Thermal Waters of Azerbaijan – Sources of Renewable Alternative Energy

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Abstract

Azerbaijan that is situated in the east of the Caucasian region of the Alpine folding belt is rich in not only oil, gas, and mineral reserves, but in unique mineral water deposits as well. There is over 1000 mineral and thermal water deposits in Azerbaijan. The majority of these deposits have not been exploited yet. These waters can be used for therapeutic purposes as well as an alternative source of renewable energy. This article is dedicated to ways to solve this problem. There are a high production rate (40 lit/sec-50 lit/sec) aquifers with water temperatures close to 100°C at depth of 3000 m in Neogene and Paleogene rocks. Geochemical and hydrogeological properties of the mineral and thermal waters of Azerbaijan have separately been analyzed in the article for various regions and specific proposals on their efficient use have been put forward.

Thermal waters can be used in heating civil and industrial premises (T=40°C-60°C). Electrical energy can be produced from waters with temperatures above 80°C (Jarli, Precaspian-Guba, etc.). The presence of thermal waters distribution patterns in time and space associated with tectonic faults and magmatic processes has been proven from the scientific point of view.

Keywords: Geothermal • Debit • Energy • Mineral content • Thermal • Reserve • Chemical • Gradient • Structure • Regions

Introduction

Azerbaijan is a country with its picturesque landscape, a curative climate with its mud volcanoes, high mountains, numerous lowlands, unique Naphtalan oil, and golden seaside beaches and countless mineral and thermal water sources.The resort business in our Republic has recently become one of the major branches of national public health services, for implementation of improvement measures, oriented on the improvement of strengthening of health of the population, sporting and development of tourism.

In ancient times, at the dawn of medicine, Azerbaijan had been using thermal and mineral natural sources for treatment of illnesses-in Istisu, Turshsu, Naphthalan, Surakhani, Asrikderesy, Ibadisu, Meshasu, Gotursu, Chukhouryurd, Elisu and in other ancient bath-houses and primitive tubs, which were directly set up in places of an output of warm and hot mineral waters [1, 2]. Numerous clinical experimental researches, established high balneal efficiency of mineral waters of the Republic (Istisu, Sirab, Turshsu, Surakhani, Shikova, Meshasu, Daridag, Arkevan, Galaalti and many other). Mineral waters with a daily production rate of over 100 mln. liter sensually erupt around 300th tons of different salts on a day surface of the Earth, that can be widely utilized in the chemical industry, pharmacology and different branches of economics.

Now scientists from many countries are anxious that the non-renewable fuel resources of our planet steadily exhaust, and in connection with the rapid development of industry and agriculture in the XXI century, consumption of fuel energy will grow extremely with fast paces. Therefore, further fundamental and applied scientific researches on the usage of alternative energy sources-solar, wind and thermal waters-gain today the relevant and prime value. The Azerbaijan Republic has considerable reserves of thermal waters Figure 1. Thermal energy of thermal waters, including open ten thousand earlier drilled oil and gas wells, can be successfully utilized in different industries and agriculture. The underground thermal waters are the main storage and carrier means of plutonic heat, due to their mobility and greatest thermal capacity.

Materials and Methods

In connection with the continuous growth of the world power consumption and gradual exhaustion of its conventional sources, such as oil, gas, black coal, the attention of scientists is centered upon searching new energy sources. We consider that in Azerbaijan's circumstances thermal waters, alongside wind and solar energy, are valuable as well. The advantage of thermal waters is, that their reserves continuously renew, there is a capability to obtain heat, energy directly in place. They are valuable for curative properties and the capabilities of obtaining valuable chemical elements. These days, in connection with crisis of fuel and energy resources, wider use of the Earth's plutonic heat for electric power production (Italy, Iceland, New Zealand, USA, Japan, Bulgaria, Czechoslovakia, Hungary and other) in agriculture, municipal services, chemical industry, and for medical purposes as well has started abroad.

