HYDROGEOLOGY

УДК 550.367

DOI: 10.46698/VNC.2023.40.99.010

Original paper

Assessment of thermal water resources of Precaspian-Guba district and methodology of its use

A.V. Islamzade, P.Y. Mammadov

Institute of Geology and Geophysics, Ministry of Science and Education of the Republic of Azerbaijan, 29a Guseyn Javid Str., Baku AZ1143, Azerbaijan, e-mail: aygulislamzade.vidadi60@gmail.com

Reseived: 17.01.2023, revised: 16.02.2023, accepted: 22.02.2023

Abstract: The relevance In the article, the results of thermal and mineral water search and exploration conducted in Yalama, Nabran, Khudat, Khachmaz areas of the Caspian-Guba thermal water field were reviewed. **The aim** of the work is to determine the fresh and low-mineralized underground water sources of the region and their effective use, evaluation and forecasting of exploitation resources is a priority issue. **Methods.** The principle of development of deep geothermal systems and its application to the studied area were considered. So that, the produced thermal water can be used for heating local and regional heating networks and also in resort hotels, industrial complexes and residential buildings. Conversion of heat into electrical energy is possible with additional technologies such as Organic Rankine Cycle (Rankine Cycle) units or Kalina units at temperatures above approximately 80°C. Therefore, economically efficient production requires a temperature of 120°C or higher. Organic Rankine Cycle (ORC) plants operate with lower boiling temperature due to the use of an organic heat transfer liquid. Thevapor phase of this liquid passes through a turbine and drives the electric generator. Kalina plants use an ammonia-water mixture as the heat carrier. **Results.** Based on the results of numerous measurements, a graphical representation of the research area was created in the Grapher program and a temperature and discharge distribution map was created in the Surfer program. The geothermal energy potential brought by the wells dug in the Nabran, Khudat, Khachmaz zone was calculated and the prospect of using this energy was determined. In the Nabran, Khudat and Khachmaz areas, and in the upper productive aquifer complex, the calculated operational reserves of important therapeutic mineral waters and thermal waters as a type of thermal energy are more than 30,000 m^3/day in categories A, B, and C_I.

Keywords: thermal waters, hydrogeological features, geothermal energy, deep geothermal systems, dual well system.

For citation: Islamzade A.V., Mammadov P.Y. Assessment of thermal water resources of Precaspian-Guba district and methodology of its use. *Geologiya I Geofizika Yuga Rossii = Geology and Geophysics of Russian South*. 2023. 13(1): 136-149. DOI: 10.46698/VNC.2023.40.99.010.

DOI: 10.46698/VNC.2023.40.99.010

Оригинальная статья

Оценка ресурсов термальных вод Прикаспийско-Кубинского региона и методика их использования

А.В. Исламзаде, П.Я. Мамедов

Институт геологии и геофизики, Министерство науки и образования Азербайджанской Республики, Республика Азербайджан, AZ1143, г. Баку, ул. Г. Джавида, 20а,
e-mail: aygulislamzade.vidadi60@gmail.com

Статья поступила: 17.01.2023, доработана: 16.02.2023, принята к публикации: 22.02.2023

Резюме: Актуальность работы. В статье рассмотрены результаты поисков и разведки термальных и минеральных вод, проведенных на Яламинской, Набранской, Худатской, Хачмазской площадях Каспийско-Кубинского бассейна термальных вод. **Цель работы**. Определение источников пресных и слабоминерализованных подземных вод региона, а также их эффективное использование; оценка и прогнозирование эксплуатационных ресурсов являются приоритетными задачами. **Методы исследования.** Рассмотрен принцип разработки глубинных геотермальных систем и его применение к исследуемому региону. Таким образом, добытая термальная вода может быть использована для обогрева местных и районных тепловых сетей, а также в курортных отелях, промышленных комплексах и жилых домах. Преобразование тепла в электрическую энергию возможно с помощью дополнительных технологий, таких как установки с органическим циклом Ренкина (цикл Ренкина) или установки Kalina при температурах выше примерно 80°С. Конечно, для экономически продуктивного производства требуется температура 120°С и выше. Установки с органическим циклом Ренкина работают при более низкой температуре кипения, благодаря органическим теплоносителям. Паровая фаза жидкости в теплоносителе проходит через турбину и приводит в действие электрогенератор. Установка Kalina применяет аммиачно-водную смесь в качестве теплоносителя. **Результаты работы.** По результатам многочисленных измерений в программе Grapher создано графическое представление района исследований и в программе Surfer создана карта распределения температуры и расхода. Рассчитан геотермальный энергетический потенциал скважин, пройденных в Набранской, Худатской, Хачмазской зонах, и определена перспектива использования этой энергии. На Набранском, Худатском и Хачмазском участках и в верхнем продуктивном водоносном комплексе расчетные эксплуатационные запасы важных лечебных минеральных вод и термальных вод как вида тепловой энергии составляют более 30 000 м^3/сут по категориям А, В и C_I.

Ключевые слова: термальные воды, гидрогеологические особенности, геотермальная энергия, глубинные геотермальные системы, двухскважинная система.

Для цитирования: Исламзаде А.В., Маммадов П.Я. Оценка ресурсов термальных вод Прикаспийско-Кубинского региона и методика их использования. *Геология и геофизика Юга России.* 2023. 13(1): 136-149. DOI: 10.46698/VNC.2023.40.99.010.

Introduction

Groundwater is one of the most common and exploited minerals. Identifying and efficient use of sweet and low-mineral groundwater sources in each region requires evaluation and forecasting of their reserves. Hydrodynamic, hydraulic, balance, hydrogeological analog, and expert evaluation methods are used in groundwater reserves forecasting.

