MINERAL WATERS IN BULGARIA

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Abstract: The present study aims to review the sources of mineral water in Bulgaria, as well as the various aspects of their use as an energy source, benefit for human health and the national economy. Several literary sources on the subject are cited. Statistical analysis was performed and data were summarized about their physical and chemical characteristics, and especially to find distribution by temperature. The production of cheap thermal energy from the geothermal plants contribute to the reduction of the environment pollution, which is of great importance for the country. The extremely good bio-climatic resources in the country provide a base for the prospective development of the balneological branch. The barriers to geothermal development in the country are shown. It is concluded that the importance of geothermal energy from mineral waters in Bulgaria is underestimated.

Keywords: mineral waters, energy, temperature, human health.

INTRODUCTION

Romans and ancient Bulgarians have builded up baths and have used mineral springs on the territory of Bulgaria. Only in the first half of 20th century studies of mineral waters' properties and classification of the sources have been initiated [19]. There, a definition of mineral water is given as: water originating from a water source, the use of which causes certain changes in the human organism that have a beneficial effect on it. This action can originate from the minimal amounts of mineral salts and from the emanations that act both when they are separated (in status nascendi). In this study, 52 sources of mineral water on the territory of Bulgaria are described along with a detailed description of their temperature and chemical composition. There is also an index with 35 diseases and the mineral springs that treat them are indicated.

There are extremely good bio-climatic resources which combined with the existing ancient Mediterranean traditions in thermal water use, provide a base for the balneological development in Bulgaria [1]. Geothermal development in Bulgaria has not marked a significant progress in last five years. It has been a time of testing and completing the new legislation concerning thermal waters and geothermal energy use [2].

The application of thermal water for space heating hasn't marked a significant progress for several reasons. These barriers are related to the harmonization of new legislation governing this activity, the complicated and time-consuming procedure for obtaining permits or concessions, and the lack of investment interest in constructing new heating systems. Great progress has been made in the policy related to promotion of renewable sources development in Bulgaria, but it is focused mainly on wind and solar energy [3].

Use of several statistical methods such as Quadrat analysis [21], Cluster analysis [24] and Geographic Information Systems has allowed revealing spatial distribution and spatial structure of mineral waters sources in Bulgaria [22]. The study rejects the hypothesis of random dispersion of mineral springs over the country's territory in favor of the alternative – more clustered, than the random model.

Chemometric expertise of Bulgarian mineral, spring and table waters shows that the chemical composition of spring waters strongly differs from that of the mineral waters from the same locations. The separation is obviously related to the specificity of the local origin of the waters, e.g. crustal and soil properties and composition [6].

Detailed investigations of the natural radioactivity of the mineral springs widely used by the people in the territory of South-Western Bulgaria have been carried out by scientists from the Institute for Nuclear Research and Nuclear Energy of BAS (INRNE). The investigated mineral springs from Southwest Bulgaria meet the Bulgarian drinking water standards and are suitable for consumption by the population. Their use in peoples' households does not pose any risks to their health, as there is no increase in the level of radioactivity [7].

Helium content in the waters can be a reliable and independent indicator for thermal water prospecting. Based on the large number of analysis for the region of Southern Bulgaria it is established that only thermal waters and their derivatives contain helium. It was found that dissolved helium is correlated with the temperature, the TDS of the waters, the lithological type and the geological age of the rocks, as well as by other factors [10].

Bulgaria has significant thermal water resources – about 4600 L/s or thermal energy amounting to 315 MWt, not including the deep waters in the artesian aquifers in Northern Bulgaria. It is recommended to

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use part of the unexploited geothermal resources (about 70% or more than 200 MWt thermal power). More efficient management of water sources, qualities and quantities of mineral waters is necessary. Recapturing the outdated water sources is recommended [8].

Natural mineral waters are characterized by specific mineral content and are classified on the basis of the main elements that compose them. Several authors explored the properties and health effects of mineral waters, sometimes through not updated studies or with low number of subjects. Gastrointestinal system results to be stimulated by natural mineral waters. In particular, bicarbonate and chloride mineral waters proved to have positive effects for gastric function. Skeletal health and bone mineralization need a regular calcium intake and calcic mineral waters represent an important dietary source of calcium and should be recognized as good low-calorie nutritional calcium supplements [20].

