UTILISATION OF GEOTHERMAL WATERS AND GEOTHERMAL ENERGY IN VOJVODINA

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INTRODUCTION

Recent exploration of thermomineral waters and hydrothermal power in Vojvodina have been conducted continuously since 1969 until the present day. At its early stage, these explorations have advanced rather fast and efficiently, owing to rich expert documentation inherited from the process of oil and gas exploration activities, as well as to substantial financial and expert resources of NIS-Naftagas. In such background, the planned and systematic approach to the regional, and later also the detailed exploration was possible. In a relative short period of time the conditions of occurrence were known, as well as the geotemperature regime and physical and chemical properties of the waters, which all allowed the second phase of application of the thermomineral waters and hydrogeothermal power.

The use of thermomineral healing waters in medical therapy and disease prevention has always had a significant place in development of the civilization, and has not been any less important in the modern society as well. The use of thermomineral waters for energy and power purposes is of a more recent date, and a wider use started with the occurrence of the first energy crisis during the 70s.

During the last thirty years 73 hydrothermal wells have been drilled in Vojvodina, which total depth is 62.847 m. The majority of the wells have been drilled in Backa (42), Banat (18), and the least number in Srem (13). Also, 23 systems for the use of thermomineral waters have been constructed, partly for energy use, and partly for the purpose of healing, medical treatment and sports and recreation use (Fig. 1).

In the last 7-8 years the tendency of development has been on a certain stand-by, although the interest of potential users has been in increase. Such a state is the result of general stagnation of the country's economic development, and particularly of the lack of financial means and credits, and the lack of any aid by the Government [1].

A SHORT HISTORY OF RECENT EXPLORATIONS OF THERMOMINERAL WATERS IN VOJVODINA

The first knowledge of thermomineral waters existence in Vojvodina were acquired at the turn of the last century, drilling artesian wells. Searching for artesian ("live") water, the drillers had often reached the depths of 400 and even 600 m, at which they

had been discovering hot waters. These wells were mostly used for public baths, such as those in Becej, Temerin, Kanjiza, Senta, Prigrevica, Zmajevo etc.

Figure 1: *The map of hydrothermal facilities in Vojvodina*

With the start of oil and gas explorations in Vojvodina in 1949, much greater depths have been drilled (over 2000 m). These activities allowed for the gaining of new knowledge and experience in the frequency and quality of thermomineral waters from greater depths, which later allowed faster and more efficient exploration.

Initial systematic and organized exploration of thermomineral waters in Vojvodina began in 1969, when "Nafta-gas" from Novi Sad, at the recommendation of the Provincial Energy Committee, accepted programming, financing and realization of the project for exploration and application of thermomineral waters in Vojvodina. The first exploration well within the project was drilled in Subotica, in 1969 [2].

The most intensive period of drilling was in the period between 1977-1990, when 2-7 wells were drilled annually. Since 1991, when NIS-Naftagas completely ceased its financing, the drilling activities dropped abruptly. The lack of financial means on the

part of potential users, who now had to finance the drilling either completely of partially, as well as high initial investments and impossibility of getting any bank credits, have all contributed to the sudden drop of development rate.

In the beginning, only exploration wells have been drilled, to introduce regional knowledge of hydrogeological properties, quantity and quality of waters, etc. At a later stage, when selecting locations, it was taken into consideration that the wells were located in the vicinity of an object, so that in case of positive results they could be practically used. Finally, only production wells were drilled, for a known user and known purpose.

The average well depth in the past was 860 m, which is relatively small for the Panonian basin conditions. However, drilling at greater depths has often been limited by highly mineralized waters, inconvenient for wider use and especially for disposal after the use.

To acquire the knowledge of hydrogeological properties of Vojvodina, besides drilling and testing hydrothermal wells, about 40 wells negative to oil and gas have also been tested in the past period. Apart from gaining valuable data, these wells have also served for evaluation of the possibilities to transfer negative oil wells into hydrothermal. It turned out that only in a small number of cases they could be adapted to produce thermomineral water. Such are the cases when the producing layer, i.e. water environment, is built of solid rock (carbons, dolomite, sandstone, etc.). In any other cases this transfer was not possible, owing mostly to producing sand and to small well capacities.

Optimal well production in self flow ranged mostly between 10-15 l/s, and the output water temperatures between 45 and 65 °C.