Discussion

Today to produce cost-effective electric power it is expedient to use temperature of a heat carrier not below 80°C. The Azerbaijan Republic is rich in thermal waters, which are known in a number of regions of the Greater and Lesser Caucasus, Absheron peninsula, Talish, and the vast Kurlowland and Precaspian-Guba areas [3]. Several wells had been drilled for oil and gas and no hydrocarbons were discovered. These well could be used for the production of thermal waters within the abovementioned areas. Nowadays negotiations are being conducted with Azerbaijan Agency on Alternative and Renewable Energy for the production of electrical power from high-temperature well waters. The Lesser Caucasus introduces especial concerns regarding a geothermal mode. Ancient thermal water sources have always been well known in its various parts. These waters are mainly associated with Quaternary rocks of magmatic nature. The known resort zone Istisu (Kalbajar region) is stretched more than 40 km along the Terter river is characterized by an abnormal thermal environment. The inverse geothermal gradient on the southern slope (health resort Istisu and Bagirsakh field) is reduced up to 2 m-5 m, and less, and for the entire resort region is close to 18 m, i.e. much less than the average for the earth crust [4]. The area is complicated by large tectonic faults and numerous carbon dioxide shows are observed therein. According to data obtained from numerous wells drilled in the area, the temperature of thermal waters on the Bagirsakh field is fast increasing and reaches 80°C at depth of about 100 m [5, 6].

The total production rate of water in the region of the Upper Istisu is 800 l/day-900 l/day, Lower Istisu-25th l/day. The elemental composition water is of carbon, chloride, sulfide, hydro carbonate, and sodium structure. The thermal waters in Masalli, Lenkeran, and Astara regions, are characterized by a regional fault intersecting the entire mountainous Talish. Waters with 44°C-65°C temperatures are encountered at depth of 500 m in wells drilled in the Arkevan water field in the Masalli region. The temperature of waters in different sources of this region changes from 50ºC up to 64ºC. The production rate of wells is 10 l/sec-15 1/sec. Water mineralized (17 g/l-18 g/l) chloride-calcium structure. In Lenkeran area (region of Meshasu, Ibadisu, Gavzavua, and Khavtxoni sources) several wells with depth 465 m-1000 m were drilled, which have opened waters with temperature up to 50ºC. The temperature of water in sources 30°C-43°C, production rate up to 10 1/sec. In regions of sources, Astara wells with depth 300 m-500 m

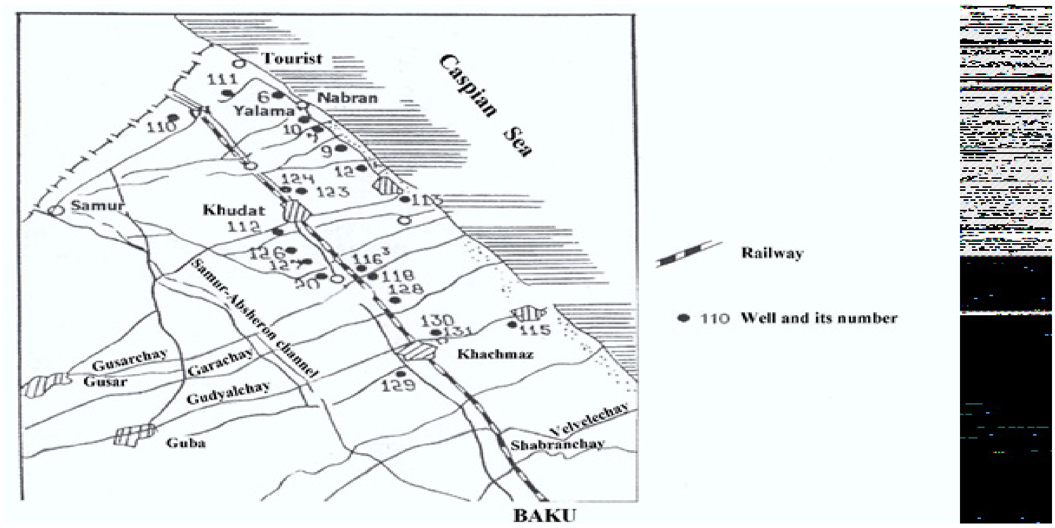

Figure 1. Schematic map of natural outlets of thermal water deposits.