High-temperature underground water is called thermal water. Thermal water is classified into absolute types based on temperature, which is higher than the average annual air temperature in the relevant area – relative (cold waters with a temperature less than 20°C can also form this type of water) and absolute, temperature 20-37°C (higher than the average maximum air temperature on the Earth and higher than the normal temperature of the human body). The temperature regime of subsurface waters is dependent on both the endogenous heat of the Earth surface and the exogenous heat related to the climate of the relevant area [Aliyev et al., 1972; Mekhtiyev, 1996]. In modern volcanic regions, these waters emerge as boiling or hot springs in the form of geysers on the Earth surface. Such waters have low mineralization degree but high alkalinity. Na predominates in the ion composition. Some types of thermal waters are called as "acrotherm" (acratotherm);andareprimarily nitrogenous in gas composition. However, thermals having carbon gas, methane and hydrogen-sulfide can also be found. Nitrogen thermals are divided into three main types: 1. A type of granite that is spread on the surface and characterized by a low mineralization degree typically with less than 0.3 g/l silicon, high levels of radon, and some trace elements; 2. A type of volcanic rock found in shale and sandstone that is characterized by the presence of hydrogen sulfide; 3. A type of sedimentary rock found in carbonate (conglomerate, dolomite, etc.) deposits characterized by high mineralization levels [Aliyev et al., 2006].

Scientific and practical researches are conducted in many developed countries for the resolution of the problems related to the use of alternative (wind, thermal waters, etc.) energy sources. The high-temperature thermal waters are also characterized as accumulators of thermal energy due to their high heat-energy capacity.

Geothermal energy is an inexhaustible source of heat energy throughout the human lifetime. Its use is harmless to the environment and provides the base load of energy. This energy source is not dependent on weather conditions and operates 24 hours a day, 7 days a week. The use of geothermal energy increases regional and local products, reduces dependence on traditional energy sources and helps preserve valuable chemical reserves for the future. Deep geothermal reserves can potentially provide reliable heat and electrical energy for the future.

Materials and methods

Deep geothermal systems [Stober, Bucher, 2013]**.** Deep geothermal systems include low-enthalpy hydro-geothermal systems that utilize heat from hot water or steam reservoirs in deep aquifers (Figure 1). The heat storage is directly used by the heat exchanger or sometimes through a heat pump.The produced thermal water can be used for heating local and regional heating networks andalso in resort hotels, industrial complexes and residential buildings. Conversion of heat into electrical energy is possible with additional technologies such as Organic Rankine Cycle (Rankine Cycle) units or Kalina units at temperatures above approximately 80°C. Therefore, economically efficient production requires a temperature of 120°C or higher. Organic Rankine Cycle (ORC) plants operate with lower boiling temperature due to the use of an organic heat transfer liquid. Thevapor phase of this liquid passes through a turbine and drives the electric generator. Kalina plants use an ammonia-water mixture as the heat carrier [Kalina, 1984; Ibrahim, 1996]. Kalina systems withdraw less thermal energy from the thermal water than ORC systems but convert it to electrical power with higher efficiency. In the low temperature range ORC systems suffer from low thermal efficiency that follows from a high auxiliary power requirement of the cooling system, especially when air cooled [Park, Sonntag, 1990].

The most commonly used form of hydro-geothermal resources is the two-well hydrothermal system. The system is based on two wells; one of them is the production well that carries hot water from the geothermal aquifer to the surface, and the other well is used to inject cooled water back into the ground. The thermal energy of hot water in the geothermal aquifer is transferred to a suitable fluid via a heat exchanger. Thermal energy cannot be completely transferred and converted into electrical energy. The hot water is typically cooled to around 55-80°C, and accordingly, most of the thermal energy remains in the thermal water. In case, if there are specific demand and the necessary infrastructure is built, it is possible to utilize the residual heat. The economic success of the power plant largely depends on the sale of residual heat.

The cooled water is returned to the injection well together with the residual heat. The filter sections of the dual well are located at precisely determined distances from each other (Fig. 1).

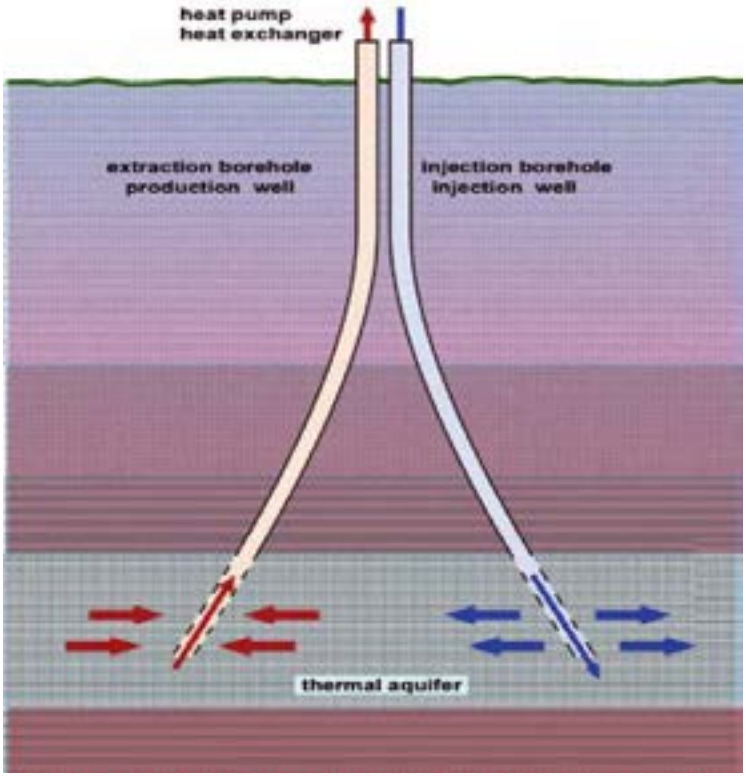

Fig. 1. Underground design of a deep geothermal open system installation (doublet, 1 producer, 1 injector) [Stober, Bucher, 2013]

Depending on the geological conditions, an injectionpump may be required. There are several reasons for the return of produced water during the closed loop (reproduction): so, that the natural refilling of deep aquifers is a very long process. Thus, it is necessary to ensure the refilling of water reservoirs. Hydrogeothermal plant pumps a large amount of water, so it is necessary to be sure of the alteration of the extracted water. Reinjection of cold water is beneficial from both economical and practical viewpoints, because water often contains high concentrations of dissolved substances and gases. Due to the wastewater management, it is useful to inject the water back into the initial water storage tank.

