ASSESSMENT OF THE POTENTIAL FOR USE OF THERMAL WATERS OF THE ABSHERON PENINSULA AS A RENEWABLE ENERGY SOURCE

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Abstract

The use of thermal waters as a source of renewable energy is considered one of the most important issues. Clean energy can improve human health in the long term by minimizing the risk of climate change, while also reducing deaths from air pollution in the short term. The risk of exhausting the oil and gas resources used by the countries of the world for many years is increasing over time. Also, considering that the oil and gas sector is one of the main causes of climate change, it is necessary to move away from this type of fuel. In this case, there is a need to use alternative and renewable energy sources in the world.

Addressing climate change requires a shift away from fuels such as hydrocarbons to renewable energy sources such as solar, wind, hydro and geothermal. Renewable energy sources are carbon-free and produce fewer emissions, making them an important component in reducing greenhouse gas emissions. Overall, the transition to renewable energy sources is critical to addressing climate change and ensuring a sustainable future for the planet. The favorable geographical position and climatic conditions of the Apsheron Peninsula allow the widespread use of ecologically clean alternative (renewable) energy sources. So, in addition to oil and gas deposits, thermal waters (Bilgah, Dubendi-Zira, Buzovna, Gala, Karachukhur, Lokbatan, Mardakan, Nardaran, Pirshagi, Sabunchu, Surakhani, Shikhov, etc.) are widespread here.

The operating reserve of thermal waters with a temperature of 40-90 ^{0}C on the Absheron Peninsula is 20,000 m^3/day. Although the studies conducted in the study areas show that the forecast reserves of thermal waters here are 27125 m^3/day, it is not doubtful that this indicator is many times higher.

The article describes the perspective of using thermal water deposits on the Apsheron peninsula as an alternative energy source. The analysis of funds and printed materials on thermal water deposits of the research area shows that the energy resources collected in this area can be considered as alternative energy and are of great importance for the future economy of the region. Studies show that the water temperature is high in the zones where the tectonic faults spread directly. As mineral water resources from thermal waters, it is also considered useful for the development of balneological, sanatorium-health complexes.

Keywords: climate change, alternative energy source, geological conditions, degree of mineralization, mineral waters

I. İntroduction

Apsheron peninsula, which is the research area, belongs to the southeastern part of the Greater Caucasus in terms of morphostructure. The sediments of the Cretaceous, Paleogene, Neogene and Quaternary periods are involved in the geological structure of Apsheron. The floors of the upper division of the Cretaceous system are involved. The sediments of these floors came to the surface in north-western Apsheron. The Paleogene system is characterized by strata of the Paleocene, Eocene, Oligocene departments. The Paleocene department is characterized by the

Sumgayit formation. This stratum is characterized by lower, middle and upper semi-stratums. The lithological composition consists of clay, marl, and sandstone layers and its thickness is 80-325 meters. The Miocene branch of the Neogene system is characterized by the Upper Maykop formation, Torton, Sarmatian, and Meotis floors. Clay facies prevailed in Upper Maykop. The Pliocene branch of the Neogene system is characterized by the Pont, Productive layer, Agcagil layers [1].

According to the tectonic structure, the Apsheron peninsula is divided into Western, Central anticlines and Eastern Apsheron synclinal areas.

In the research area, winter months are mild, summer months are hot, and autumn and spring months are cool. Atmospheric sediments fall less in these areas, and strong winds prevail. The type of climate belongs to semi-desert, dry, desert climate. Autumn months are warmer than spring. March and the first half of April correspond to winter, the second half of April and May correspond to summer. In these areas, January, the coldest month, has an average monthly temperature of 1.1 ^{0}C, and June, the hottest month, has an average monthly temperature of 27 ^{0}C. The average annual temperature ranges from 14.3 to 14.7 ^{0}C. The absolute minimum air temperature varies from -18 ^{0}C to -21 ^{0}C [2,3].

In the years when the weather is very hot, the highest temperature is 36-39 ^{0}C in the coastal zone of the sea, and 40-43 ^{0}C in the areas far from the sea coast. The minimum value of the average daily absolute air humidity occurs in January, and the highest value occurs in July-August.

The hydrogeological conditions of the Absheron Peninsula are extremely complex. In Western Apsheron, clay sediments of rocks older than the Quaternary period prevailed. Groundwater in these areas is sporadically distributed in Upper Pliocene and Quaternary sediments. The groundwater spread in these sediments is characterized by a high degree of mineralization. These waters are not suitable for drinking or use for economic purposes. Groundwater with sweet and weak mineralization is very rare [4,5].