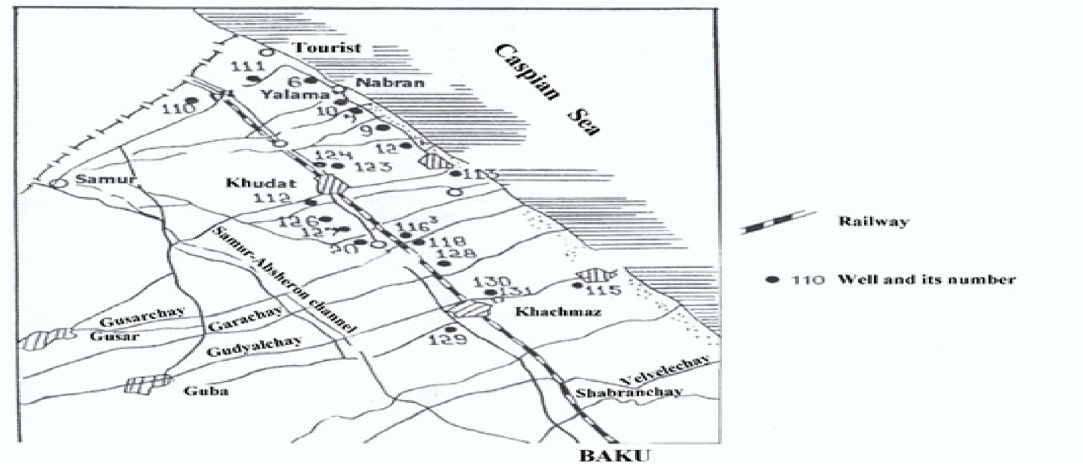

Figure 2. The layout of wells drilled for mineral and thermal waters.

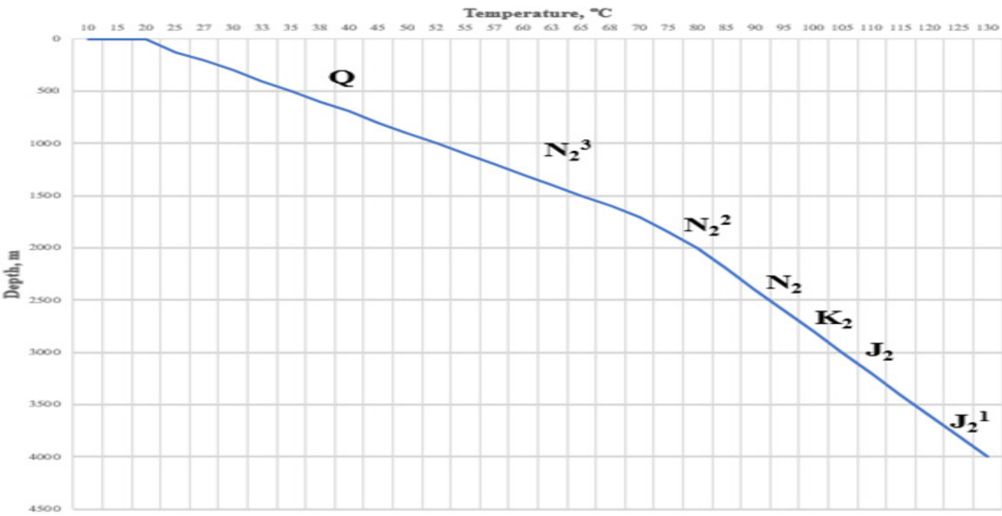

Figure 3. Rock temperature variations as a function of depth for Precaspian-Guba thermal aquifer structures.

opened thermal waters with temperature 35°C-50°C [7, 8].

Water mineralization reaches 18 g/l-29 g/l and they are of sodium chloride content. The total production rate of sources in wells in Talish is 23625 m^3/day. In the Precaspian-Guba zone (southern slope of Greater Caucasus) 8 drilled wells (Figure 2) opened thermal waters with a total production rate of 112360 m^3/day, temperature 50°C -84°C. In Khacmaz region a single thermal water well only has a production rate 1228 m^3/day, with temperature 58°C [9]. Thermal waters with temperature 50°C -81°C, with a total production rate of 30000 m^3/day have been obtained from prospecting boreholes in the Precaspian-Guba zone from Mesocenozoic deposits a single well 3 reached thermal waters with temperature 81°C (on the surface), and with a production rate 4500 m^3/day. Temperature change as a function of depth in the area is reflected in Figure 3.

