MINERAL RESOURCES OF GEOTHERMAL WATERS AND BRINES

Svalova V.B.
Institute of Environmental Geoscience, Russian Academy of Sciences, Moscow, Russia

Key words: geothermal resources, thermal waters, rare elements, complex use

Abstract

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

Geothermal energy use is a prospective way to achieve clean sustainable development of the world. Russia has rich high and low temperature geothermal resources and makes good steps in their use. In Russia the geothermal resources are used predominantly for heat supply, heating of several cities and settlements on Northern Caucasus and Kamchatka. In addition, in some regions of country the deep heat is used for greenhouses. The most active hydrothermal resources are used in 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 of these waters in economic activities can promote the decision of some social - economic and environmental problems.

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 number of the population 500000. In addition, in some regions of country the deep heat is used for greenhouses of common area 465000 $м^2$. The most active hydrothermal resources are used in Krasnodar territory, Dagestan and on Kamchatka. (Fig. 1, Fig.2).(Gadzhiev *et al*., 1980, Kononov *et al.,* 2000). Approximately half of extracted resources is applied for heat supply of habitation and industrial buildings, third - to a heating of greenhouses, and about 13 % - for industrial processes. Besides the thermal waters are used approximately in 150 health resorts and 40 factories for bottling mineral water. The quantity of electrical energy developed by geothermal stations of Russia, by 1999 almost twice has increased as contrasted to the former level. Nevertheless, it remains extremely minor, making some 0,01 of percent from common development 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 m^3/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 prospective 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, in the Urals 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.

The 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 geothermal power plant (11MW $_e$ installed capacity) and two Severo-Mutnovka geothermal power plants (12 and 50 MW_e). Moreover, another geothermal power plant of 100 MV_e is now under preparation in the same place. Two small geothermal power plants are in operation in Kuril's Kunashir Isl, and Iturup Isl, with installed capacity of 2,б 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), bring 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, economical 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 geothermal power plant (V-MGeoPP) of 12 (3x4) MW was constructed (Fig. 3, a, b). It has been operating in extremely severe climatic conditions on the site located near 1000 m above sea level. 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 geothermal power plants equipment from corrosion and salt depositions was solved by using a special technology of film-forming amine additives. Over the last years the Verkhne-Mutnovsky geothermal power plant has proved sustained reliability in generating reasonably priced electricity of about 1.5 cents/kWh (Nikolski, Parshin, and Bezotechestvo 2003). The experience gained while constructing and operating the Verkhne-Mutnovsky geothermal power plant was used for construction of the 50 MW Mutnovsky geothermal power plant – a completely automated power plant with a satellite-based communication and control system (Fig. 4, a, b, c). The economic impact from geothermal power plants is especially high in remote locations. As there is practically no detrimental gas emission, modern geothermal power plants can be considered as practically absolutely environmentally friendly (Tomarov, Bubon, and Martynova, 2003).

THERMAL WATERS COMPLEX USE

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

Thermal waters, especially chloride brines, contain in the 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 in 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. They are polycomponental raw material and can be used simultaneously 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 hydromineral raw material from great depths.

Geothermal waters and brines are characterized by the big variety of mineralization, the contents of useful components and their quantitative ratio, and also gas structure and temperatures. The most widespread types of hydromineral 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 evaporite pools of a sea or oceanic origin and continental lakes; sea waters.

Profitability of industrial reception of those or other components from hydromineral raw material is determined not only by their concentration, but also by depth of underground waters and permeable features, filtrational properties of rocks, flow rate of operational stocks etc. Economic parameters are influenced by the way of disposing of the waste waters for protection of the natural environment.

Proceeding from the general conditions and laws of distribution of underground geothermal waters and the brines containing rare elements, and also in view of experience of use of such waters as hydromineral 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, caesium - 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 the 1970s about 85 % of world extraction of this metal was carried out in such a way. (Kogan and Nazvanova, 1974).

In Japan from geothermal underground brines are commercially extracted I, Br, B, Li, As, Ge, W and a number of mineral salts. In Israel from brines of the Dead Sea the carnallite, bromine, chlorides of magnesium and calcium, and also raw material for manufacture of medical products and perfumery are produced. In the 1980s hydromineral raw material was the source for 30 % of world extraction of lithium, 31 % - caesium, 8 % - boron, 5 % - rubidium, and also in significant scales Ca, Mg, Na, K, S, Cl, U, Ra, Cu. (Bondarenko, 1999; Bondarenko, Popov, Strepetov, 1986).