GEOTHERMAL REGIONALIZATION OF VOJVODINA

Groundwater temperature reflects the geotemperature regime of geological surroundings in which it is accumulated. The temperature grows with depth, and the rate of growth depends on geothermal gradient. Vojvodina has the conditions of high geotemperature influences.

Based on a great number of temperature measures in wells geothermal gradients were calculated for the whole of Vojvodina. The majority of data regards the neogenic complex, and a very small number on older formation. Geothermal gradients of Vojvodina range between 4,5 - 7,5 °C/100 m. High gradients have been recorded in parts of Backa and Srem, particularly in areas where the bases of neogenic sediments are made of Triassic carbons and dolomites, in which convex heat transmission in the reservoir prevails, and also in areas where neogenic sediments are thin, namely where Mesozoic and Paleozoic formation lay in small depths.

Higher Triassic depressions in northern and middle Banat are characterized by lower geothermal gradients.

To allow easier evaluation of hydrogeological conditions for production of thermomineral water, geothermal regionalization of Vojvodina has been conducted and a map of output water temperatures has been drawn (Fig. 2). Regionalization was based on three criteria: depth of hydrogeological collectors (depth structure map of Vojvodina on neogenic base was used), geothermal gradients (map of geothermal gradients of Vojvodina), and physical and chemical properties of thermomineral waters (laboratory analyses from a great number of wells).

Areas, i.e. geological formations, from which waters of output temperatures over 80 °C have been separated, then areas with output water temperatures between 50 and 80 °C, and finally areas with output water temperatures under 50 °C. Owing to specific hydrogeological conditions (high production rate wells, low collector depth, good water quality), some areas have been particularly emphasized - those with collectors built of cracked and cavernous carbons and dolomites of the Triassic period, with output water temperatures ranging between 45-75 °C.

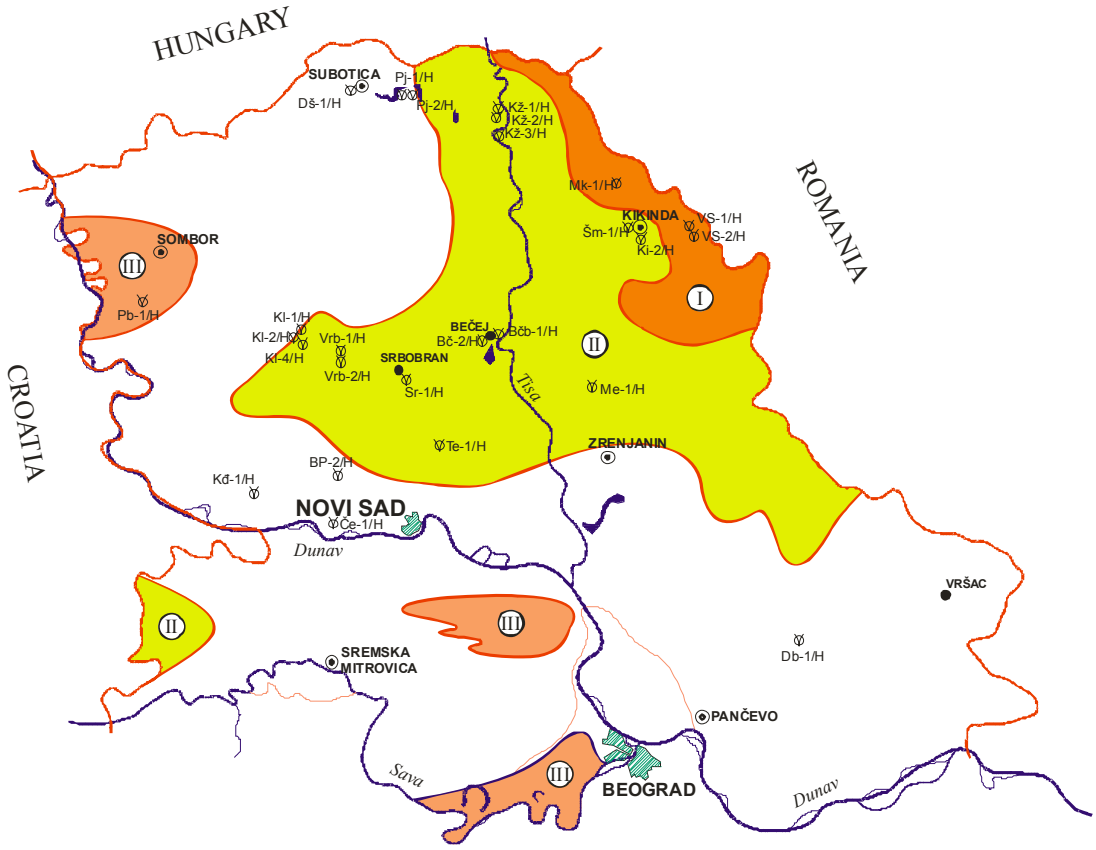

Figure 2: *Map of geothermal water output temperatures in Vojvodina for I and III hydrogeological systems*