Pressurized groundwater in pre-Quaternary sediments is commonly associated with oil fields. Most of these waters have a high degree of mineralization. Iodine, bromine, potassium, lithium and other microcomponents are widely distributed in these waters.

Groundwater is almost ubiquitous in Eastern Apsheron. Groundwater in Eastern Apsheron is mainly distributed in Quaternary sediments. The depth of groundwater is from a few cm to 20 m and more. The direction of groundwater flow is from the central parts of the Apsheron peninsula to the shores of the Caspian Sea.

The degree of mineralization and chemical composition of groundwater is very complex. The chemical composition is mainly hydrocarbonate-chlorine. Salty chlorinated waters are widespread mainly in Bina-Hovsan muldas, where oil-waste waters are spread, while in other areas weakly saline and saline waters are widespread. Pressurized waters in Upper Pliocene and Quaternary sediments are fresh and weakly saline. Underground pressurized waters lying in older strata are characterized by high mineralization rates [6,7].

II. Methods

The formation of groundwater in the Apsheron peninsula took place under different conditions. Both natural and man-made factors played a role in the formation of underground water in the Apsheron Peninsula.

Geological-geomorphological conditions are the most important factor in the formation of groundwater on the Apsheron Peninsula. Since clayey rocks of various ages spread in Western Apsheron cover the earth's surface, they did not create conditions for the formation of groundwater in this area. In some areas, as a result of the outcrop of limestone and sandy rocks, it has created conditions for the formation of groundwater here. Geological-geomorphological conditions in Central and Eastern Apsheron are favorable for the formation of groundwater. So, since the lithological composition of these areas includes sand, sandstone, and limestone, groundwater is spread everywhere in these areas. As is known, relief plays a key role in the formation of groundwater. Therefore, in the Apsheron peninsula, groundwater is more common in the low areas of the terrain. Thus, atmospheric sediments, which are already small in these areas, are collected and filtered underground, forming groundwater.

Climatic factors are quantitative and qualitative indicators of groundwater formation. On average, 227 mm of annual precipitation falls in the study area, and evaporation is 947-1344 mm. The total mineralization rate of atmospheric precipitation varies from 56 to 208 mg/l. 184.8 kg/ha of salt fall during the year due to atmospheric precipitation. 12.9% of these salts were NaCl. In addition, water formed from condensation vapors in the air plays an important role in the formation of groundwater.

Artificial factors play an important role in the formation of groundwater on the Apsheron Peninsula. Artificial factors are formed as a result of human activity. These include irrigation of fields, feeding with highly mineralized water extracted from oil wells, losses from the Samur-Apsheron canal, etc. includes. Apart from these, groundwater in the Baku synclinal soil is also fed by losses from water lines. As underground water resources are limited in the Apsheron peninsula, the waters of the Samur-Apsheron canal were widely used for irrigation purposes. Due to the losses from this channel, fresh groundwater is found in areas along the channel suitable for the formation of groundwater. According to calculations, the annual loss from this channel is 5-10%.

The process of formation of hydrogeological conditions on the Apsheron Peninsula is extremely complex. Geomorphological, tectonic, geological-lithological conditions, the activity of the Caspian Sea, and climate indicators are involved to some extent in the process of underground water formation. It is impossible to reconcile with the classifications determined in the process of formation of hydrogeological conditions in Apsheron territory and accepted for general geological structures. Distribution of geological stratigraphic divisions on the Apsheron peninsula, their lithological compositions are heterogeneous on the area, and the geomorphological-tectonic structures of the areas confirm the so-called.

Common patterns for the studied areas include uneven distribution of surface water, lack of rivers, low atmospheric precipitation, and several times more evaporation than atmospheric precipitation.

In the territory of the Apsheron peninsula, clayey facies are abundant in stratigraphic units of different ages. The collector layers involved in the cutting are in the form of laminations, the aquifer rocks contain clay, the layers separating them consist of solid, thick-layered clays, the presence of various salts in the clay rocks, etc. created conditions for the formation of fresh and slightly saline water horizons in these areas. Complex tectonic conditions in the researched areas also confirm what we said. Thus, the alternating anticlines and synclines consisting of rocks of different ages in the area, the presence of numerous tectonic fractures and disturbances have led to the formation of water complexes that are completely unrelated to each other [8,9].

The natural state of hydrogeological conditions in Apsheron Peninsula is uncertain in different areas. So, with the exception of some areas of Western Apsheron, fundamental changes have occurred as a result of human anthropogenic activity in most areas. For many years, in some areas of the Apsheron Peninsula, the groundwater levels have approached the ground surface, their distribution areas have increased, and the process of sweetening of groundwater has begun. In some areas, the opposite was observed. All this had a certain effect on the formation and change of the hydrodynamic and hydrochemical conditions of the areas [11,12].