On Absheron peninsula thermal waters are encountered in wells at different depths. Thus, the temperature of salt waters to the east of Hovsan village from the drilled wells reaches 100°C. In Bibi-Heybat, which is immediate close to Baku city, waters with salinity 16 g/l, 5 g/l, with temperature 71°C and production rate 450 this 1/day are of chloride hydro carbonate sodium content [10, 11].

There are large artesian basins with the composite distribution of temperature (with high temperature manifestation) and the structure of water in the Kurlow land. These thermal waters are associated with

Table 1. Probable reserves of thermal waters Republic of Azerbaijan.

Region	Reserves, m^3/day	Temperature,^{0}C
Absheron	2830	17-68
Precaspian-Guba	81000	40-85
Kur lowland	170000	30-100
Talish mountainous area	23400	13.5-67.4
Lesser Caucasus	14500	8.5-71
Nakhchivan	16800	7.5-52
Greater Caucasus	9090	11-85

Table 2. Main characteristics of several of high production rate wells for geothermal waters of Azerbaijan.

Geothermal regions	Number of oil and gas bearing structures	Temperature^{0}C		Value of flow, W/m^2		Factors that have an impact on the value of heat flow
		3000 m deep	4000 m deep	Back-ground	Abnor-mal	
Precaspian-Guba	15	90	100	30	50	Low HF (30 мВт/m^3) levels are typical for the region. HF reaches 50 мВт/m^2 towards the south-east of the Siyazan monocline, what's associated with fragmentation of the basement by deeply rooted faults of N-E direction
Absheron	23	74	88	20	90	Relatively high HF associated with the impact of faults of N-E direction, that supply deep-lying fluids
Baku Archipelago	15	66	75	30	50	The thermal background is mainly formed due to the combined effect of conductive well as convective components of HF
Low Kur	10	64	76	20	50	The thermal background is mainly formed due to a conductive component of HF
Shamakhi-Gobustan	6	80	100	70	99	High HT is caused by fragmentation of the basement transverse and longitudinal faults
Yevlakh Agjabedi	8	75	97	20	50	The thermal background is mainly formed due to convective component of HF
Ganja	8	99	129	30	70	High HT is caused by the presence of pre- Lesser Caucasian deep-seated from N-W to S-E

Table 3. Probable reserves of thermal waters in Precaspian-Guba zone.

Geothermal zones	Probable reserves, m^3/day	Heat power potential Q, cal/year	Fuel economy, ton/year
Yalama	3006	87774	17556
Khudat	13500	296935	52662
Begimdag-Tekchay	6918	163966	32793
Telebi	1153	23123	4625
Total	24576	511698	107586

Table 4. General hydro geologıcal and hydro chemical characteristics of the mıneral and thermal waters of the Absheron age aquifer complexes ın Precaspıan-Guba zone.

Well number on a map	Well location	Sampling interval	Water temperature, C (surface/depth)	Well flow rate, l/sec	Staticlevel, m	pH	Mineralization, gr/l	Ionic content (mg/l, mg-eq, % mg-eq)						Gas content, %	Microelements, mg/l
								HCO_3'	SO_4''	Cl'	Na'+K'	Mg''	Ca'		
3	Khachmaz region, in a forest slightly aside from the seaside, on Nabran-Yalama road	513-607	29/29	10,2	20,0	7,5	1,2	842 13,80 62,2	16,0 0,33 1,5	285 8,06 36,3	482,0 20,98 94,6	5,0 0,41 1,8	16 0,8 3,6	H_2S-1,2 CO-3,9 H_2-9,3 CH_4-7,4 N_2-63	I-0,5 Br-5,1 B_2O_3-18,1 SiO_2-20
5	Khachmaz region, east of Baku-Derbend railway, west of the Khanoba village	420-480	24/26	0,5	Gra-vity flow	-	0,5	878 6,20 69,0	74,0 1,54 17,8	42,0 1,18 13,2	180,0 7,85 83,8	10,0 8,82 8,8	13 0,7 7,4		
7	Khachmaz region, east of the Lejet village	412-442	25/25	3,0	2,5	8,4	0,3	256 4,19 70,0	58,0 1,20 18,0	29,0 0,81 12,0	84,0 3,65 54,4	13,0 1,05 15,8	40 1,09 30	H_2S-1,6 CO-2,1 H_2-1,9 CH_4-19 N_2-69,5	Br-0,3 B_2O_3-5 SiO_2-15 O_2-3,37 Al-0,76 As-0,02