The Riehen plant located near Bazel (Switzerland), which has been continuously providing heat energy to residential areas in Switzerland and nearby Germany since its commissioning in 1994, can be mentioned as an example of geothermal binary system,. The two wells are located at a distance of 1 km from the residual water reservoirs at a depth of 1547-1247 m, correspondingly (Fig. 2).

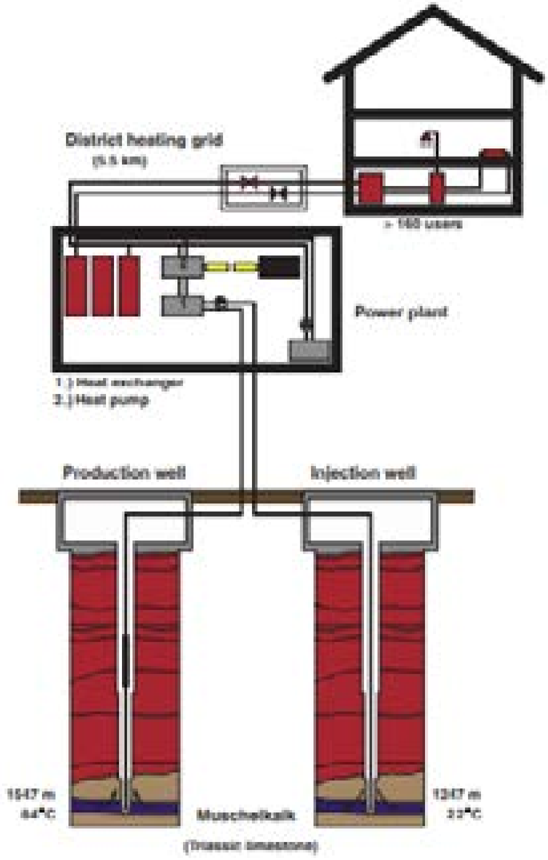

Fig. 2. The hydrogeothermal binary system at Riehen (Basel, Switzerland), redrawn from documents of Gruneko Corp [Stober, Bucher, 2013]

A hydrogeothermal binary system consisting of a production and an injection well can be drilled obliquely from a single drilling point. This reduces the land required for surface plant construction. Underground, the bottom of the hot water aquifer is typically 1000-2000 m apart from each other. An optimal distance between the wells must be determined prior to drilling through the system's numerical modeling. If the wells are too close together, there is a risk of thermal short-circuit. This means that the cooled recycled water can reach the production well too quickly and in turn, cool the geothermal water. On the other hand, the wells should not be too far apart, as the production well cannot get hydraulic support from the injection well in this case. Thus, the filling of the fluid reservoir depends on the reflux of the cooled water. The heated water after being pumped and cooled down is stored in a closed system that allows maintaining a specific pressure. This is necessary to prevent or minimize buildup of high mineralized and gas-rich fluids in the equipment due to pressure drop and gas loss. Calcium carbonates (calcite-aragonite) are the most typical and widespread scales. The release of CO_2 gas from the pumped hot water leads to the precipitation of carbonates in the piping system. Even though carbonates aremore soluble in cold water,the loss of CO_2 is more influenced by pressure than temperature. In closed pipe systems, the pressure can be adjusted to prevent degassing and scale formation. In some areas, a strong acid (such as hydrochloric acid) or small amounts of other chemicals (organic inhibitors) may be required to prevent scale formation. Geothermal power plants usually use two types of pumps: Submersible electric pumps (SEP) and surface-mounted line shaft pumps (SLSP). The pumps used to bring the hot liquid to the surface must be resistant to high pressure and corrosion and, therefore. it is considered the most important component of the geothermal power plant. The SEP raises the hot liquid to the surface, to the heat exchanger, under the influence of centrifugal force. The extracted thermal energy can then be converted into electricity or fed directly into the central heating network. Improves energy efficiency by reducing combined power and heat emissions. The combined power and heat increase energy efficiency by reducing emissions. They are particularly environmentally friendly and economically viable. Consequently target temperature is 200 °C andbeyond. The hot rocks, usually crystalline basement (granites and gneisses), function as a heat exchanger. Heat transfer to the surface is achieved by natural water present in the fracture pore space of the basement [Stober, Bucher 2007a, b; Bucher, Stober, 2010]. In crustal sections with average geothermal gradients,5–7 km deep wellbores are necessary to reach the required rock temperatures. The crystalline basement of the continental crust is generally fractured in its upper part. The fractures are the result of failure of stressed rocks in the brittle deformation regime in the uppermost about 12 km thick layer of the Earth. The fractures are flow paths for advective water transport. The hydraulic properties of the fractures depend on fracture aperture, surface roughness of fracture surfaces, connectivity and frequency of fractures and other parameters [Caine, Tomusiak, 2003]. The hydraulic behavior of the fractured basement corresponds to an infinite homogeneous low-conductivity aquifer (aquitard). High-pressure injection of water into the borehole increases the aperture of natural fractures and unlocks partly sealed fractures therefore improving the hydraulic conductivity.

The use of thermal water through dual systems (two-phase systems) for heating purposes can often be considered feasible using hydrothermal binary systems. Geothermal plants operating with them have been used for years and are currently used all over the world.

