

Thermomineral Waters Complex Use and Heat Supply for the Town Velingrad (Bulgaria)

Valentina Svalova and Stojka Tetimova
IEG RAS, Ulansky per., 13, Moscow 101000, Russia
inter@geoenv.ru

Keywords: Thermal waters, complex use, heat supply, Russia, Bulgaria

ABSTRACT

Geothermal energy use is the perspective way to clean sustainable development of the world. Russia has rich high and low temperature geothermal resources and makes good steps in their use.

The most perspective direction of usage of low temperature geothermal resources is the use of heat pumps. This way is optimal for many regions of Russia - in its European part, on Ural and others.

Electricity is generated by some geothermal power plants (GeoPP) only in the Kamchatka Peninsula and Kuril Islands.

There are two possible forms of utilization of geothermal resources depending on structure and properties of thermal waters: heat/power and mineral extraction.

The mineral-extraction direction is basic for geothermal waters, containing valuable components in industrial quantities. The most significant deposits of thermal waters represent the brines containing from 35 up to 400 and more g/l of salts. They are mineral raw materials for many chemical elements.

1. INTRODUCTION

Thermal waters are used for many purposes - for the development of electric power, central heating and cooling, hot water supply, in agriculture, animal industries and fish culture for the food, chemical and oil-extracting industry, in balneology and spa for the recreational purposes.

In Russia, the geothermal resources are used predominantly for heat supply of several cities and settlements on Northern Caucasus and Kamchatka. Besides in some regions of the country the deep heat is used for greenhouses. Most of the hydrothermal resources are used in the Krasnodar territory, Dagestan and on Kamchatka.

At the same time, the problem of the most effective utilization of a natural source of raw materials is put forward in the category of actual tasks, including thermomineral waters and brines. Involving these waters in economic activities can promote the decision of some social - economic and environmental problems.

2. GEOTHERMAL ENERGY USE

In Russia, the geothermal resources are used predominantly for heat supply of several cities and settlements on Northern Caucasus and Kamchatka with a total population of 500,000. In some regions of the country the deep heat is used for greenhouses of common area 465,000 m². Most of the hydrothermal resources are used in the Krasnodar territory, Dagestan and on Kamchatka. (Gadzhiev et al., 1980, Kononov et al., 2000, Svalova, 1998-2008). Approximately half of the extracted resources is applied for heat supply of habitation and industrial puttings, a third to heating of greenhouses, and about 13 percent for industrial processes. The thermal waters are also used at approximately 150 health resorts and 40 factories on bottling mineral water. The quantity of electrical energy developed by geothermal stations of Russia, per 1999, almost twice has increased as contrasted to by former level. Nevertheless, it remains extremely minor, making some 0.01 percent of the electric power in the country.

The Western Siberian plate is another promising region for direct use applications. The aquifers located down to 3 km in this region have a high hydrostatic pressure, temperatures of up to 75°C, and are capable of producing about 180 m³/s. These waters are used to heat dwellings in some small settlements and, on a small scale, assist in the recovery of oil, the extraction of iodine and bromide, and for fish farming. The region is rich in natural gas, which has limited geothermal development.

The most perspective direction of usage of low temperature geothermal resources is the use of heat pumps. This way is optimal for many regions of Russia in its European part, on Ural and others.

Heat pumps are at an early stage of development in Russia. An experimental facility was set up in early 1999 in the Philippovo settlement of Yaroslavl district. The source supplies 5-6°C to eight heat pumps that heat the water to 60°C for a 160-pupil school building. There are some buildings with supply of heated water, using heat pumps, in Moscow (Figures 1 and 2).



Figure 1: Moscow, Anokhina Str., 50. House for pilot heat-pump installation. (Photo of Svalova V.)



Figure2: Moscow, Anokhina Str., 62. House with heat-pump supply. (Photo of Svalova V.)

Electricity is generated by some geothermal power plants (GeoPP) only in the Kamchatka Peninsula and Kuril Islands. At present three stations work in Kamchatka: Pauzhetka GeoPP (11MW_e installed capacity) and two Severo-Mutnovka GeoPP (12 and 50 MW_e). Moreover, another GeoPP of 100 MW_e is now under preparation in the same place. Two small GeoPP are in operation in Kuril's Kunashir Island and Iturup Island with installed capacity of 2.6 MW_e and 6 MW_e respectively.

