common gases which are associated to Chloride waters and the proportion of the CO_2/ H_2S is about 100 to 10. Al and Fe are considered as geo-indicators in the chloride waters. Chloride water pH is neutral. Of course it may be in acid or base area and it depends on the amount of the CO_2 in the solution. So one of the characteristics of the chloride water is neutral pH. Sub-surface waters in which concentration of the SO_4^{-2} and HCO^{-3} is more than chloride are called sulphate and bicarbonate waters and the probability of their association with geothermal reservoir is very low.

METHODOLOGY OF IDENTIFICATION OF THE SPRINGS AFFECTED BY GEOTHERMAL RESERVOIR

One of the ways to recognize the springs affected by geothermal reservoir is to identify the springs with chloride water and neutral pH. Also among the evident characteristics of these springs which discharge chloride water is the large amount of SiO_2 in the entrance of the spring and this phenomena is because of saturation of the geothermal fluid with the non-crystalline SiO_2 and this SiO_2 at time of coming out gets deposited because of changing situation and gathers at the point of exit. It must be said that in the geothermal springs containing chloride water, fluids comes out of the reservoir with high speed and this matter is very useful in the geothermal studies considering the location of the geothermal reservoirs. Making three-dimensional and triangular diagrams are calculating and technical methods of identifying springs affected by geothermal reservoirs and they are quick and efficient methods for evaluation of the hot springs and wells. To draw these diagrams having the concentration of chlorine, Br, lithium, sodium, potassium, magnesium, carbonate and sulfate is necessary.

In the following phases of the studies, by analysis of the triangular diagrams of chlorine, sulfate, bicarbonate, and by examination of the proportion of the concentration of that parameters, chloride wells were identified and then by using triangular diagrams of chlorine, Lithium and Br while checking the correctness of the results from the previous diagrams by controlling the proportion of Br to Cl, we became sure of the geothermal source of chloride in the springs and the springs which were affected by geotectonic were identified. In the next phase of the study by using triangular diagrams of Na, k and Mg the way different springs associate with geothermal reservoir was evaluated by examining the location of the springs to the complete equilibrium in the diagram and the approximate temperature of the reservoir was estimated. And finally by using concentration of the geo-indicators the temperature of the geothermal reservoir was calculated based on the coefficient of the ion-equilibrium reactions which are present in water.

RESULTS AND DISCUSSIONS

In the beginning of the sampling in the spring of 2007and before start of drilling, 4 phases of sampling from 4 station along the river and 9 springs was done. Also since March 2009 at which the first seasonal report was prepared, 9 phases of sampling and analysis were done. In table No. 3 the average result of the analysis of the samples consists of three phases:

1. Before starting the drilling (March 2007- August 2008)

2. The first season after starting the drilling (autumn 2008),

3. Second season after starting the drilling (winter 2009) was proposed.

By using the results of the first phase of sampling and by the method mentioned above, triangular diagram by three indicators of Na-K-Mg was drawn to determine the equilibrium temperature of the springs. In this diagram three areas of full Equilibrium (points on a curve), partial equilibrium (intermediate area and checked diagram) and immature and without equilibrium (in which spring water in its course get mixed with the surface water and shows lower temperature than the real temperature of the reservoir) were drawn. Springs fluid compositions were examined and modified on the diagram.

In describing these diagrams we mention that all the diagrams were prepared based on calculation formulas mentioned in references and with the development of the studies and gathering more data they will be examined more. In the Figure 3 triangular diagrams of Na, K, Mg were introduced for preliminary examination of association of springs and geothermal reservoir.

Based on the evaluations Maleksoo M2, Gheinarjeh M3, Gheinarjeh M4 and Ilandoo M9 probably connected to geothermal reservoir and being affected by some extend. If the assumption was correct the temperature of the geothermal reservoir estimated about 240 degree centigrade based on the K-Na geothermometry experimental equations.

Based on preliminary studies the continuation of the sampling from Maleksoo, Khosrosoo, Gheinarjeh and Ilandoo springs is necessary for conclusive interpretation of geothermal reservoir concentration to surface manifestation. Aghsoo, Moeil 2 and moil hot spring were less probable to associate with the geothermal reservoir but more studies are necessary to be done. Sampling and analysis will be done on the rest of the springs considering their use; most of them were commonly used for drinking.