Special kinds of geothermal plants are used inbalneological resorts using thermal deep waters. Along with the use of hot water in baths and pools, the pumped thermal water is also used for the heating of buildings in local areas. After the use, the wastewater are cleaned, but not reinjected into the aquifer.

Hydro-geothermal systems include thermal fluid reservoirs and crack and fracture zones with high permeability in sedimentary masses.

In addition to the low-enthalpy geothermal systems presented above, the high-enthalpy steam or two phase systems are used for the generation of electric and heating energy.

Deep geothermal wells are, in principle, a form of oil-thermal systems. Here, heat energy is extracted from any type of rock or rock sequence by using a closed circuit of heat transfer fluid in the deep well. Deep geothermal wells are used only for heat supply. Currently, it is not possible to generate electricity with the available technology due to the relatively low temperature of the wells.

The technology of deep geothermal wells can be compared with near-surface geothermal well technology. The geothermal heat carrying fluid in deep wells circulates in a single borehole up to 3000m depth. The system doesn't require conductive rock formations at depth and can be installed anywhere. The existing abandoned wells are particularly suitable for installing deep geothermal wells. The heat production of deep geothermal well can range up to 500 kVt depending on local conditions.

Heat transfer from hot rocks occurs by heat transmission from the solution of the probe and corpus to the conducting fluid. Ammonia is a commonly used heat transfer fluid. The cold liquid slowly flows down the ring of the double tube system and is gradually heated by the surroundings. The downward flow rate is typically 5-65 m/s. In a thermally insulated central pipe, thermal energy is lifted to the surface by the heated fluid. In a surface heat exchanger, heat is removed from the hot fluid. The cooled liquid (15°C) is pumped back into the loop. The heat extracting process cools the subsoil near the well. The amount of the heat produced from the deep well is primarily dependent on the temperature of the ground. Therefore, areas with positive heat anomalies areparticularly profitable from economical viewpoint. Additional parameters affecting the productivity of deep wells include the thermal characteristics of ground, especially heat conductivity, overall operating time, well's technical design, and thermal properties of the used corpus and screen materials. Long and large diameter wells have greater heat exchange surfaces.

The structure of deep aquifers is often characterized by transition or mixed properties between hydrogeothermal and petrothermal (oil-thermal) systems. The future applications of deep geothermal energy sources include the extraction of heat from deep underground mines and thermal energy from boreholes, and storing them in deep geological structures.

Geothermal energy sources of Azerbaijan

Azerbaijan has abundant potential of alternative energy sources. In terms of geothermal, the Greater Caucasus region is particularly abundant with low-temperature geothermal fields. In most parts of the area, this parameter is evaluated as not more than 30mW/m^2, only in the south-eastern part-Siyazan monocline the heat flux reaches 50mVt/m^2. The increase of heat flux in a regional scale towards the east and south is related to the approach of Siyazan regional fault to the transition zone of the Great Caucasus geosynclinal deformation zone [Mekhtiev, 1970; Huseynov et al., 1970; Aliyev, 1988; Aliyev et al., 1996; Aliyev et al., 2002; Mukhtarov, 2004; Gubanov, 2022]. Due to its geological and geomorphological characteristics, Azerbaijan has sufficient reserves in terms of thermal water sources. As a result of the conducted research, more than 1000 thermal water deposits with a total reserve of more than 245,000 m^3/day have been identified in Azerbaijan [Mammadova, 2016].

In total, the forecasted reserves of thermal waters of the Caspianriperian-Guba zone – Jurassic, Cretaceous, Maikop and Absheron sediments are estimated at 81.4 thousand m^3/day.

During the years from 1983 to1996, exploration and prospecting of thermal and mineral waters was carried out in the Yalama, Nabran, Khudat, Khachmaz, Guba and Gusar areas of the Gaspianriparian-Guba thermal water deposit and positive results were obtained.

As a result of the hydrogeological tests carried out in the wells dug in the mentioned areas, underground thermal and mineral waters with high flow rate and temperature were discovered in the Middle Jurassic, Upper Cretaceou and upper productive layer aquifer complex.

The main purpose of the hydrogeological regime observations conducted in the wells dug in the Nabran, Khudat and Khachmaz areas in 1998-2000 years, was:regular study of the changes in the water level, flow rate, temperature, mineralization degree, chemical and gas composition of the wells depending on the natural factors (geological, hydrogeological, hydrodynamic characteristics of the area, the interconnection of water horizons, ways of recovery of underground water resources and changes in the balance); consistent monitoring the technical conditions of the wells; implementing the necessary technical measures and finally preventing the changes that may occur in the ecological balance of the region [Mekhtiev et al., 1960; Muradov, Salahov, 1998; Muradov et al., 2001; Sazonov et al., 2022].

The underground thermal waters of theLower Cretaceous water complex were studied in the wells drilled in the Khudat area at depths of 2275-2040 and 2541-2348 meters. The water flow was 76.2-316.6 m^3/day, with a temperature of 38-64°C.

The groundwater thermal waters of the Upper Cretaceouswater complex have been studied in the Khudat area in the thermal water well with a depth of 2837-2228 m. The flow rate of the water was 6000 m^3/day, and the temperature is 85 °C.

The groundwater thermal waters of the lower productive aquifer complex were explored in the Yalama region at depths of 1192-972 m with 35°C temperature, 1140-945 m with 41°C temperature. In the Nabran region, the thermal waters were explored at depths of 1609-1483 m with 42°C temperature, 1845-1516 m with54°C temperature and 1915-1648 m with39°C temperature. In the Khudat region, the thermal waters were explored at depths of 1853-1624 m with 40°C temperature, 1676-1426 m with 38°C temperature and 1526-1406 m with 50°C temperature. In the Khaçmaz region, the thermal waters were explored at depths of 2477-1640 m with 45°C temperature and 1800-1660 m with 41°C temperature in the drilled wells.