The major factors promoting geothermal development in Bulgaria are the long existing tradition in thermal water use, favorable climate, and appropriate thermal water composition for therapy; as well as for bottling of potable water and soft drinks and a well-developed spa system. There has been a significant growth in building of hotels in the mountains and in the seaside resorts [9].

The adoption of the new concept concerning the utilization of thermal waters for different purposes, including space heating, (the Concession law), opens up broad vistas to the development of the geothermal energy utilization in the country (see Table 1). The increase of foreign investments from some World Financial Institutions aimed for the numerous spas in Bulgaria create more favorable conditions for the expansion of the geothermal market. Besides the production of cheap thermal energy, the geothermal plants contribute to the reduction of the environment pollution, which is of great importance for the country [11].

Table 1. Geothermal installed capacity in Bulgaria by region

No	Region	Installed capacity MWt	Produced energy TJ/year	TOE/year
1	Montana	05	72	1 721
2	Vratsa	00	00	00
3	Pleven	20	290	6 931
4	Lovech	34	493	11 783
5	Gabrovo	00	00	00
6	Veliko Tarnovo	66	957	22 872
7	Rousse	00	00	00
8	Targovishte	00	00	00
9	Razgrad	00	00	00
10	Silistra	00	00	00
11	Shoumen	18	261	6 238
12	Dobrich	87	1 262	30 162
13	Varna	245	3 554	84 941
14	Bourgas	115	167	3 991
15	Jambol	05	72	1 721
16	Sliven	135	196	4 684
17	Stara Zagora	23	334	7 983
18	Haskovo	29	421	10 062
19	Kardzali	00	00	00
20	Plovdiv	27	392	9 368

21	Smoljan	11	159	3 800
22	Pazardzik	146	2 118	50 620
23	Sofia	40	580	13 862
24	Pernik	02	29	693
25	Sofia city	40	580	13 862
26	Blagoevgrad	88	1 276	30 496
27	Kjustendil	425	616	14 722
	Total	**9 535**	**13 829**	**330 512**

Hristov [12] presents some problems concerning more rational and full application of the available geothermal resources, as well as the management of the existing geothermal resources to protect mineral water from contamination. A brief information is provided on a new environmental technology for the use of geothermal energy, developed by the Canadian company "Eavor". This technology could be applied in the near future in a number of areas in Central North and Northwestern Bulgaria where geological conditions are similar.

The low-enthalpy hydrothermal resources in Bulgaria have potential for future development as direct application. The existing know-how in geothermal energy use for space heating and air-conditioning, combined with the new administrative regulations, will provide better conditions for the utilization of these renewable sources. The application of ground source heat pumps will likely continue to grow and balneotherapy will preserve its leading role [18].

As a result of the survey, a conceptual model was proposed for rational utilization of the mineral waters and the main reason for directing the attention towards the abilities of the theory of the traditional expenses in the utilization of the mineral water is the application of the transaction approach in determining the concession component in the structure of the lease agreements for extraction of the underground resources [26].

Major current barriers for the geothermal development in the country remain the same: Lack of preferential status to the use of geothermal energy for heat production; Lack of expertise in preparation of exploration and business plan. Insufficient commercial financing. Local taxes and fees are important but very insufficient source of funds for the Municipalities budgets. Lack of investments and organizational problems are still the major obstacles for the geothermal development in the country [4].

Nevertheless, natural mineral waters have intrinsic demonstrated properties and this review intends to explore them and their wide proved effects on the energy, health and the environment.

MATERIALS AND METHODS

Economically beneficial resources from renewable energy sources are solar radiation, wind energy, biomass, hydropower and geothermal energy from mineral springs. In a study on the possibilities of using renewable energy sources in Bulgaria [5], it is indicated that the total quantity of geothermal energy is unknown and it is less than 0.1% from the reserve energy potential for this country. The main technologies for the use of geothermal energy in Bulgaria are balneotherapy and heating of buildings.