Waters up to 160 °C could also be produced in Vojvodina, but owing to their unsuitable physical and chemical properties (high mineralization, inconvenient ionic composition, tendency towards scale formation on well and pipe walls, aggressiveness towards metals and concrete), their use in practice could not be successful. Therefore,

when geothermal regionalization was conducted, only those areas that could produce quality waters suitable for practical use have been taken into account.

Areas that could produce waters of output temperatures higher than 80°C (maximum up to 95 °C) are located in north-east Banat, and comprise the total space of approximately 1000 km^2 (marked on the map with I). Hydrogeological collectors are built of sandstone of the upper miocene period, that lay in depths ranging between 1700 and 2000 m. Production rates of 10-17 l/s (about 13 l/s in average) per well could be achieved.

Areas that could produce waters of output temperatures between 50-80 °C (II) are located in northern and middle Banat, mid parts of Backa and western Srem, and comprise the total space of about 6000 km^2. Hydrogeological collectors are built of sandstone and sands of the upper miocene and pliocene period, and lay in depths between 750 and 1700 m. Production rates of 10-28 l/s (average of 12,6 l/s) per well could be achieved.

Because of very suitable conditions for producing thermomineral waters, areas of carbons and dolomites of mostly Triassic period (III) have been emphasized, that could yield waters of output temperatures 45-75 °C. These areas are located in southern and eastern Srem and western Backa, and are of about 1300 m^2 in size. Hydrogeological collectors are built of cracked and cavernous carbon rocks of mostly Triassic period, that lay in depths ranging between 500-1300 m. They could produce 14-42 l/s (average of 22,5 l/s) per well.

In other parts of Vojvodina, except the Fruska Gora mountain and Vrsac mountains, thermomineral waters of output water temperatures under од 50 °C can be expected, that could mostly be used in healing and sports and recreation purposes, for growing fish, etc.

PHYSICAL AND CHEMICAL PROPERTIES THERMOMINERAL WATERS

With occasional exceptions, all ground waters of Vojvodina from depths over 400-500 m could be determined as thermomineral, since they contain more than 1 g of soluble mineral matters per 1 liter of water, and also have the temperature over 20 °C. [3].

As for the ionic compositon, certain paradigms could be derived. As a rule, waters of pliocenic and upper pontiassic age belong to HCO_3-Na type, water of miocenic age to Cl-Na type, and waters of lower pontiassic age belong to intermediate Cl-HCO_3-Na type. Waters from older formations belong to mixed water type, depending on the fact with which formations they are in hydraulic connection.

Prevailing microcomponents are: Na^{1+}, K^{1+}, Ca^{1+}, Mg^{2+}, Cl^{1-}, CO_4^{2-} and HCO_3^{2-}.

Other microcomponents are: iodine, bromine, strontium, lithium, fluorine, etc. Presence of organic matters is very high, particularly huminskih, in the first hydrogeological system, which is the reason that these waters have a slightly yellow color, and that is particularly visible when these waters are used in recreation swimming pools.

Regular subcomponents of thermomineral waters are dissolved gasses. The most common is methane, found in water in contents of 0,5-1,5 m^3/m^3. Other gasses (CO_2, H_2S, N_2) either occur in smaller contents or not at all. Before the water is used it has to be degassed because of the danger of methane concentration and explosion if the water is used in a closed environment.

The majority of thermomineral waters contain components that have an active impact on humans. Most common are iodine waters (iodine content is up to 20 mg/l). Besides iodine, waters often contain bromine (up to 500 mg/l), fluorine (up to 11 mg/l), strontium (up to 180 mg/l), metasilicon acid (up to 50 mg/l) and metaboric acid (up to 400 mg/l). Some of these water types are used as healing waters in thermal springs and spas ("Junakovic", "Kanjiza", "Rusanda", etc.).

In waters of Vojvodina most common unwanted substances are phenols, but rarely in quantities that exceed the allowed.