9	Gusar region, on a bank of the Khanarkh channel, 1,5 km to the north-east of the Lejet village	338-456	23/28	93,0	40,3	7,4	0,3	322 5,28 80	52,0 1,08 16,0	11,0 0,8 4,0	53,0 2,3 34,8	23,0 1,89 28,6	50 2,5 37		
10	Khudat region, 1,8 km to the south-west from the Khudat station	500-525	25/29	7,0	40,5	8,95	0,4	244 4,00 53,2	120,0 2,49 33,0	37,0 1,05 13,8	111,0 48,6 64,5	12,0 0,98 13,0	34,0 1,69 22,5		SiO_2-10 O_2-4,14 CO_2-8 (free)
12	Gusar region, left bank of the channel, to the south west of the Lower Lejet village	715-765,5	28/40	28,0	40,0	-	0,6	246 4,03 42,0	205,7 4,27 44,0	47,1 1,33 14,0	164,2 7,13 75,0	1,0 0,08 0,5	46,8 2,33 24,5		Fe-0,02 SiO_2-10 As-0,02
14	Khachmaz region, 2 km to the north-west of the Khezri village	479-500	23/27	3,0	0,7	8,8	0,8	220 3,60 25,3	282,0 4,82 34,0	205,0 5,78 40,7	302,0 13,17 92,7	3,0 0,24 1,7	16,0 0,79 5,6	H_2S-2,5 O_2-2,0 H_2-4,7 CO-8,0 N_2-13,7	Br-0,4 F-0,16 B_2O_3-3 SiO_2-10
15	Khachmaz region, to the south-west of the Suduroba village	619-679	25/51	7,0	51,85	7,6	1,3	342 5,60 25,8	401,0 8,34 38,5	274,0 7,72 35,7	454,0 19,15 91,2	7,0 0,57 2,6	27,0 1,34 6,2		

Table 5. Characteristics of wells drilled for mineral and thermal waters of Precaspian-Guba Zone.

№	Area	Well №	Well depth	Well location	Test results			
					Filter, m	Flow- rate, m^3/day	Tempe- rature, °C	Mineraliza- tion degree, gr/l
1	Yalama	110	3003	Yalama settlement of Xachmaz region	2940-2840 2806-2622 1940-1755 1523-1440 1192-972	80 310 617 300 230	38 48 44 35 34	48 44 32 18 14
2	Yalama	111	1850	Salimoba village of Xachmaz region	1778-1464 1444-1147 1140-946		Sukhoy layer//41	Sukhoy layer//36,9
3	Nabran	6	1664	Nabran settlement of Xachmaz region	1609-1483 1403-1140 1124-981 880-732	210,7 200 30 117,2	36 34 28 27,5	44,5 9,9 4,2 1,8
4	Nabran	7	1845	Nabran settlement of Xachmaz region	1845-1516 1480-1250 1231-943 930-753	314,2 254,1 216,6 105,4	48 46 45 34	57,1 4,8 4,1 4,1
5	Nabran	9	1852	Nabran settlement of Xachmaz region	1810-1785 1676-1480 465-1287 1007-808	54 157 261,8 85	26 31 45 34	16,5 12,2 5,1 4,5

Table 6. The Basic performance of wells of geothermal waters of Azerbaijan.