According to Bulgarian legislation, mineral waters are used by granting a concession or issuing a permit for water abstraction in accordance with the Water Act by the relevant competent authority (director of the Basin Directorate or mayor of a municipality). The most significant deposits with proven qualities of mineral waters, are exclusive state property. They are 102 in number and are exhaustively listed in Schedule 2 of the Water Act. The remaining deposits and manifestations of mineral water are public municipal property [16].

NIMH has a water source monitoring network. Fig. 1 shows a map of groundwater monitoring stations and points [17]. Overview of geothermal resources and activities in Bulgaria is presented in the publication Atlas of geothermal resources in Europe [23].

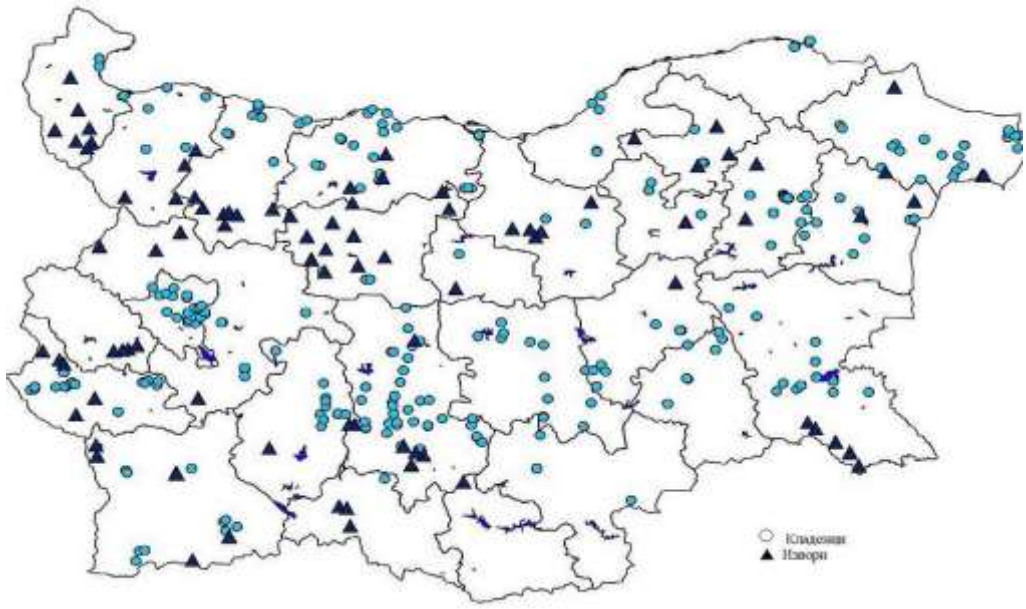

Fig. 1. Map of the stations and points for monitoring of groundwaters

Statistical analysis of mineral waters aims to describe and summarize data about their physical and chemical characteristics, and especially to find distribution by temperature. Data from 146 sources (natural springs) are object of the analysis [13; 14; 15] and other sources. The following physical and chemical characteristics have been analyzed: Capacity (l/s), Temperature (°C), Acidity (pH), Hardness (H°), Mineralization (g/l), Chemical composition – HCO_3+CO_3, SO_4, Cl, Na+K, Ca, Mg, Si, F (g/l) and Rn (nCi/l). Such set of data is sufficient for reliable inferences and conclusions.

RESULTS AND DISCUSSION

After processing of the available data results of the physical and chemical characteristics are given in Table 2.

Table 2. Descriptive statistics of mineral waters (N=146)

Variable	N	Mean	Median	Min	Max	Std.Dev.	Skew.	Kurt.
Capacity	142	13.8	6.0	1	101	18.18	2.379	6.543
t	145	36.0	31.0	8	101	20.64	0.977	0.448
Mineral	146	3230.7	675.5	101	121065	12273.37	7.499	63.675
pH	146	8.5	7.7	3	101	7.79	11.689	139.704
CO3	146	349.7	243.5	0	2075	365.64	2.395	7.344
SO4	146	342.9	74.0	0	4444	734.54	3.692	14.571
Cl	146	1338.5	24.5	2	73482	7400.58	7.738	67.236
Na+K	146	892.8	141.5	2	39139	4012.76	7.440	62.285
Ca	146	161.2	30.0	1	6297	590.87	8.471	82.785
Mg	146	55.1	5.7	0	896	143.69	4.027	17.048
Si	146	44.5	38.0	1	208	29.96	1.533	4.950
F	146	4.6	2.5	0	101	9.12	8.394	87.090
Rn	110	4.7	0.0	0	110	15.52	5.535	33.016
H	146	35.0	6.0	0	1086	109.79	7.107	61.013

One of the most important characteristics of mineral deposits is the temperature of their water. In the study, they are divided into the following categories (see Table 3).