In practice, thermomineral waters of the HCO_3-Na type and general mineralization of up to 6,4 g/l are used for energy and nonenergy purposes. Apart from the problems of minor occurence of corrosion on wellheads and scarce and insignificant occurence of incrustation on pipeline walls, which had been successfully solved, there have been no other comments made on the part of the water users. Disposal of the used thermomineral waters have been made into surface recipients, rivers and canals. No pollution of eco system have been recorded, although no organized observations nor tests have been conducted.

STATE OF THERMOMINERAL WATER USE IN VOJVODINA

There is a long tradition of thermomineral water use in thermal springs, spas and public baths, and today this particular use is most common in Vojvodina. The use of thermomineral waters in healing and medical treatment dates back to Roman time. Water was used from several springs on the slopes of the Fruska Gora mountain. A much wider application of healing waters began with drilling of artesian wells, by the end of the 19th and beginning of the 20th century, when a number of public baths and spas were built. This specific use widened significantly with the start of drilling hydrothermal wells, which resulted in expanding or constructing new spas and sports and recreation centers and complexes ("Kanjiza", "Junakovic", Rusanda, sports and recreation centers in Palic, Becej, Kula, Temerin, Celarevo, etc.).

Based on world and domestic experience and taking into account physical and chemical properties of the geothermal waters in Vojvodina, it can be concluded that they could be used for the following purposes:

- in agriculture, for heating green houses,
- in cattle and poultry breedingy, for heating farms,
- in industry, as technical hot water,
- in healing and medical treatment and in sports and recreation centers and tourist resorts,
- for heating households and other facilities,
- for supply of sanitary hot water,
- in fisheries, etc.

In most cases, all the above uses have been tested in practice over the years in our country, through the existing hydrothermal systems [4]. The structure of application of geothermal waters treated in the manners described above is very wide, and the consumers can be classified into several categories:

Regular - continual consumers of geothermal waters in Vojvodina are the thermal springs, spas and rehabilitation centers, as well as the consumers that use thermal waters for technical purposes. This first group of consumers can be determined as a combined

group, since the continual consumption is the one taking place the whole year round, mainly for healing and medical treatment and recreation purposes in open and closed swimming pools. Other thermal water consumption is directed towards heating such. The most important consumers of this group are:

- The "Junakovic" Spa (Pb-1/H) uses thermomineral water for heating its facilities, and for healing and recreation in its swimming pools. Total heating power of the well is 2,54 MW, and this hydrothermal facility was the first in Vojvodina to use heating pumps. A possible annual black oil substitution according to the designed capacity is 1228 t.
- The "Banja Kanjiza" Spa (Kz-1//H, Kz-2/H and Kz-3/H) uses thermomineral water for heating its facilities through the pipes of low temperature working regime, and for healing and recreation. Thermal water for sanitary purposes has also been used in all the guest rooms. Total heating power of the wells is about 6,61 MW, and if used optimally, thermal water could substitute about 2934 t of black oil per year.
- In the vicinity of the well (Bc-2/H) an industrial facility has been constructed that has the possibility of additional heating of thermomineral water by dissolved gas. The water is used in sports and recreation center for heating, treatment of hot water and heating of the closed swimming pool water. A certain part of the water is used for heating the facilities of the nearby spa and the "White Boat" hotel. Total heating power of the well is 4,53 MW, and about 2097 t of black oil could be substituted per year, according to the original design.
- Two hydrothermal wells in Kula are used for technical needs during the whole year: for washing wool in textile factory "Sloboda" (Kl-4/H), and for leather treatment in the factory "Eterna" (Kl-2/H). If total annual thermal water consumption is shown as energy (total heating power of these two wells is 3.70 MW), about 1155 t of black oil could be substituted according to the design.

Season consumers make up the second consumptio group, that use thermal water for heating during winter months, and in sports and recreation swimming pools in the summer. Representatives of this group are:

- Three thermal wells in the vicinity of Kikinda (Kikinda, Mokrin and Banatsko Veliko Selo) use thermomineral water for heating pig farms. Air heating through central air heater is applied in the farms facilities. Total heating power of these wells is 3.84 MW, which substitutes 1952 t of black oil per year according to the designed capacities and rates.
- In Srbobran (Sr-1/H) thermomineral water is used for heating solid greenhouse of the area 0.5 ha. A process of burning dissolved gas from the water in a special device was applied in this facility for the first time ever, and thus additional energy was used for heating thermal water. Total heating power of the well is 2.55 MW, and 852 t of black oil can be substituted per year according to the designed capacity.