<table>
<tr><th>Region</th><th>Field name</th><th>Well №</th><th>Test intervals, m</th><th>Produc- tion rate, m^3/day</th><th colspan="2">Tempe rature of water, ^0C</th><th colspan="2">Age</th><th>P_f, MPa (P_f\ $P_{cond.unit}$)</th></tr>
<tr><td rowspan="11">Precaspian- Guba</td><td>Yalama</td><td>1</td><td>3168-3157</td><td>5000</td><td colspan="2">87</td><td colspan="2">K_2</td><td>1,0</td></tr>
<tr><td></td><td>22</td><td>3216-3285</td><td>40</td><td colspan="2">100</td><td colspan="2">J_2</td><td>1,1-1,5</td></tr>
<tr><td></td><td>9</td><td>3140-3285</td><td>30</td><td colspan="2">100</td><td colspan="2">J_2</td><td>-"-</td></tr>
<tr><td></td><td>-</td><td>2370-2965</td><td>500</td><td colspan="2">100</td><td colspan="2">J_2</td><td>-"-_</td></tr>
<tr><td></td><td>17</td><td>3138-3965</td><td>500</td><td colspan="2">130</td><td colspan="2">J_2</td><td>-"-</td></tr>
<tr><td>Khudat</td><td>10</td><td>2461-2940</td><td>2000</td><td rowspan="5">17350 m^3\ day</td><td>98</td><td rowspan="5">50-96 ^0C on pour</td><td>J_2</td><td>-"-</td></tr>
<tr><td></td><td>11</td><td>2337-3215</td><td>6350</td><td>96</td><td>J_2</td><td>-"-</td></tr>
<tr><td></td><td>112</td><td>2603-2877</td><td>2500</td><td>97</td><td>J_2</td><td>28,6(1,04)</td></tr>
<tr><td></td><td>116</td><td>2730-2999</td><td>4500</td><td>100</td><td>J_2</td><td>-"-</td></tr>
<tr><td></td><td>20</td><td>2590-3038</td><td>2000</td><td>92</td><td>J_2</td><td>-"-</td></tr>
<tr><td></td><td>113</td><td>1895</td><td>234,7</td><td colspan="2">50</td><td colspan="2">N_2^2ps</td><td></td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Khachmaz</td><td>4</td><td>3671</td><td>5,0</td><td colspan="2">82</td><td colspan="2">K_2</td><td></td></tr>
<tr><td>115</td><td>2500</td><td>960</td><td colspan="2">59</td><td colspan="2">N_2^2ps</td><td></td></tr>
</table>

	Nabran	7	1245	304,4	48	N	
		12	1925	549	50	N_2^2ps	
		110	3005	456	82		
		111	1140	100,6	41	N_2^2ps	
Yevlakh-Agjabedi Kurda-mir	Murad-khanli	50	4171-4367	_	125	₽$_2$	51(1,2)
		33	4360	100	120	K_2	57,4(1,32)
		19	4258-4250	144	125	K_2	65,5(1,53)
		3	3236-3333	720	-	K_2	_
		44	4093-4061	160	148	K_2	56,08
		10	3987-3338	3	120	K_2	57,6
		70	3857-3875	11	145	K_2	61,2
		68	3903-3900	-	145		66,8
		12	4358-4279	-	120	K_2	72,5
		40	5010-4452	-	124,7	K_2	59,4
	Jafarli	7	3930-4802	-	118,1	₽$_2$	56,0
		33	4360-4130	-	120	₽$_2$	70,0
	Boz goubu	1	4991-4884	-	122,2	₽$_2$	70,0
	Amir-arkh	6	5387	-	139,4	K_2	75,5
	Zardab	1	4330-4367	430	-	K_2	68,0(1,55)
	Gara-jalli	1	3005-3483	890	-	K_2	-
	Sorsor	3	3618-3582	700	90	K_2	55,7(1,54)
		3	4000	20000	101	K_2	46,5(1,16)
		8	3920-3992	860	-	K_2	
		6	3995-3854	-	128	K_2	41,0
		1	4865-4490	-	100,9	K_2	67,9
	Duzdag	1	4163-4270	-	128	K_2	46,2(1,1)
		1	4506-4690	96	-	K_2	62,5(1,37)
	Agjabe-di	6	1771-1676	2000	18	K_2	1,0
Ganja	Delimemmedli	11	588-576	6000	76	N_2^2ps	~1,0

Absheron age deposits, have high pressure and are of sodium content [12]. The Kur lowland has fair supplies of thermal waters, it is possible to use them completely in a cost-effective way to heat the civil and industrial facilities, obtain chemically rare elements, and also in the balneal purposes.