Apsheron Peninsula is one of the most widespread areas of thermal and mineral waters in the Republic of Azerbaijan (Fig. 1). The operating reserve of thermal waters with a temperature of 40-90 ^{0}C on the Apsheron Peninsula is 20,000 m^3/day.

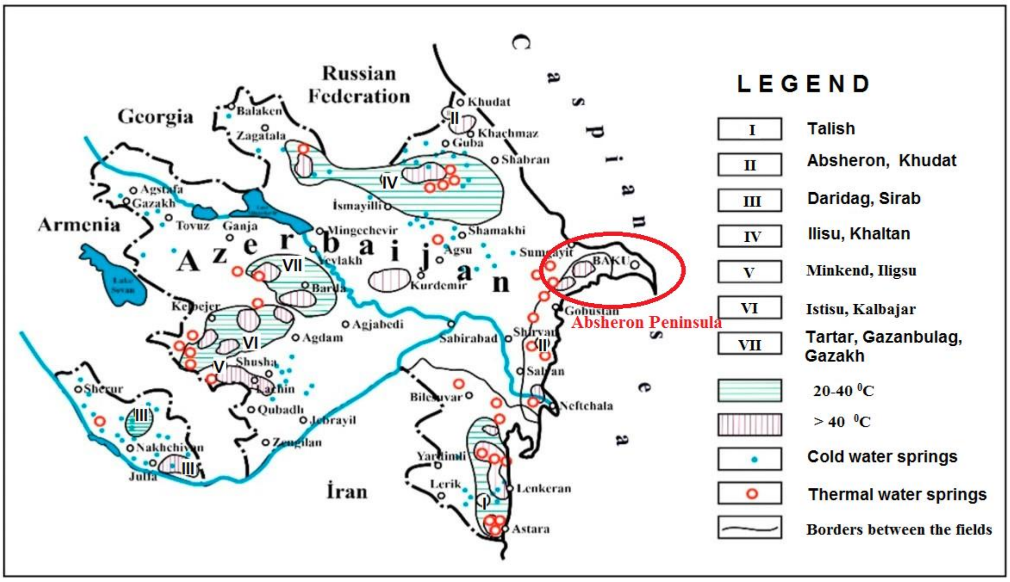

Figure 1: *Mineral-thermal waters map of Azerbaijan*

Formation water temperature. When determining the temperature of the layers, the terms geothermal step and geothermal gradient are used. The temperature of formation water inside the hydrocarbon deposits is taken according to the geothermal gradient of the formation. Taking this into account, it is possible to calculate the temperature of the water inside the layer using the following formula:

$$T = a + H/k$$

T – formation water temperature, °C;

a – average annual temperature on the earth's surface;

H – the depth where the layer is located, m;

k – geothermal gradient, m/°C.

The temperature of the layers was measured for the first time in 1880 on the Apsheron Peninsula (Sabunchu) at a depth of 100-200 m. Later Sh.F. Mehdiyev for the first time determined the geothermal stage by conducting large-scale research works in the Balakhani-Sabunchu-Ramana oil fields. As a result of these studies, it was determined that the geothermal step in shallow oil fields of Apsheron region varies between 21-37 m [11]. Temperatures can reach higher levels in layers in deep deposits. Table 1 provides information on temperature indicators of different depths in the structures of the Apsheron Peninsula.

Table 1: *Temperature indicators of different depths in the structures of the Apsheron Peninsula*

Temperature indicators	Depth, m								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
Average temperature of rocks, ^{0}C	43	52	60	70	78	86	97	105	112
Geothermal step, m/^{0}C	33,6	38,8	42,9	44,1	46,4	48,2	48,4	49,1	50,7
Geothermal gradient, ^{0}C/100 m	2,97	2,57	2,32	2,26	2,15	2,07	2,06	2,03	1,96

The Apsheron Peninsula has a large number of thermal water resources. Thus, among the largest thermal water deposits, Dubendi-Zire, Surakhani, Baku Muldasi, etc. can be shown. Although the studies conducted in the study areas show that the forecast reserves of thermal waters here are 27125 m^3/day, it is not doubtful that this indicator is many times higher (Table 2).