Huge stocks of rare-metal raw material is in geothermal underground waters and brines on territories of Russia and the CIS. They contain over 55 % of the common stocks of lithium, 40 % of rubidium and 35 % of caesium. (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, at a depth of 1650 m are met 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, in Ukraine, Kamchatka, Kuriles, Sakhalin. (Shcherbakov, 1985, Resources …, 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 highly soluble and does not collect in rocks. Iodine concentrates in seaweed but to extract this seaweed as industrial raw material is effectively only by their big congestion. Bromine can be extracted from some salts and seaweed, but traditionally bromine also is extracted from concentrated 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 for many chemical elements. Many brines which occur at great depth, can become deposits of the most valuable chemical elements: caesium, 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 the high cost of technology. A prospective method is use of ion-exchange pitches for selective extraction of the certain components from natural waters. The 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 procedures of chemical processing of hydromineral raw material and to expand the spheres of its economic application.(Bondarenko, Lubensky, Kulikov, 1988; Bondarenko, Kulikov, 1984; Klimenko, Medvedev, Popov, 1981; Pozin, 1974). 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.

Conclusion

Depending on 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 preferable 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 material 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 an added 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. Calculations show, that complex use of thermal waters in a mineral-raw material 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., 1998. “Mineral raw materials. Bromine and iodine.” Reference book. “Geoinformmark”, M., 30 pp.

Bondarenko, S.S., 1999. “Mineral raw materials. Industrial waters.” Reference book. “Geoinformmark”, M., 45 pp.

Bondarenko, S.S., Kulikov, G.V., 1984. “Underground industrial waters”. Nedra, Moscow.

Bondarenko, S.S., Lubensky, L.A., Kulikov, G.V., 1988. “Geological-economical estimation of deposits of underground industrial waters”. Nedra, Moscow.

Bondarenko, S.S., Popov, V.M., Strepetov, V.P., 1986. “The main types of deposits and scale of extraction of hydromineral raw materials in capital and developing countries”. VIEMS, Moscow, 43 pp.

Gadzhiev, A.G., Kurbanov, M.K., and Suetnov V.V., 1980. “The problems of geothermal energy in Dagestan”. Nedra, Moscow.

Klimenko, I.A., Medvedev, S.A., Popov, V.M., 1981. “State and perspectives of complex utilization of valuable components of natural and man-caused mineralized waters”. VIEMS, Moscow.

Kogan, B.I., and Nazvanova, V.A., 1974. “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.

Kononov, V.I., Polyak, B.G., and Kozlov, B.M., 2000. “Geothermal development in Russia: Country update report 1995-1999.” Proceed. of the World Geothermal Congress 2000, Vol. 1, p. 201 – 206.

Kremenetsky, A.A., Linde, T.P., Yushko, N.A., Shaderman., 1999. “Mineral raw materials. Lithium.” Reference book. “Geoinformmark”, M., 49 pp.

Kurbanov, M.K., 2001. “Geothermal and hydro mineral resources of Eastern Caucuses and Pre-Caucuses.” Nauka, Moscow, 260 pp.

Nikolski, A.I., and Parshin, B. Ye., 2003. “Verkhne-Mutnovsky geothermal power plant – the first environmentally friendly power plant.” Energoprogress, Science Technology Newspaper, Moscow .

Pozin, M.E., 1974. “Technology of mineral salts”. Chemistry, Leningrad.

"Resources of thermal waters of Dagestan and optimization of schemes of their complex developing." Collection of articles, Editors: Kurbanov, M.K., Sardarov, S.S., Dejnega, G.I., et al., 1985. Ed. 4. Institute of geothermic problems, Dagestan branch of the USSR Academy of Sciences, Makhachkala, 156 pp.

Shcherbakov, A.V., 1985. "Geochemical features of thermal waters as mineral resources for chemical industry". Geothermal investigations in Middle Asia and Kazakhstan. Nauka, Moscow, p.57-67.

Tomarov, G.V., Bubon, S.V., and Martynova, M.V., 2003. "Investment and environmental attractiveness of geothermal power projects in Kamchatka." Energoprogress, Science Technology Newspaper, Moscow.