Russia has considerable geothermal resources and the available capacity is far larger than the current application. This resource is far from adequately developed in the country. In the former Soviet Union, geological exploration was well supported for minerals and oil and gas. Such expansive activities did not aim to discover geothermal reservoirs even in a corollary manner; geothermal waters were not considered among energy resources. Still, the results of drilling thousands of "dry wells" (in oil industry parlance), brings a secondary benefit to geothermal research. These are the abandoned wells themselves, and the data on the subsurface geology, water-bearing horizons, temperature profiles, etc., that were collected during exploration. Not all currently operating companies are willing to disclose their well data, still, in face of the cost of maintaining shut-in wells, it is cheaper to turn them over to others for new purposes.

Development and implementation of geothermal power technology is facilitated by social, scientific, economic and environmental aspects.

Social aspects reflect public opinion and willingness to reject old, traditional power generating methods and implement new, non-traditional, environmentally friendly geothermal power technology.

Nowadays the scientific and technical level of geothermal technology is very high in Russia. Unique geothermal power equipment has been developed domestically and for the first time in the world two environmentally friendly power plants were constructed in Kamchatka, In 1999 the unique pilot Verkhne-Mutnovsky GeoPP (V-MGeoPP) of 12 (3x4) MW was constructed (Figures 3 and 4).



Figure 3: Verkhne-Mutnovsky GeoPP. First ecologically clean GeoPP (Photo of Svalova V.).



Figure 4: Verkhne-Mutnovsky GeoPP. (Photo of Svalova V.)

It has been operating in extremely severe climatic conditions on the site located about 1000 m above sea level. A high level of environmental protection is provided due to isolating the geothermal fluid from the environment by using both air condensers and a system of full re-injection of the waste geothermal fluid back into reservoir. The major problem of protecting the GeoPP equipment from corrosion and salt depositions was solved by using a special technology of film-forming amine additives. Over the last years the V-MGeoPP has proved sustained reliability in generating reasonably priced electricity of about 1.5 cents/kWh (Nikolski, and Parshin, 2003). The experience gained while constructing and operating the V-MGeoPP was used for construction of the 50 MW Mutnovsky GeoPP (MGeoPP), a completely automated power plant with a satellite-based communication and control system (Figures 5, 6 and 7).



Figure 5: Mutnovsky GeoPP. (Photo of Svalova V.).



Figure 6: Mutnovsky GeoPP. Primary separators provide MGeoPP with the high-quality steam. (Photo of Svalova V.).



Figure 7: Mutnovsky GeoPP. The main entrance. (Photo of Svalova V.).

The economic impact from geothermal power plants is especially high in remote locations. As there is practically no detrimental gases emission, modern GeoPPs can be considered as practically absolutely environmentally friendly (Tomarov, Bubon, and Martynova, 2003).

3. THERMAL WATERS COMPLEX USE

Thermal waters are used for many purposes, for the development of electric power, central heating and cooling, hot water supply, in agriculture, animal industries, fish culture for the food, chemical and oil-extracting industry, in balneology and spa for the recreational purposes.

Thermal waters, especially chloride brines, contain in its structure a huge complex of metal and nonmetallic microcomponents. The saturation of brines microcomponents is in close dependence both on genetic essence of brines, and on lithological-structural and geothermal features of containing breeds.

Interest to geothermal waters and brines as mineral raw material is connected to a number of advantages of this kind of raw material in comparison with firm sources of rare elements, metals and mineral salts.

Industrial underground waters are characterized by wide regional distribution and big geological and exploitation stocks. They are polycomponental raw material and simultaneously can be used in balneology and power system. Extraction of this raw material demands realization concerning small capital works and is carried out by boreholes methods, allowing to take hydro mineral raw material from the big depths.