Many wells drilled for oil and gas in Babazanan, Neftchala, Khilly, Mishovdag were void and stroke thermal waters, instead. There is a well 3 in Jarli field (Kurdemir region) with a depth of 3050 m and with a production rate of 20000 m^3/day and temperature reaching 100°C on the surface. Information on mineral and thermal waters for some regions is submitted below in Tables 1-6:

Conclusion

The geothermal conditions in the areas mentioned above change under general effect of many factors influential on the density of heat flow. The detected anomaly of a geothermal mode can be explained by the lithological structure of rocks, tectonic faults, mud volcanoes, and dynamics of underground waters.The deep faults create favorable conditions for heat conduction from internal areas of the earth to its surface, reshaping local thermal anomalies. The thermal waters of Azerbaijan, as a whole, are not involved in industrial development. They will be used with a primitive application for balneal purposes only. However, there is a positive experience, when at the end of the XX century 10 greenhouses with the use of thermal waters were built in Lenkeran, and crops are yielded 2 times a year in the abovementioned a greenhouses.

2 pilot farms were established at the end of the 60s of the last century in the Astara-Lenkeran-Masalli area, each of which possessed greenhouse with metal pipes of 40 mm-55 mm in diameter, where hot water circulated and heated air and soil. The spacing interval between adjunct pipes was approximately 100 sm. 5 greenhouses with a total area of 700 m^2 were constructed in the Masalli region. Water from drilled wells with temperature 44°C-60°C and total production rate of 5 1/sec-6 1/sec. Cucumber and tomato sprouts were planted in December 1967 and crop was obtained in March 1968.

In Alashin-a region of thermal sources (Astara region)-4 greenhouses with a total area of 1000 m^2 were constructed. Water, with temperature 45°C-58°C and total production rate 15 1/sec-18 1/sec. Sprouts of tomato and cucumber had been planted in 1968, the crop is obtained at the beginning of May. The first experience of usage of thermal waters for heating of greenhouses has shown large prospects of the method and also the capability of obtaining 2 crops-3 crops annually at minimum costs.

It is necessary to separately note that there are more 1000 natural outputs of mineral waters in Azerbaijan. More than 50% of these sources have temperatures more than 42°C, which demonstrates their considerable temperature at depth and mixing of thermal waters with cold waters in the upper horizons.

The usage of underground mineral waters in Azerbaijani resorts play an important role in recovery capacity for people suffering from diseases, such as, to be necessarily noted, atherosclerosis, idiopathic hypertension, coronary failure etc., and several valuable fields of mineral waters have temporarily remained in lands occupied by Armenia. All the above mentioned give grounds for a statement on the necessity of acceptance of complex measures on the involvement of huge resources of underground mineral and thermal waters of Azerbaijan in the national economy. Underground waters, including, mineral and thermal waters, are invaluable in the development of the chemical industry. They can be utilized to obtain several chemical agents (boric acid, iodine, bromine, strontium, etc.). Some water deposits in Nakhchivan (Sirab, Daridag) already produce carbon dioxide. Taking into account the high concentration of rare chemical elements (arsenic, lithium, antimony, selenium) their production is possible as well. Thermal waters can be used in heating civil and industrial premises (T=40°C-60°C). It was put into practice in the Talish-Lenkeran region while heating greenhouses and administrative premises using waters with temperatures 40°C-66°C, production rate 160000 m^3/day from the depth of 200 m-1000 m.

These waters can be widely used for curing various diseases. They are currently being used in low volume in Kalbajar (Istisu), Masalli (Yeddi Gardash), Kurdemir (Jarli), Shamakhi (Chukhur-Yurd). Extraction of I, Br, B, Sr, Mg, and other chemical elements from thermal waters is commercially advantageous. Electrical energy can be produced from waters with temperatures above 80°C (Jarli, Precaspian-Guba, etc.). The presence of thermal waters distribution patterns in time and space associated with tectonic faults and magmatic processes has been proven from the scientific point of view. These waters are the source of reliable information in the elaboration of the history of geologic development of the area, which cannot be denied.

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