The groundwater thermal water of the upper productive aquifer complex in Nabran was determined at depths of 1463-1140 m with 42°C, 1466-1287 m with 45°C, 1480-1250m with 46°C, and 1614-1342 m with 39°C. In Khudat, the temperature was measured at depths of 1360-1182 m with 48°C, 1360-1170 m with 54°C, and 1426-1208 m with 60°C. In Khachmaz, the temperature was measured at depths of 1615-1557 m with 60°C, 1515-1420 m with 52°C, and 1624-1473 m with 52°C.

Aghchagil fluid complex. The underground waters of this fluid complex have been determined in mineral wells in the Nabran area at temperatures of 38°C for depths of 1124-931 m, 45°C for depths of 1231-993m, 45°C for depths of 1224-1028 m, and 36°C for depths of 1203-996 m. In thermal wells of the Khudat area, temperatures have been determined to be 50°C for depths of 1371-1260 m and 38.5°C for depths of 1512-1260 m.

The underground waters of the Absheron water complex have been discovered in mineral wells 6, 7, 9, and 10 in the Nabran area at depths of 1006-732 m. The flow rate of the waters is 5-172.8 m^3/day, and the temperature was 31-34°C.

Quaternary aqueous complex. Groundwater is very widespread in this zone and consists of New Khazar, Khvalin, Khazar, Baku and Turkan floors. In this water complex, both ground and pressure waters with different flow rate (5-55 l/sec) and mineralization degree (0.51g/l) are distributed.

As a result of hydrogeological tests (up to 12 wells) and monitoring in thermal wells drilled in Khudat and Khachmaz areas, changes have occurred in the hydrogeological indicators (flow rate, temperature, dynamic and static levels, chemical and gas compositions) of the developed waters in the upper productive aquifer complex to a noticeable degree.

It was found that there is a little differencewhen comparing the hydrogeological results obtained during the initial testing phase in the wells with those obtained during the monitoring phase.

Thus, as a result of hydrogeological monitoring carried out in wells drilled into thermal waters in the Khudat and Khachmaz areas, the hydrogeological properties of groundwater in the upper productive aquifer complex have been clarified, and its potential for profitable use in various fields (heating systems and balneology purposes) has been confirmed once again.

In addition, it was revealed that the studied wells are technically useful, and it is possible and expedient to continue hydrogeological monitoring on them [Muradov et al., 2001].

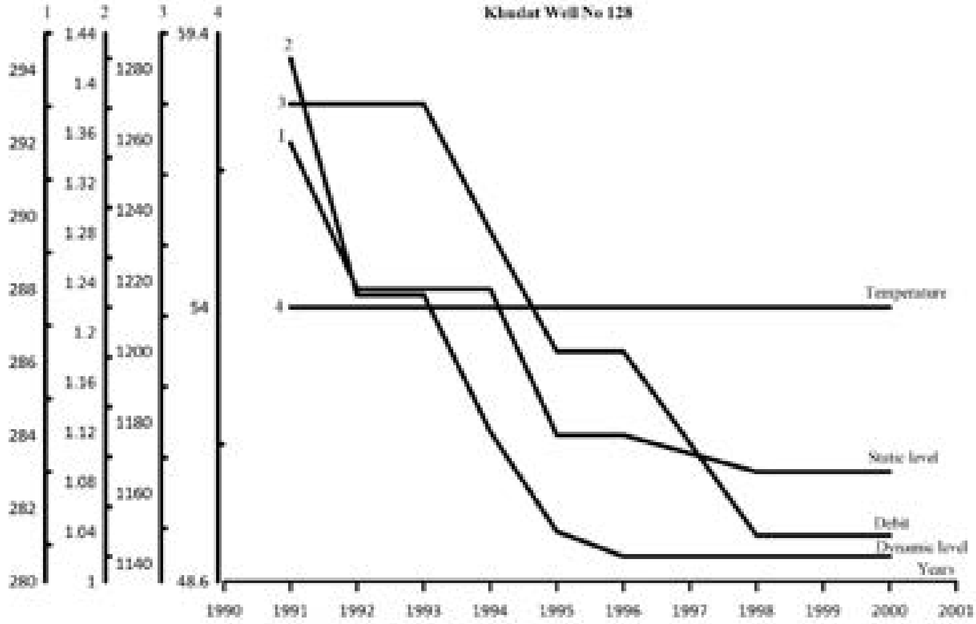

Fig. 3. The changes in temperature, debit, static and dynamic levels in well №124 in the Khudat field in 1990–2001 years.

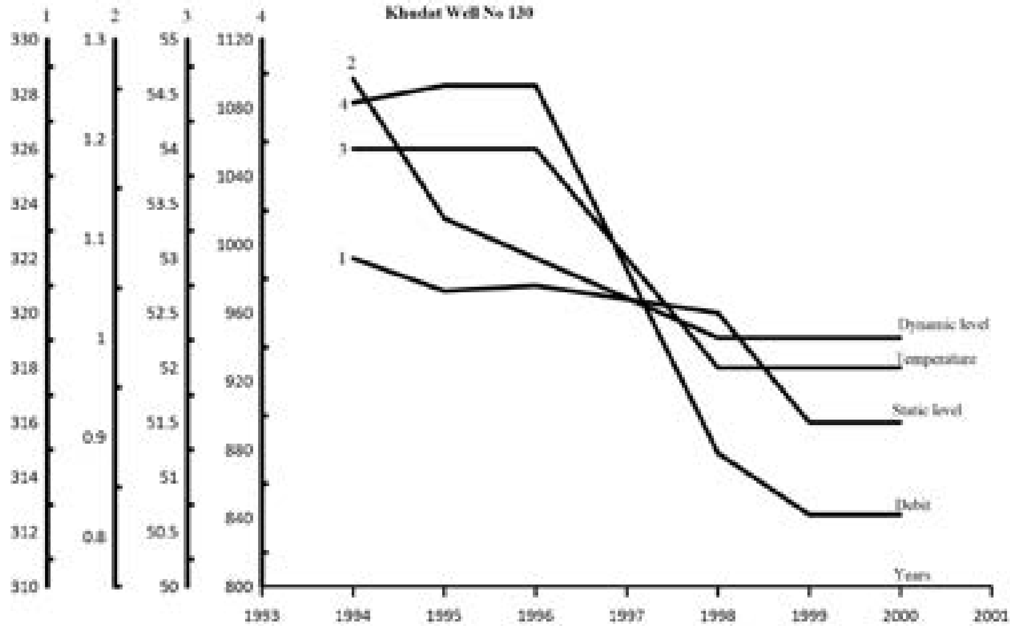

Fig. 4. The changes in temperature, debit, static and dynamic levels in well №128i n the Khudat field i n 1990–2001 years.