Geothermal waters and brines are characterized by the variety of mineralization, chemical compound, the contents of useful components and their quantitative ratio, and also gas structure and temperatures. The most widespread types of hydro mineral raw material are: thermal brines of intercontinental rift zones; thermal waters and brines of island arches and areas of Alpine folds; waters and brines of artesian pools; brines of modern evaporate pools of a sea or oceanic origin and continental lakes; sea waters .

Profitability of industrial reception of those or other components from hydro mineral raw material is determined not only by their concentration, but also by depth of underground waters and operational chinks, filtration properties of rocks, flow rate of operational stocks etc. On economic parameters of operation the way of discharge of the fulfilled waters that defines expenses for protection of the natural environment essentially influences.

Proceeding from the general conditions and laws of distribution of underground geothermal waters and the brines containing rare elements, and also in view of the experience of use of such waters as hydro mineral raw material in Russia and abroad the following limits of concentration of elements at which waters represent industrial interest are established (mg/l): iodine - 10, lithium - 10, cesium - 0.5, germanium - 0.5, bromine - 200, rubidium - 3, strontium - 300. (Bondarenko, 1999).

Even before the Second World War abroad, in particular, in USA, the technology of extraction from hydro mineral raw material of one of its components - lithium was developed. In 1970s years about 85 % of world extraction of this metal was carried out in such a way. (Kogan and Nazvanova, 1974).

In Japan, the following are commercially extracted from geothermal underground brines: I, Br, B, Li, As, Ge, W and a number of mineral salts. In Israel the brines from the Dead Sea, carnallite, bromine, chlorides of magnesium and calcium, and also raw material for manufacture of medical products and perfumery are produced. In the 1980s 30% of the world extraction of lithium, 31% - cesium, 8% - a boron, 5% - rubidium, and also in significant scales Ca, Mg, Na, K, S, Cl, U, Ra, Cu was from hydro mineral raw material (Bondarenko, 1999). Huge stocks of rare-metal raw material are in geothermal underground waters and brines on territories of Russia and the CIS (Commonwealth of Independent States). They contain over 55% of the common stocks of lithium, 40% of rubidium and 35% of cesium. (Kremenetsky et al., 1999)

Thermal waters with a high mineralization are located in the greater territory of Russia and the former USSR. They are known almost in all areas. Brines with mineralization higher than 200 g/l are known in Perm and Kujbishev areas, Tatarstan, Moscow, Ryazan and other central areas. In Moscow, for example, on a depth of 1650 m are chloride brines with mineralization of 274 g/l. In Western and Eastern Siberia there are large deposits of brines with high temperature. Some deposits have mineralization of 400-600 g/l. There are many thermal brines in Central Asia, Kazakhstan, on Ukraine, Kamchatka, Kuriles, Sakhalin. (Shcherbakov, 1985, Kurbanov et al., 1985, Kurbanov, 2001).

There are chemical elements which are possible for taking only from underground waters. So iodine is extracted from brines since iodine is good dissoluble and in breeds iodine does not collect. Iodine concentrates in sea seaweed but to extract this seaweed as industrial raw material is effectively only at their big congestion. Bromine can be extracted from some salts and seaweed, but traditionally bromine also is extracted from superstrong chloride brines. (Antipov et al., (1998)).

The significant part of deposits of thermal waters represents the brines containing from 35 up to 400 and more g/l of salts. They are mineral raw material on many chemical elements. Many brines which are taking place on the big depth, can become deposits of the most valuable chemical elements: cesium, boron, strontium, tantalum, magnesium, calcium, tungsten etc. Under the cheap technological circuit from natural solutions basically it is possible to take iodine, bromine, boron, chloride salts of ammonium, potassium, sodium, calcium, magnesium. Extraction of other chemical elements is complicated because of dearness of technology. A perspective method is use of ion-exchange pitches for selective extraction of the certain components from natural waters. In a basis of a method there is the principle of selective sorption of ions of useful elements or their complexes in solutions with special compounds.

Works of some scientific institutes in Russia allow to create the processes of chemical processing of hydromineral raw material and to expand spheres of its economic application. Many laboratory and natural tests on extraction of valuable components from thermal waters confirm the necessity and an opportunity of complex use of this nonconventional raw material.

It is planned to recover I, Br, KCl, CaCl, NaCl from brines in Yaroslavl area. New methods of mineral and valuable elements extraction from industrial solutions are developed on the basis of biosorbent use.