Table 2: *Forecast reserves of thermal waters of Apsheron Peninsula*

Thermal water deposits	Forecasting reserve, m^3/day
Buzovna	4
Gala	1006
Surakhani	2811
Baku Muldasi	3087
Bine-Govsan	1270
Dubandi-Zire	18947
Total	27125

Jurassic and Cretaceous sands and sandstones, flysch clay shales, Paleogene and Neogene clay rocks are mainly involved in the geological structure of the areas where thermal and mineral water deposits are spread.

Mineral-thermal water deposits of Apsheron are concentrated in different stratigraphic horizons. It should be noted that the formation of mineral thermal waters of the Absheron Peninsula is also greatly influenced by mud volcanoes and various types of reservoir waters of oil fields. About 80% of the 20 deposits registered here are hydrogen-sulfide (H_2S), and about 20% are methane (CH_4)-containing gases.

While chlorinated-sodium waters with a high content of calcium and magnesium form a specific group on the Apsheron Peninsula (Surakhani, Amirjan, etc.), mineral waters in the Shikhov region, located in the southwest of Baku, are characterized by a chlorinated-hydrocarbonate-sodium type composition.

The Apsheron peninsula is rich in mineral and thermal waters, important for treatment. Hydrogen sulphide mineral water wells and sources are located near Surakhani, Amirjan, Gala, Binagadi settlements, in Pirallahi, and therapeutic mud volcanoes - Lake Boyukshor, Masazir, Murdalabi, Fatmayi, Ramana, etc. spread in the areas. Here, three processes – oiliness, mud volcanism and mineral water formation processes occur in interaction.

Mineral-thermal waters of the Apsheron Peninsula are found in different stratigraphic horizons - in the sediments of the Pont floor characterized by sand and limestone-sandstone intermediate clays, in the sandstone sediments of the productive layer with a large thickness. Hydro-geothermal indicators calculated for different depths of the aquifer complex of the Absheron Peninsula are given in Table 3.

Table 3: *Hydrogeothermal properties of the Apsheron Peninsula aquifer complex (Productive layer)*

The field	Well №	Hydrogeological survey depth, m	The temperature of the water at the wellhead, ^{0}C	Degree of mineralization of water, g/l	The main microcomponents, mg/l	Gas content of water
Buzovna	3^2	1953-1390	42	116	J-24 Br-198	CH_4
	4^2	1464-1389	46	114		
Gala	62	1705-1582	52	134		
		1566-1410	45			
	1162	1612-1574	40		J-30	
	1028	1516-1501	38	144	Br-214	
		1634-1614	42		J-28	
	1323	1714-1701	40	156		
Surakhani	1^2	2218-1967	42			
	14	2172-2024	48	146	J-28 Br-	

					192	
	2r	1668-1487	50		Br-142	
	1222	2172-2024	48	136		
		1712-1710	43			
Baku Muldasi	1304	1853-1720	47		J-32 Br-214	
	1415	2122-1996	46	118		
Zire	36	2828-2790	38	128	J-28 Br-199	
		2724-2636	57			
Bine-Govsan	628	1318-1197	53		J-29 Br-320	
		1145-1063	37			
	849	1300-1213	39			
	1046	1196-1110	39			
	1214	1352-1247	43	138	J-26,8 Br-296	
	1416	2122-1996	42			
Duvandi-Zire	925	1063-949	36			
	707	1044-982	36			
	808	1383-1291	42	142	J-26 Br-216	
	36	2828-2740	48			
	114	843-799	36			
	707	968-876	40			
	628	1004-913	42			
	800	1243-1144	45	124	J-28 Br-23,4	
	926	831-800	39			
	1106	1194-1103	38	166	J-24,8	
	1527	848-816	39	138	J-26	
	1032	956-892	41		Br-214	
	1101	987-928	40			
	1227	932-873	350			
	1070	998-960	36			
	932	997-936	37			
	1323	963-899	36			
	953	921-790	44			
	628	709-680	37	124	J-28,8 Br-204	CH_4
	800	1049-876	42			
	904	809-757	37			
	925	762-595	42			
	1527	770-623	36			
	1146	843-663	36			
	948	480-470	35			
	649	915-728	35			
	211	1247-1048	36	114	J-32 Br-199	
	1304	1384-1118	52			
	1046	882-705	48			
	925	1063-949	48			
	114	843-799	50	128	J-33,4 Br-214	
	707	968-876	38			
	628	1004-913	36			
	800	1243-1144	40			
	926	831-800	44			
	1106	1194-1103	45			
	1527	848-816	42			
	1032	956-892	38			
	1101	987-928	39			
	1227	932-873	41			
	1070	998-960	40	136	J-26	