Hydrogeological analysis performed in the upper productive aquifer complex have revealed that the flow rate, temperature, and chemical composition of the waters of this area are suitable for direct use, as well as for the use of balneologyand agricultural purposes. The flow rate and temperature of the deep-lying aqueous complex create the basis for sufficient energy potential in the upper part of the productive layer. The hydrogeological characteristics of the upper productive aquifer complex in Nabran, Khudat, Khachmaz areas are given in Table 1.

Table 1

Hydrogeological characteristics of the upper productive layer aquifer comple

Observation area	Number of wells	Hydrogeological testing intervals, m	Flow rate of the well, m^3/day	Water temperature, °C	Degree of mineralization of water, g/l	Chemical composition of waters
Nabran	6	1463-1140	178.4	42	9.90	$Cl\text{-}SO_4$,Na
“	7	1480-1250	254.1	46	4-8	“
“	9	1466-1287	261.8	45	5.1	“
“	12	1614-1342	170	39	6.85	Cl, Na
Khudat	123	1360-1182	520.4	48	3.4	“
“	124	1356-1180	2400	54	1.7	$Cl\text{-}SO_4$,Na
“	126	1360-1170	2009.4	54	8.9	Cl, Na
“	127	1426-1208	6171.4	60	4.7	“
“	128	1570-1367	1148	54	4.4	“
“	116^3	1616-1310	2618	54	4.7	“
Khachmaz	115	1615-1557	960	60	8.3	“
	129	1550-1420	884	52	4.2	SO_4-Cl, Na
“	130	1624-1473	842	52	4.9	$Cl\text{-}SO_4$, Na

Results

The thermal energy (outlet) brought from within the Earth by hot springs is evaluated based on its flow rate. If we express the flow rate as q=m/t, water with mass m brings m=qt energy. The heat amount Q=mcΔT and it can be expressed as Q=qtcΔT. Hence, we can find the the average heat amount (heat power) brought by thermal waters per unit time.

$$W = Q/t = qc\Delta T.$$

Based on the abovementioned, we can calculate the energy for the areas given based on Table 1.

In Nabran area, energy potential per one day in wells №7 and № 9 will be:

$$W_7 = 254.1 * 4200 * (46 - 16) = 32.016.600\,Vt = 32.017kVt$$
$$W_9 = 261.8 * 4200 * (45 - 16) = 31.887.240Vt = 31.887kVt$$

Here, the heat capacity of water is c=4200 J/K, ΔT is the difference in temperature between the temperature of the water at the outlet of the well and the temperature of the air at the time of measurement, and q is the flow rate of the water.

Energy potential per one day in wells №124 and №127 in Khudat area will be:

$$W_{124} = 2400 * 4200 * (54 - 16) = 383.040.000Vt = 383.040kVt$$
$$W_{127} = 6171.4 * 4200 * (60 - 16) = 1.140.474.720Vt = 1.140.475kVt$$

The energy potential per one day in wells №115 and №130 in Khachmaz area will be.

$$W_{115} = 960 * 4200 * (60 - 16) = 177.408.000Vt = 177.408kVt$$
$$W_{130} = 842 * 4200 * (52 - 16) = 127.310.400Vt = 127.310kVt$$

If we assume the average monthly energy consumption of an house is 150 kWh, and the daily consumption is 150/30 = 5 kWh, then for example, 32.017/5≈6, 31.887/5≈6, 383.040/5≈77, 1.140475/5≈228, 177.408/5≈35, 127.310/5≈25.

As it is seen, the calculated geothermal energy potential based on the drilled wells in Nabran, Khudat, and Khachmaz zones provides energy for a certain number of homes. However, it should be noted that we have only given examples based on two wells for each zone. In this case, the number of homes supplied with energy and the energy potential will increase.

In the studied region, the use of thermal waters as a type of thermal energy in relatively large settlements such as Khachmaz, Khudat and other settlements would enable the saving of oil, gas, electricity, firewood and coal, and the damage to the environment would decrease.