4. THERMOMINERAL WATERS OF BULGARIA, VELINGRAD

There are more than 3250 mineral springs in Bulgaria with different chemical compounds and temperature (from 10 oC to 100 oC). Mineral waters in Bulgaria are used for medical treatment, prophylactic and consumption. The warm and hot mineral waters in Bulgaria are **natural energy source** for heating buildings, greenhouses, and so on. They are used in **everyday living** - washing, baths, etc. They are useful for agriculture - for watering crops, which can play a positive bio-stimulating role, for making nonalcoholic beverages, which make them healthier and preferred by the people. There are many spa resorts in Bulgaria. One of the most famous is Velingrad, spa capital on the Balkan.

Velingrad is the best mountain balneology resort in Bulgaria. The resort of Velingrad is located between the Rhodope and Rila mountains at 700 - 800 m above sea level. Mountains, ridges, and beautiful pine forests surround the town. Its climate is moderately continental, gentle, and mountain-fresh. The atmospheric pressure is relatively low (693 mm mercury). The average air temperature is + 10°C. The summers are not hot, while the winter is only moderately cold. There is no danger of overheating or too much cooling of the body. Over 2000 hours of sunlight in a year make cloudy and foggy days a rare occurrence. The winds are not strong at all - about 1m/s.

The resort's biggest treasures are its prolific hot and cold mineral springs. Also located here is a unique and enormous hydro-mineral find with a total capacity of 7630 l/s. Velingrad's mineral waters were known and utilized by people since antiquity.

All mineral springs in Velingrad are lightly mineralized, in other words, they contain mineral substances up to 1g/l. These are the types of waters most commonly found in Bulgaria.

The mineral waters of Velingrad spring deep and are crystal-clear, pure, warm and hot. They are divided between the three quarters (parts) of the town, where there are springs and boreholes – Chepino, Ludjene and Kamenitsa. In Chepino before 1957, there were nine tapped and three untapped springs with temperature between 43 and 48°C and a summational capacity of 3180 l/s. After scientific drillings, the capacity rose to 3615 l/s. The water is characterized as hypothermal, lightly mineralized hydro-carbonated-sulfated with sodium, fluoride, silica, and rhodium. In Ludjene, the springs have been characterized into three basic groups: the westernmost group by Veliova bania is made up of 18 springs; at the men and women's baths, there are 11 springs, and by the Topilata - seven springs. The mineral water is characterized as hypothermal, lightly mineralized hydro-carbonated-sulfated, with sodium, fluoride and silica. In Kamenitsa, 8 springs spout out and the most important springs are at Siarna bania and Vlasa. The water is characterized as hypothermal, lightly mineralized sulfate-hydro-carbonated, with sodium, fluoride and silica. The physical and chemical characteristics of the mineral waters in Velingrad are outlined in Table 1 (Krusteva-Iordanova, 2006).

Table 1. Characteristics of mineral waters in Velingrad

	Chepino	Ludjene	Kamenitsa
Physical and Chemical Indexes			
Capacity (C l/s)	62	65	30
Temperature (T°C)	48	60	90
Mineralization (M mg/l)	187	317	551
PH	9.2	8.2	8.3
Hardness (Ho)	0.3	0.3	0.7
Rhodium (nCi/l)	10	3	1.7
Meta siliceous acid	48	63	91
Hydro carbonate	68	85	122
Sulfate	26	71	171
Flouride	4.2	5.5	6.3
Chloride	4	6	10
Sodium	43	84	144
Calcium	2	2	4
Magnesium	0.3	TRACES	0.4

The analysis of the physical and chemical indexes of the three groups of mineral waters points to a rise in the temperature, mineralization and the content of the separate mineral substances, while there is a lowering of the gas components towards Chepino - Ludjene - Kamenitsa. The quantity of substance of the indexes is of great importance for the healing processes. Especially important is the presence of rhodium in healing concentration, as is found only in the mineral water in Chepino (over 5 nCi/l).

All three groups of waters are siliceous, containing within them remedy effective concentrations of the meta-siliceous acid. It is most potent in the water in Kamenitsa, which is helpful for the external balneology treatment.