Typical summer season consumers are open swimming pools built on hydrothermal systems in Temerin (Te-1/H) and Palic (Pj-1/H).

Many technical problems regarding the processes of thermomineral waters application have been solved in the past. The very use of thermomineral waters have also shown many advantages in energy terms: renewable source of energy, domestic resources, high level of security and reliability of the hydrothermal systems functioning, availability of domestic equipment, possibilities of multilevel use.

As an alternative energy source, geothermal waters have their specific properties in terms of availability, production and treatment, as well as in terms of distribution to the consumers, use disposal of the used waters.

Table 1: *Hydrothermal systems and their users in Vojvodina and their basic characteristics*

Nº:	HT system (location, place)	Bigining of use	Rate of well (l/s)	Water temperature (°C)	Heating power (MW)		Possible subst. black oil (t/year)	User	Purpose
					Water	Gas			
1	Backo Karadjordjevo	1978	2,2	34	0,08	-	27	Yugoslav Army	Closed swimming pool
2	Kanjiza (three wells)	1981 1986 1998	5,0 14,0 20	41 65 72	0,33 2,34 3,94	- - -	76 1067 1791	The "Kanjiza" Spa	Heating, healing
3	Kula	1981	9,5	50	0,99	0,46	123	Sports and recreation center	Open swimming pool
4	Prigrevica spa	1983	20,8	54	2,54	-	1228	The "Junakovic" Spa	Heating, healing
5	Srbobran	1984	11,67	63	1,86	0,69	852	Agricultural complex "Elan"	Greenhouse heating
6	Kikinda Sumice	1984	6,17	50	0,64	-	369	"6th October"	Space heating
7	Mokrin	1984	10,5	51	1,44	-	569	"Mokrin"	Farm heating
8	Kula	1984	8,33	53	0,98	1,40	599	Leather factory "Eterna"	Technical needs
9	Subotica	1984	4,83	35	0,20	-	-	Sports and recreation center	Open swimming pool
10	Palic lake	1985	12,17	48	1,17	0,63	178	"Akumulacija"	Open swimming pool
11	Melenci	1985	10,33	33	0,35	-	133	The "Rusanda" Spa	Healing
12	Kula	1985	8,5	51	0,93	0,39	567	Textile factory "Sloboda"	Technical needs
13	Kikinda	1985	15,17	51	1,65	-	950	Pig farm "Jedinstvo"	Farm heating
14	Vrbas (two wells)	1986 1986	3,5 4,33	39 51	0,20 0,47	0,14 0,18	82 157	Sports center	Closed swimming pool
15	Becej spa	-	1,16	-	-	-	-	Iodine spa	Healing
16	Devojacki bunar	1986	10,0	25	-	-	-	Hotel	Open swimming pool
17	Temerin	1987	20,0	41	1,34	0,99	179	Local municipality	Open swimming pool
18	Backi Petrovac	1987	7,83	45	0,86	-	403	Agricultural Institute	Heating
19	Ban. Veliko Selo	1987	10,0	43	0,75	-	433	Pig farm "Kozara"	Farm heating
20	Palic lake	1987	5,0	45	0,42	-	241	Hotel "Jezero"	Hotel heating
21	Becej	1988	19,4	65	3,26	1,27	2097	Sports center "Mladost"	Heating
22	Ban. Veliko Selo	1990	6,67	45	0,56	-	-	Agricultural complex	Space heating
23	Celarevo	1996	5,0	31	0,12	-	-	Textile factory "Dunav"	Closed swim. pool in Motel "Dunav"

Transportation and distribution of thermal waters to the consumers is made through centrifugal pumps within the hydrothermal systems. Thermal waters in Vojvodina have the property of being low enthalpic and do not allow long distance transportation. The usual thermal water temperature of this region ranges between 50 and 65 ^{o}C, which does

not allow great distances between the reservoir (well) and the user, either through subsurface or surface contemporary transportation systems.

Almost all thermal wells are located in the close vicinity of the users, sot that there have been no troubles with the water temperature drops during transportation. Thermodynamic analyses for this temperature level show technical and economical feasibility of thermal water transportation of this region to the distances up to 1000 m. In such cases, the ration between costs for pipeline isolation and electric power consumption for the operation of the pumps is within the working efficiency and the thermal water price.

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