Table 3. Distribution by temperature

Type	Temperature (°C)	Sources (number)	Capacity (l/s)	Part of total capacity (%)
Cold	< 20	37	47	2.5
Hypothermal	20 - 34	26	532	28.8
Hyperthermal				
little hot	37 - 42	14	220	11.9
moderately hot	43 - 50	20	498	26.9
very hot	> 50	28	552	29.9

The following Tables 4 to 7 show the sources of mineral water by category: cold, hypothermal, little and moderately hot, and very hot mineral waters. The location and district of the deposit are indicated, as well as the capacity, temperature, mineralization and acidity.

Table 4. Cold mineral waters

	Location	Capacity	t	Mineral	pH
Cold	Bogatovo (Gbr)	1	8	1537	8.4
	Boianovo (Yamb)	1	12	11271	7.3
	Breznik (Pk)	1	12	6334	3.2
	Bulgarene (Plv)	2	12	5981	7.8
	Chukovo (Gbr)	1	12	1201	7.3
	Gorni Lom (Vdn)		12	2293	6.4
	Slivek (Lv)	1	12	1289	8.8
	Vardun (Trg)	1	12	672	7.6
	Beronovo (Bs)	1	13	582	7.3
	Jeravna (Slv)	1	13	818	7.9
	Smochan	1	13	992	8.8
	Voneshta voda (VT)	4	13	1275	6.7
	Triavna	1	14	1052	7.5
	Chukovec (Sls)	1	15	2193	7.0
	Devenci (Plv)	1	15	5928	8.0
	Dlagnevo (StZ)	1	15	3073	6.6
	Dragoevo (Sch)	3	15	1503	8.8
	Gorno uino (Knd)	1	15	2241	2.6
	Inzovo (Yamb)	1	15	2847	7.0
	Nova Varbovka (VT)	1	15	3098	7.5
	Pchelarovo (Krj)	1	15	1348	7.2
	Pelovo (Plv)	1	15	3742	4.2
	Radomirci (Plv)	1	15	1832	7.4
	Starosel	1	15	766	8.3
	Varbica (Sch)-izvor	1	15	1378	7.0
	Varbica (Sch)-sondaj	1	15	13105	7.7
	Vozarci (Dbr)	1	15	731	7.7
	Granitovo (Yamb)	1	16	1723	6.7
	Oriahovica (Plv)	1	16	1355	7.4
	Yambol	5	17	2180	7.0
	Alexandrovo (Sch)	1	18	973	9.2
	Boliarovo (Yamb)	1	18	1591	7.3
	Enchevci (Gbr)	1	18	1293	8.6
	Seslav (Rzg)	1	18	1372	6.8
	Banichan (Blg)	1	19	308	7.5
	Pravo burdo (Blg)	1	19	1671	6.3
	Shipkovo (Lv)	1	19	2476	7.2
	Pravdino (Yamb)	1	19.5	406	10.0