Thermal waters in Kamenitsa are used for the heat supply of 2 schools, but does not produce enough heat. A new project for heat supply is suggested and it includes 6 buildings – Historical Museum (2 buildings), library, school and 2 kindergartens (Figures 8-12). The principal scheme for the heat supply in Kamentsa is in Figure 13. The project is at the stage of looking for investments.



Figure 8 . Library “Vasil Levsky”.



Figure 9 .Kindergarten “Happiness”



Figure 10 . School “Dragan Manchov”.



Figure 11. Historical museum.



Figure 12. Kindergarten "Children paradise".

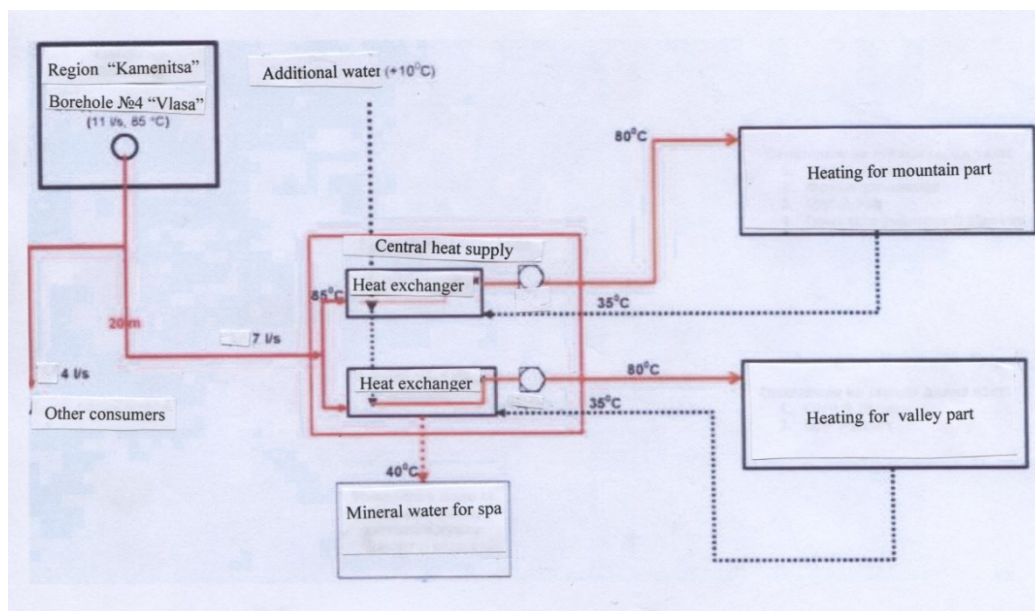


Fig 13. Principal scheme for heat supply in Kamenitsa

4. CONCLUSION

Depending on the structure and properties of thermal waters it is possible to allocate two basic directions of use of geothermal resources: heat power and mineral-raw materials.

The heat power direction is the basic for fresh and low mineralized waters when valuable components in industrial concentration practically are absent, and the general mineralization does not interfere with normal operation of system. When high potential waters are characterized by the raised mineralization and propensity to scaling, the recycling of mineral components should be considered as the passing process promoting the effective heat supply.

The mineral-raw direction is the basic for geothermal waters, containing valuable components in industrial quantities. Thus the substantiation of industrial concentration is caused by a level of technologies. For such waters the heat is a passing product which use can raise efficiency of process of reception of basic production and even to save fuel.

Designing such systems the process of allocation of valuable components should be dominant at. Calculations show, that complex use of thermal waters in a mineral-raw direction economically is more effective, than in heat power. The choice of a direction of complex use of thermal waters should be defined not only by their structure and properties, but also by the level of development of complex technological processes of extraction and processing of hydromineral raw material and by technology of heat power processes. But for all that the presence of consumers and needs for thermal water play the main role.