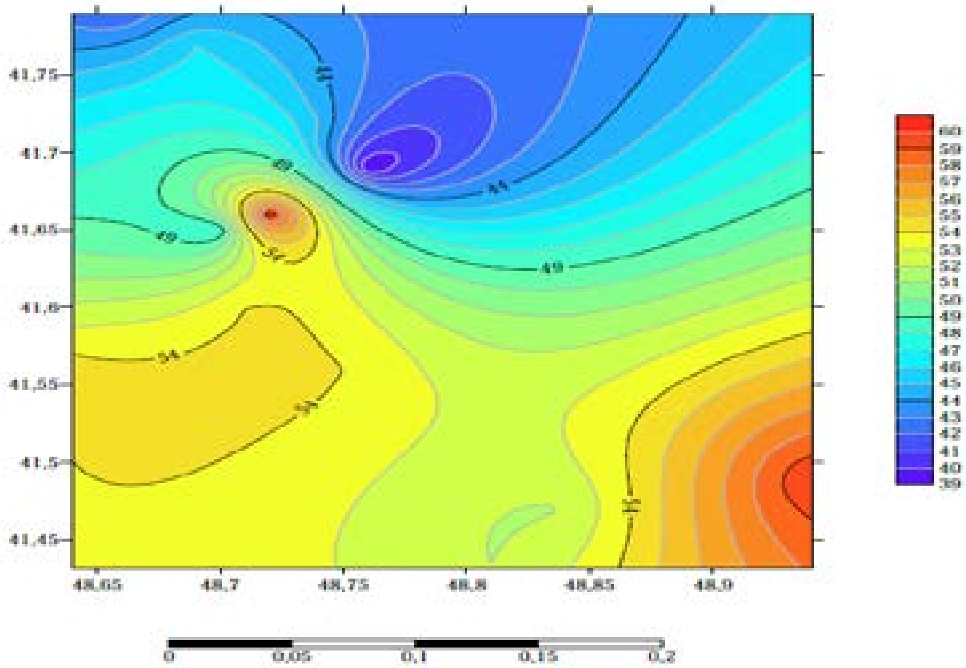

Fig. 5. Temperature distribution map for Nabran, Khachmaz, Yalama and Khudat areas

It should be noted that in Nabran, Khudat, and Khachmaz areas, and in the upper productive aquifer complex, the exploitation reserves calculated for the medicinal and thermal waters, which are considered as a type of heat energy, are more than 30,000 m^3 per day in categories A, B, and C1.

The use of such amount of water should be implemented at the state level or by large companies, which will allow for effective utilization of thermal and mineral waters, proper geoecological and hydrogeological control and compliance with sanitary-hygienicnorms. The distribution map of temperature and debit in the Caspianriperian-Guba area was developed using the Surfer program.

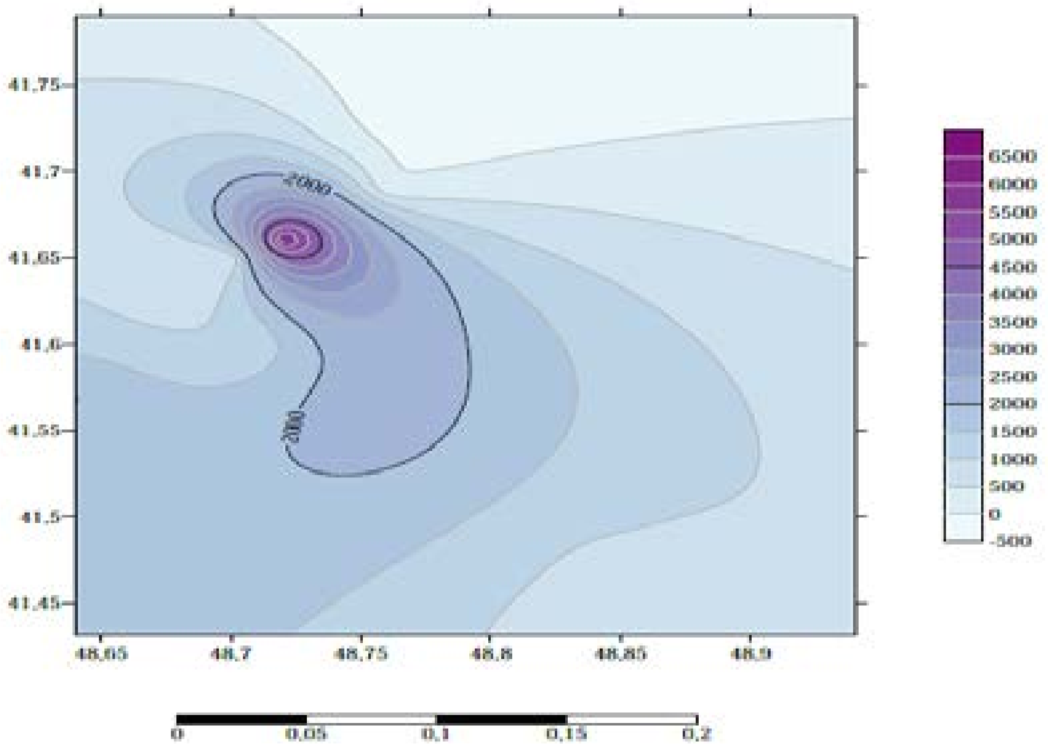

Fig. 6. Debit distribution (change) map for Nabran, Khachmaz, Yalama and Khudat areas

It is known that thermal energy (geothermal energy) is abundant on the Earth and it can be used under certain conditions. In some cases (volcanic eruptions, thermal springs, pressure of thermal water wells, etc.), this energy comes to the Earth's surface by natural ways.On the other hand, despite the fact that there is a significant amount of geothermal energy per square meter in the deep layers of the Earth, its use is accompanied by many problems, among which the delivery of geothermal energy from the depth to the surface is the main one.This, in turn, is one of the most important factors determining the profitability and efficiency of geothermal energy.

Recently, the efficiency of thermal energy use depends mainly on the deep drilled wells. However, there are many unused exploratory wells in Azerbaijan, which can be rehabilitated and used for the production of geothermal energy with small investment.

Conclusion

Based on hydrogeological regime observations carried out in the productive well complex in the Nabran-Khudat and Khachmaz areas of the Caspianriperian-Guba region, the changes occurred over time in the flow rate, temperature, dynamic and static levels, mineralization degree, and chemical composition of underground waters depending on the natural factors have been investigated.

Based on the results of hydrogeological works carried out, it should be noted that:

1. When comparing the results of the first hydrogeological tests carried out in the upper productive aquifer complex with the results obtained during the regime observations, it was found that there is no noticeable difference in the hydrogeological properties of groundwater. This also gives priority to consider that groundwater has a stable regime and that calculated reserves of thermal waters are natural reserves.