	932	997-936	37		Br-214	
	1323	963-899	36			
	953	921-790	44			
	628	709-680	37			
	800	1049-876	44			
	904	809-757	36			
	925	762-595	35			
	1527	770-623	35			
	1146	843-663	36	146	J-29,8 Br-190	
	948	480-470	44			
	649	915-728	35			
	211	1247-1048	40			
	1304	1384-1118	40			
	1046	882-705	48	142	J-28	
	877	940-804	38		Br-198	
	130	1003-785	42			
	152	1030-804	38			
	144	1258-997	42			
	1501	1715-1480	47	136	J-29	
	1518	1693-1470	50		B-215	
	1408	1623-1400	47			
	41	1580-1353	36			
	36	2556-2243	48			
	628	605-572	39			
	841	550-492	36			
	800	792-709	38			
	904	710-664	38	136	B-215	
	1106	792-709	36			
	1515	1266-895	36	144	J-28 Br-214	
	1822	1827-1402	45			
Duvanni	50	926-880	54			
	55	2933-2915	56	35		CH_4
	4	1788-1684	76	36	J-28,9 Br-48	
	15	1798-1774	58	34		
	58	2448-2413	36	33		
Kenizdag	27	3200-3100	66	56	J-24 Br-98	
	56	1848-1814	48	44		
	38	1863-1806	49	44		
	26	1824-1823	47	36	Br-42	
Garadag	14	1346-1344	44			
	53	1695-1603	45			

As a result of the conducted research, the highest temperature of thermal water in the Apsheron peninsula was recorded in Duvanni area (76 ^{0}C), Surakhani area (52 ^{0}C), and Kenizdag area (56 ^{0}C) (Table 4). There is no doubt that the temperature is even higher as you go deeper.

III. Results

It is of great importance to comprehensively study underground thermal water, which is an ecologically clean source of energy, along with other types of fuel (mainly oil, gas) and provide it to the people.

The formation of hydro-geothermal conditions on the Apsheron peninsula reflects the geological-lithological, geomorphological, tectonic conditions of the area. The formation of hydrochemical conditions was influenced by waste water from oil fields and various household wastes. Along with these factors, the rocks of the aeration zone are also important in the formation of the chemical composition.

On the Apsheron peninsula, thermal and mineral waters are distributed in Khazar-Khvalin, Baku, Apsheron, and Productive layer sediments. There is a little hydraulic connection in the sediments of the Caspian-Khvalin. The pressurized waters lying in the Baku-Productive layer sediments have no hydraulic connection. Hydrochemical conditions were formed separately.

Table 4: *Hydro-geothermal properties of thermal waters on the Apsheron Peninsula*

The field	Calculated wells	Geological age and depth of the aqueous complex	Degree of mineralization of water, g/l	water temperature, ^{0}C	Main components, mg/l
Buzovna	32, 4	N_2^1b 1950-1390	116	42	J-24 Br-198
Gala	62, 1028, 1162, 1323	N_2^1b 1714-1410	134	38-52	J-28-30 Br-214
Surakhani	12, 22, 14, 11, 12	N_2^1b 2218-1487	132-146	42-50	J-28 Br-192
Baku Muldası	1304, 1415	N_2^1b 2122-1720	118	46-47	J-32 Br-214
Bine-Govsan	628, 849, 1046, 1214, 6, 1304, 1416	N_2^1b 2122-1063	134-138	37-53	J-29 Br-320
Dubendi-Zire	707, 808, 628, 926, 1527, 1227, 932, 152, 144, 1822, 1518, 628, 926, 1046	N_2^1b 2828-595	114-144	35-50	J-26-32 Br-198-216
Garadag	14, 26, 38, 53, 56	N_2^1b 1863-1344	36-44	45-48	J-22 Br-92
Duvanni	22, 24, 40, 45, 47, 50, 51, 58	N_2^1b 2933-880	33-44	36-76	J-16-28,9 Br-209
Kenizdag	27	N_2^1b 3200-3100	34	56	J-24 Br-98

The operating reserve of thermal waters with a temperature of 40-90 ^{0}C on the Apsheron Peninsula is 20,000 m^3/day. Although the studies conducted in the study areas show that the forecast reserves of thermal waters here are 27125 m^3/day, it is not doubtful that this indicator is many times higher.

The thermal and mineral waters of the Apsheron Peninsula contain various gases that have a positive effect on the human body, specific chemical components and pharmacological ingredients, and useful biologically active elements, so they can be used for the treatment of many diseases. Although mineral-thermal water deposits containing iodine, bromine and other chemicals with great healing power are currently not used enough, their widespread use in the field of balneology and spa treatment in the near future is currently considered promising and necessary.

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