REFERENCES

- Antipov, M.A., Bondarenko, S.S., Strepetov, V.P., and Kasparov, S.M.: Mineral raw materials. Bromine and iodine, Reference book. "Geoinformmark", M., 30 pp. (1998).
- Bondarenko, S.S.: Mineral raw materials. Industrial waters, Reference book. "Geoinformmark", M., 45 pp. (1999).
- Gadzhiev, A.G., Kurbanov, M.K., and Suetnov V.V.: The problems of geothermal energy in Dagestan, Nedra, Moscow. (1980).
- Kogan, B.I., and Nazvanova, V.A.: Industrial use of natural continental mineral waters abroad. Rare elements. Raw materials and economics. Ed. 10. Rare elements in natural mineral waters. Moscow, p. 4-117. (1974.)

- Kononov, V.I., Polyak, B.G., and Kozlov, B.M.: Geothermal development in Russia: Country update report 1995-1999. Proceedings, the World Geothermal Congress 2000, Vol. 1, p. 201 – 206. (2000).
- Kremenetsky, A.A., Linde, T.P., Yushko, N.A., Shaderman.: Mineral raw materials. Lithium, Reference book. “Geoinformmark”, M., 49 pp. (1999).
- Krusteva-Iordanova, D.: Velingrad’s mineral waters. IVRAI, Sofia. (2006).
- Kurbanov, M.K.: Geothermal and hydro mineral resources of Eastern Caucuses and Pre-Caucuses, Nauka, Moscow, 260 pp., (2001).
- Kurbanov, M.K., Sardarov, S.S., Dejnega, G.I., et al. (editors): Resources of thermal waters of Dagestan and optimization of schemes of their complex developing. Collection of articles, Ed. 4. Institute of geothermic problems, Dagestan branch of the USSR Academy of Sciences, Makhachkala, 156 pp., (1985).
- Nikolski, A.I., and Parshin, B. Ye.: Verkhne-Mutnovsky geothermal power plant – the first environmentally friendly power plant, Energoprogress, Science Technology Newspaper, Moscow . (2003).
- Shcherbakov, A.V.: Geochemical features of thermal waters as mineral resources for chemical industry, Geothermal investigations in Middle Asia and Kazakhstan. Nauka, Moscow, p.57-67, (1985).
- Svalova, V.B.: The History of Geothermal Resources Use in the Former USSR. Proceedings, 1998 GRC Annual Meeting, San Diego, California, USA. (1998).
- Svalova, V.B.: The history of geothermal resources use in Russia and the former USSR. Proceedings, World Geothermal Congress 2000, Japan. (2000).
- Svalova, V. B.: Geothermal energy use in Russia and environmental parks. Proceedings, 2002 Beijing International Geothermal Symposium. (2002).
- Svalova, V. B.: Geothermal Energy Use in Russia and Sustainable Development. Proceedings, International Geothermal Workshop, New Zealand (2002).
- Svalova, V.B.: Geothermal energy use in Russia and environmental problems, Proceedings, World Geothermal Congress in Turkey, (2005).
- Svalova, V.B.: Geothermal energy use in Russia: progress and future, Proceedings, First East African rift geothermal conference. Geothermal energy: an indigenous, environmentally benign and renewable energy resource, Addis Abeba, Ethiopia (2006).
- Svalova, V.B.: Geothermal resources and thermal waters of Russia: complex use, Proceedings, Geothermal Resources Council 2006 Annual Meeting “Geothermal Resources Securing Our Energy Future”, San Diego, California (2006).
- Svalova, V.B.: Mineral resources of geothermal waters and brines, Proceedings, International conference “Mineral extraction from geothermal brines”, Tucson, Arizona, USA (2006).
- Svalova, V.B.: Complex Use of Geothermal Resources. CD Proceedings, European Geothermal Congress 2007, Germany, N 233. (2007).
- Svalova, V.B.: Problems and prospects of geothermal resources utilization. Bulletin “Use and protection of natural resources in Russia“, N5, pp. 3-10. (in Russian) (2008).
- Svalova, V.B.: Mineral extraction from brines and geothermal resources complex use in Russia. Proceedings. WGC2010, Bali, Indonesia (2010).
- Tomarov, G.V., Bubon, S.V., and Martynova, M.V.: Investment and environmental attractiveness of geothermal power projects in Kamchatka., Energoprogress, Science Technology Newspaper, Moscow (2003).