2. In the Nabran, Khudat and Khachmaz areas, and in the upper productive aquifer complex, the calculated operationalreserves of important therapeutic mineral waters and thermal waters as a type of thermal energy are more than 30,000 m^3/day in categories A, B, and CI.

3. The presence of valuable chemical elements, including high-concentration of iodine and bromine, revealed in the Middle Jurassic, Cretaceous and Lower Productive layers and upper productive aquifer complex, allows for comprehensive utilization of these waters.

4. The main source of the environmental contamination in the research areas is both thermal and mineral waters with various physical and chemical compositions flowing from wells. Especially, the waters located in the Middle Jurassic, Cretaceous and Lower Productive layers and upper productive aquifer complexes are characterised by high degree of mineralization and contain a number of harmful elements and compounds. Therefore, the specified water wells (№112 and №116 in the Khudat area, №121 in the Gusar area and №110 in the Yalama area) should be permanently closed.

References

1. Aliyev S.A. Geothermal fields of the South Caspian depression and their connection with oil and gas potential. Baki. Geol. Inst. Azerb. Acad. Sci. 1988. 28 p. (In Russ.)

2. Aliyev S.A., Mukhtarov A.Sh., Aliyeva Z.A. Results of geothermal research. In: Geophysical Investigations in Azerbaijan. Baku. Sharg-Gharb, 1996. pp. 381-386.

3. Aliyev S.A., Mukhtarov A.Sh., Aliyeva Z.A., Bagirli R.J. Geothermal research in Azerbaijan. In: Geology of Azerbaijan. Vol. V. Physics of the Earth. Baku. Nafta-Press, 2002. pp. 229-263. (In Russ.)

4. Aliyev S.A., Salaev S.G., Efendiev D.I., Karakashly V.L., Akhmedova H.A. Geothermal characteristics of the Caspian-Kuban region in connection with the assessment of oil and gas potential prospects. Sov. Geology. 1972. No12. p. 133-138. (In Russ.)

5. Aliyev G.A. et al. Explanatory dictionary of geological terms. Azerbaijan National Academy of Sciences Institute of Geology, Terminology Commission. Baku. Nafta-Press, 2006. 680 p.

6. Bucher K., Stober I. Fluids in the upper continental crust. Geofluids. 2010. Vol. 10. pp. 241–253.

7. Caine J.S., Tomusiak S.R.A. Brittle structures and their role in controlling porosity and permeability in a complex Precambrian crystalline-rock aquifer system in the Colorado Rocky Mountain Front Range. GSA Bulletin. 2003. Vol. 115(11). pp. 1410–1424.

8. Gubanov R.S. Assessment of the state of water protection zones of the Central Caucasus, on the example of water bodies of the Krasnogvardeysky Municipal District of the Stavropol Territory using remote sensing methods of the Earth. Geology and Geophysics of Russian South. 2022. Vol. 12. No.3. pp. 157-169. DOI: 10.46698/VNC.2022.95.62.011 (in Russ.)

9. Huseynov G.A., Saikin E.M., Plyushch A.M. To the study of geothermy of the Siyazan oil and gas region. ANKh. 1970. No.5. pp. 13-14. (In Russ.)

10. Ibrahi, O.M. Design Considerations for Ammonia-Water Rankine Cycle. Energy. 1996. Vol. 21. pp. 835–841.

11. Kalina A.L. Combined-cycle system with novel bottoming cycle. Journal of Engineering for Gas Turbines and Power. 1984. Vol. 106. pp. 737–742.

12. Mammadova A.V. Geothermal energy potential of the Pliocene complex of the Absheron Peninsula. Baku. 2016. 133 p.

13. Mehdiyev Sh.F., Abdullayev R.N., Alizade A. et al. Dictionary of geological terms. Institute of Geology of the Azerbaijan Academy of Sciences, Azerbaijan State Oil Company, Azerbaijan State Geology and Mineral Resources Committee. Baku. Elm, 1996. 360 p.

14. Mekhtiev Sh.F., Mirzajanzade A.Kh., Aliyev S.A. et al. Thermal regime of oil and gas fields. Baku. Azerneftneshr, 1960. 384 p. (In Russ.)

15. Mukhtarov A.Sh. Thermal field of the Caspian Sea. In: Geology of the regions of the Caspian and Aral Seas. Almaty. Kazakhstan Geological Society «KazGEO», 2004. pp. 195-200.

16. Muradov T.D., Salahov C.Sh. The report of the Caspian hydrogeological exploration team on the results of the precise exploration works carried out on thermal waters in Khudat-Khachmaz areas in 1990-1998. Baku, 1998

17. Muradov T.D., Salahov S.Sh., Agasiyev A.A. Results of conducting hydrogeological regime and maintenance works in 1998-2000 in wells dug for mineral and thermal waters in Yalama, Nabran, Khudat, Khachmaz, Guba, Gusar areas of the Caspian-Guba region. Baku, 2001

18. Park Y.M., Sonntag R.E. A Preliminary Study of the Kalina Power Cycle in Connection with a Combined Cycle System. International Journal of Energy Research. 1990. Vol. 14. pp. 153–162.

19. Sazonov A.D., Zakrutkin V.E., Reshetnyak O.S. Time variability of surface hydrochemical runoff in the Bolshoi Yegoryk River basin under anthropogenic influence and climate change. Geology and Geophysics of Russian South. 2022. Vol. 12. No.1. pp. 117-130. DOI: 10.46698/VNC.2022.37.47.009 (in Russ.)

20. Stober I., Bucher K. Hydraulic properties of the crystalline basement. Hydrogeology Journal. 2007a. Vol. 15. pp. 213–224.

21. Stober I., Bucher K. Erratum to: Hydraulic properties of the crystalline basement. Hydrogeology Journal. 2007b. Vol. 15. p. 1643.

22. Stober I., Bucher K. Geothermal energy, from theoretical models to exploration and development. Springer. 2013. p. 290.