Table 5. Hypothermal mineral waters

	Location	Capacity	t	Mineral	pH
Hypothermal	Bankia (Pk)	36	20	417	7.3
	Dolno Botevo (Hsk)	1	20	485	8.2
	Harmanli (Hsk)	3	20	4414	7.6
	Klisura (Pd)	10	20	328	7.8
	Vlahovo (Sml)	5	20	288	7.4
	Balchik	12	21	622	7.5
	Kirkovo (Krj)	1	21	291	7.5
	Stefan Karadjovo	13	21	1473	6.4
	Bansko	3	22	202	7.5
	Goliama fucha (Knd)	1	22	2210	7.7
	Musomishte (Blg)	75	22	355	7.4
	Voiniagovci (Sf)	1	22	463	7.5
	Zlatna Panega	3	22	587	7.3
	Belovo (Pz)	80	24	551	7.0
	Sindel (Vn)	5	24	710	7.4
	Dolno Ezerovo (Bs)	3	25	9533	9.7
	Varbina (Sm)	40	25	239	7.6
	Bachevo (Blg)	6	26	222	8.7
	Burgas	5	26	1309	7.6
	Mihalkovo (Sm)	15	26	3406	6.1
	Narechen (Sm)	5	26	1558	7.3
	Varna - Akvariuma	1	26	673	7.8
	Bojurishte (Sf)		27	439	7.8
	Bracigovo (Pz)	3	27	466	7.2
	Belotinci (Mon)	2	28	907	7.9
	Elenov dol (SfO)	1	28	975	7.9
	Krichim (Pd)	20	28	788	7.3
	Rudarci (Prk)	15	28	300	9.1
	Georgi Traikov (Vn)	1	29	12180	7.6
	Albena (Dbr)	6	30	614	7.4
	Staro Jelezare	3	30	299	8.3
	Birimirci (Sf)	1	31	3232	7.5
	Dolni Rakovec (Prk)	20	31	462	7.4
	Jeleznica (Sf)	20	31	278	9.5
	Kniajevo (Sf)	10	31	119	9.4
	Spanchevci	5	31	175	8.8
	Varna - Zlatni piasaci	42	31	560	7.5
	Barzia (Mon)	20	32	271	9.4
	Djebel (Krj)	12	32	574	6.9
	Gradec (Vdn)	10	32	4361	7.3
	Ovcha kupel (Sf)	8	32	1188	7.0
	Stoletovo	2	32	217	8.7
	Voivodinovo (Pd)	6	32	500	8.3
	Salmanovo (Sch)	1	34	1331	7.3

Table 6. Little and moderately hot mineral waters

	Location	Capacity	t	Mineral	pH
Little Hot	Bankia (Sf)	24	37	280	9.6
	Gorna Breznica (Blg)	3	37	558	8.6
	Miromir (Pd)	2	37	323	8.8
	Varshec	15	38	194	8.7
	Asenovgrad	34	39	1407	7.6
	Bania (Pd)	30	40	348	9.2
	Bania (Pz)	20	40	635	7.7
	Belchin (SfO)	10	40	312	9.5
	Dobroslavci (Sf)	2	40	1360	7.9
	Bania (Bgs)	36	41	604	9.9
	Ladja -Banite (Sm)	5	41	913	7.1
	Yagoda	9	41	625	8.6
	Gorna bania (Sf)	10	42	148	9.7
	Starozagorski bani	20	42	498	6.9
Moderately Hot	Dobrinishte (Blg)	20	43	309	9.0
	Merichleri (Hsk)	12	43	6328	6.9
	Ognianovo (Blg)	70	43	222	9.1
	Aitos	7	44	441	9.9
	Devin (Sm)	83	44	223	9.4
	Ovoshtnik (StZ)	20	45	502	8.4
	Georgi Dimitrov (SfOk)	15	46	249	9.2
	Gorni Bogrov (Sf)	2	46	1288	7.9
	Hisaria (Pd)	35	46	254	8.9
	Kostenec (SfO)	15	46	249	9.2
	Sofia - Centar	16	46	302	9.4
	Strelcha	18	46	288	8.8
	Varna - Drujba	43	46	592	7.2
	Vidin	5	46	57346	6.8
	Pancharevo (Sf)	12	48	495	7.1
	Pavel bania (StZ)	16	48	650	7.6
	Slivenski bani (Slv)	17	48	1986	6.8
	Velingrad-Chepino	62	48	187	9.2
	Korten (Slv)	12	49	905	7.9
	Varna - Asparuhovo	18	50	611	7.8