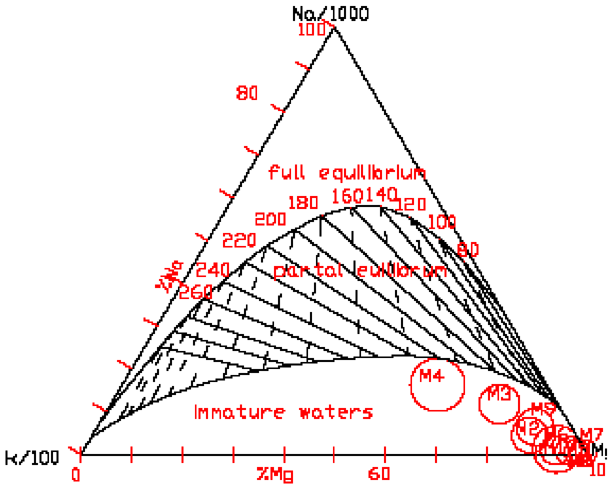

Figure 3 triangular diagrams of Na, K, Mg

SUMMARY AND CONCLUSION

Geothermal energy is one of the reliable and clean methods of electrical power generation. There are many prospective areas in Iran which have potential for geothermal energy development. One of these areas is located at north-western part of Iran and south part of Sabalan Mountains. the summary of monitoring plan in a geothermal filed is; site is located at a high sensitive environment with surface manifestation of hot springs and high density of tourism attraction.

Because the Meshkin shahr geothermal power plant is at construction stage, and drilling of wells is not finalized yet, monitoring of surface water quality, discharge of important springs, soil and air pollution shows no considerable impact on the environment. But, because of probable wide spread contamination to the environment during drilling and afterward, monitoring of the environment especially water resources during construction and operation stage of the geothermal plant is very important. At this moment, by starting the drilling of the injection wells monitoring of the water resources specially spring is done biweekly.

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Table 3: Results of environmental monitoring in hot springs and river

	Sampling points	pH	Temperature ºC	Chloride mg/Lit	Br mg/Lit	Bicarbonate mg/Lit	SiO2 mg/Lit	Sulfate mg/Lit	Li mg/Lit	Na mg/Lit	k mg/Lit	Mg mg/Lit	Ca mg/Lit	Fe mg/Lit
1st phase[1]	R2	7.25	8.13	0.95	0.02	35.58	22.83	2.12	0.11	1.98	4.83	1.75	6.79	16.26
	R5	7.29	14.17	31.78	0.04	37.33	50.45	76.55	0.29	33.03	7.25	5.02	20.46	19.34
	Gheinarjeh	6.61	82.63	1336.97	2.09	261.23	94.25	309.46	5.99	876.07	116.83	11.38	92.57	14.75
	Maleksoo	5.98	43.70	264.02	0.38	174.20	176.25	89.90	0.48	205.32	43.15	16.34	33.88	16.84
	Ilandoo	5.92	34.80	390.82	0.56	176.65	134.75	283.03	1.45	327.60	37.09	19.82	76.40	14.51
	Khosrosoo	6.68	62.68	836.10	0.94	127.23	82.80	249.56	2.97	508.35	49.95	11.08	59.09	16.75
1st season of 2nd phase[2]	R2	8.14	7.17	1.55	N.D.	14.33	13.68	3.42	N.D.	3.87	1.70	4.80	15.33	
	R5	7.21	12.10	14.30	N.D.	31.23	28.18	36.01	0.13	27.41	10.97	5.20	27.33	8.91
	Gheinarjeh	6.88	81.67	1620.00	N.D.	85.33	75.47	158.17	4.37	833.67	149.71	12.40	124.67	4.29
	Maleksoo	6.24	46.50	121.50	N.D.	60.07	82.43	125.67	0.19	216.23	41.05	10.60	53.67	5.68
	Ilandoo	6.13	37.30	740.00	N.D.	64.17	56.57	158.50	1.25	186.67	42.56	16.73	99.33	5.59
	Khosrosoo	8.32	24.73	15.15	N.D.	44.27	41.97	28.50	0.03	24.17	5.29	7.80	25.67	5.73
2nd season of 2nd phase[3]	R2	7.51	5.00	-	N.D.	86.99	28.05	N.D.	0.11	1.73	1.15	4.76	10.67	7.08
	R5	7.31	8.50	-	N.D.	86.93	40.75	53.50	0.35	31.20	5.77	11.55	24.25	9.41
	Gheinarjeh	6.92	78.33	-	N.D.	277.05	109.27	170.25	2.69	587.68	102.93	17.86	121.17	6.89
	Maleksoo	6.94	43.25	-	N.D.	205.88	191.30	85.00	0.82	97.98	21.72	14.58	41.00	5.88
	Ilandoo	6.33	36.50	-	N.D.	209.43	115.42	211.25	0.66	309.06	28.52	12.50	101.50	5.95
	Khosrosoo	8.19	27.00	-	N.D.	142.30	79.10	N.D.	0.02	19.03	3.44	6.03	37.25	

1. Before starting the drilling (March 2007- August 2008)

2. The first season after starting the drilling (Autumn 2008),

3. Second season after starting the drilling (winter 2009)