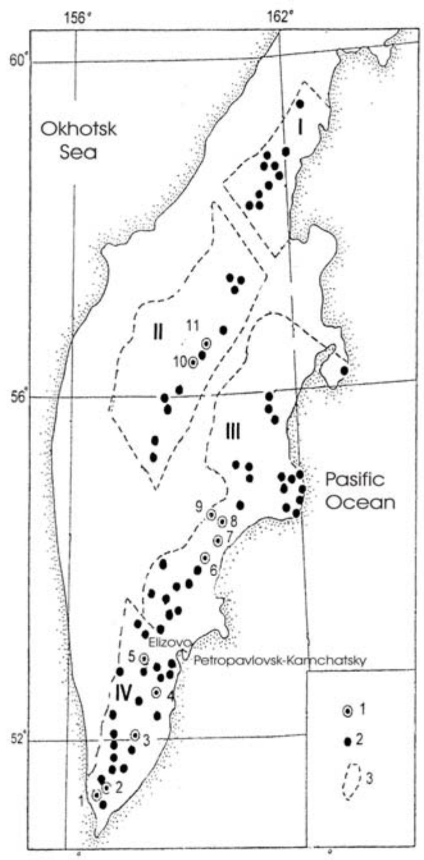

Figure 1: . Geothermal resources of Kamchatka

1 – geothermal deposits (1 – Pauzhetskoje, 2 – Nizhne-Koshelevskoje, 3 – Khodutkinskoje, 4 – North-Mutnovskoje, 5 – Big-Bannoje, 6 – Karimskoje, 7 – Semjachinskoje, 8 – Geysers Valley, 9 – Uzonskoje, 10 – Apapelskoje, 11 – Kireunskoje);

2 – groups of thermal springs;

3 – hydrogeothermal provinces (I – North, II – Middle, III – Easten, IV – South).

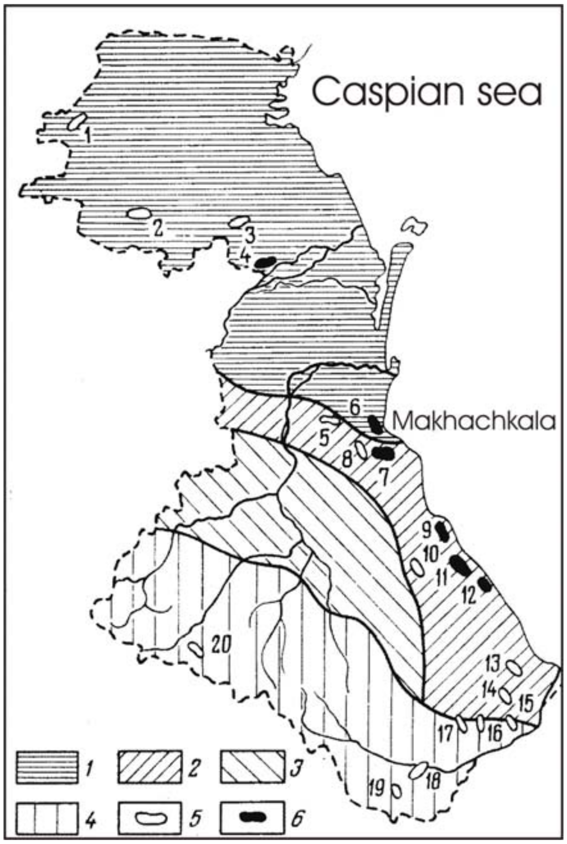

Figure 2: Map of hydrogeothermal deposits and perspective areas of Dagestan

1-4 – measure (1 – Quaternary, 2 – Neogene, 3 – Cretaceous, 4 – Jurassic); 5 – perspective areas; 6 - hydrogeothermal deposits; fingers on the map – thermal anomalies (1 – Bazhigan, 2 – Terekly-Mekteb, 3 – Tarumovka, 4 – Kizljar, 5 – Istisu, 6 – Makhachkala, 7 – Talgi, 8 – Zauzanbash, 9 – Izberbash, 10 – Salgabak, 11 – Kajakent, 12 – Berikej, 13 – Belidzhy, 14 – Choshmenzin, 15 – Giljar, 16 - Adzhinaur, 17 – Richalsu, 18 – Akhty, 19 – Khnov, 20 – Khzanor

Figure 3,a. Verkhne-Mutnovsky geothermal power plant (GeoPP). First ecologically clean GeoPP. Photo of Svalova V.B.

Figure 3,b. Verkhne-Mutnovsky geothermal power plant. Snow in August. Photo of Svalova V.B.

Figure 4,a. Mutnovsky geothermal power plant. Many visitors always. Photo of Svalova V.B.

Figure 4,b. Mutnovsky geothermal power plant (MGeoPP). Primary separators provide MGeoPP with the high-quality steam. Photo of Svalova V.B.

Figure 4,c. Mutnovsky geothermal power plant. The main entrance. Photo of Svalova V.B.