Table 7. Very hot mineral waters

	Location	Capacity	t	Mineral	pH
Very Hot	Varna - sondaj P-1x	22	52	620	7.2
	Dolno Osenovo (Blg)	8	55	560	9.0
	Krasnovo (Pd)	14	55	324	9.1
	Blagoevgrad	30	56	678	8.1
	Eleshnica (Blg)	25	56	302	9.2
	Haskovski bani (Hsk)	35	56	1571	6.9
	Bania (Blg)	65	57	327	9.4
	Oshtava (Blg)	5	58	402	8.6
	Blagoevgrad-zapad	5	60	1077	9.1
	Velingrad-Ludjene	35	60	317	9.2
	Simitli (Blg)	27	62	599	8.8
	Marikostinovo (Blg)	20	63	1031	7.3
	Dolna bania (SfOk)	25	64	623	9.0
	Bobov dol (Kn)		65	2058	8.2
	Dolni Dabnik (Plv)	10	65	121065	6.2
	Momin prohod (SfO)	15	65	964	7.7
	Gomotarci (Vdn)		67	56618	6.5
	Gradeshnica (Blg)	10	68	548	8.6
	Kiustendil	33	73	678	8.9
	Pchelinski bani (SfO)	12	73	921	8.0
	Beden (Sm)	12	76	1626	6.6
	General Todorov (Blg)	35	76	2134	6.8
	Sapareva bania (Knd)	19	79	707	9.4
	Sandanski (Blg)	21	81	653	7.7
	Dalgodelci (Mon)	4	90	36067	6.4
	Varvara (Pz)	20	90	773	8.3
	Velingrad-Kamenica	30	90	551	8.3
	Velingrad-Draginovo	15	94	648	8.2

Below in Fig. 2 are given locations of very hot mineral waters with their temperature (^{o}C). Most of them are in south-western part of Bulgaria.

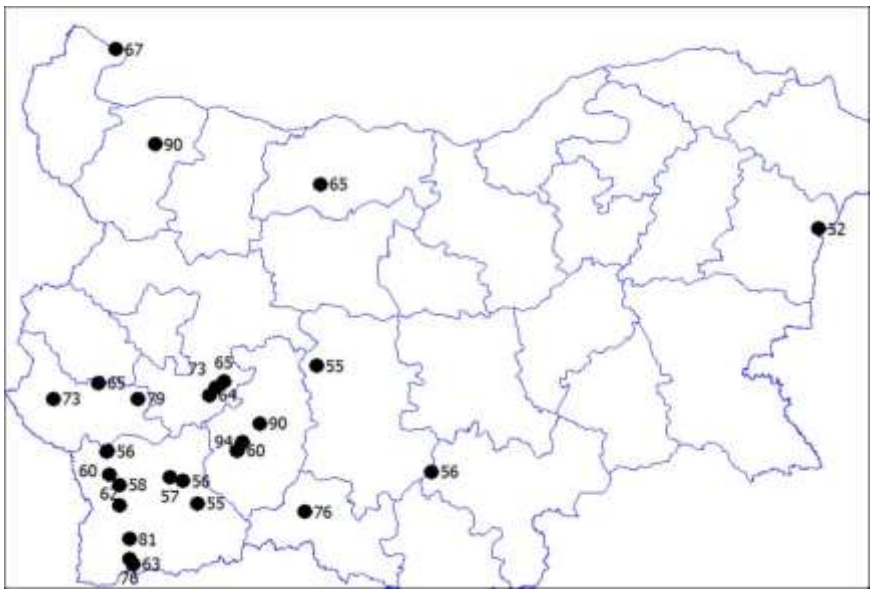

Fig. 2. Map of very hot mineral waters.

The Assessment shows that Bulgaria's rich geothermal energy resource base can be tapped extensively and sustainably to achieve real contribution in energy sector. This is a viable technology for thermal use and this would provide important environmental benefits through the reduction of carbon dioxide emissions [25].

CONCLUSIONS

The result of present study indicates more perspectives for geothermal energy from mineral water sources. The major factors promoting geothermal development in Bulgaria are the long existing tradition in thermal water use, favorable climate, and appropriate thermal water composition for therapy; as well as for bottling of potable water and soft drinks and a well-developed spa system. The study confirms that the significance of geothermal energy from mineral waters in Bulgaria is underestimated. More efficient management of water sources, qualities and quantities of mineral waters is necessary.

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