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CONDITIONS AND POSSIBILITIES OF GEOTHERMAL ENERGY UTILIZATION FOR ECONOMIC-TOURISTIC DEVELOPMENT

Andjelina Marić[1*], *Tomislav Pavlović*[1]
[1] University of Niš, Faculty of Natural Sciences and Mathematics, Niš, Serbia

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Abstract: Using thermal mineral water in various economic activities would reduce the need for conventional energy sources and increase complementarity and sustainability of the tourism business. Since the temperature of spring wells of Vranjska banja ranges from 63 °C to 95 °C, this paper deals with the possibilities of their use as a renewable energy source. The paper gives the results of water physical and chemical characteristic testing, the temperature and discharge of ten geothermal springs in Vranjska banja, respectively [illegible]-1, A-2, E[illegible]-2, EX-3, EX-2, B-1, A-3, B-2, Gornji source and a collecting drain. Test results show that the water contains a high concentration of fluorine (8–8.5 mg/l), the impact of which exhibits in the treatment of cancer, nervous system diseases, and a lot of respiratory diseases, arthritis and musculoskeletal disorders. Based on the results of the temperature and the abundance of the geothermal resources in Vranjska banja, the paper presents data on the heat capacity of the spa springs. The paper reports the results of the possibilities of using water springs of Vranjska banja water temperatures up to 25 °C and 37 °C in agriculture, industry, sports activities, etc.

Keywords: geothermal springs, touristic valorization, Serbia,Vranjska banja

Introduction

Within the territory of Serbia, excluding the Pannonian Basin, there are 159 natural thermal springs with temperatures T > 15 °C. The warmest springs (96 °C) are located in Vranjska banja. The total flow rate of all natural springs is about [illegible],000 l/s. The total heat capacity of all flowing wells drilled in Serbia is about 1[illegible]6 MWt (calculated for dT = T–25 °C). The total heat capacity of all natural springs and wells is about 320 MWt (calculated for dT = T–12 °C). Estimated energy reserves of geothermal resources are about 800 MWt. More than 80 low enthalpy hydrogeothermal systems are present in Serbia. The most important are located at the southern edge of the Pannonian Basin (Karimov, Abid, & Karimova, 2012).

* Correspondence to: andjelinamaric14@gmail.com

By its geothermal resources, Serbia belongs to the richer countries. Currently, only 9% of the available geothermal energy potential is used, from geothermal and mineral water for the therapeutic, sports and recreational purposes. The use of geothermal energy for heating and other energy purposes is still at an early stage and very modest compared to the potential of geothermal resources (Tripanagnostopoulos, 2015).

Serbia nurtures widespread and deeply rooted opinion that electricity produced from fossil fuels, and most notably coal, is much cheaper than electricity produced from renewable energy sources. The production price of electricity is one of the key reasons why the country so adamantly refuses renewable energy and keeps delaying the implementation of projects which are in the pipeline. (Dessler & Parson, 2010).

Hot springs — spas have been used even in the ancient period for swimming and rehabilitation. Going to places with healing springs as the forerunner of the modern spa tourism was widespread in the Roman Empire. The ancient Romans built near hot springs baths, swimming pools, water supply systems, floor heating systems, drainage, sacred objects, and not far from these, summer houses, amphitheaters, urban settlements, military fortifications, roads, etc. Traces of material culture from the Roman period were found in many of the Apennines spas, in Central Europe and Serbia (Niška banja, Vrnjačka banja, Gamzigradska banja), etc. (Stanković, 2008).

Thermo-mineral (TM) water utilization in Serbia has a much longer history than their scientific research.. During the Ottoman rule from the 15th to the 19th century, baths were built, known as hamams around the mineral springs in Serbia (Protić, 1995; Kostić, Pivac, Romelić, Lazić, & Stojanović, 2011).

Scientific publications referred to the first decade of the 21st century dealt with TM springs in Serbia from the aspect of their use as a renewable energy source, the possibilities of substitution of fossil fuel, radioactivity of water, exploitation in spa tourism and the conditions and possibilities of the thermo-mineral water utilization for the spa purposes (Milivojevic & Matinovic, 2005; Joksimović & Pavlović, 2013).

Tourist major Serbian spas have developed around thermo-mineral springs in the basin of the Western Morava and Southern Morava rivers. The regional-geographic approach to the spa research corresponds to 10 spas division zone, according to which Vranjska banja, together with Niška banja belongs to the Southern Morava zone. These are typical European spas located next to the very springs of the thermal mineral waters in the suburban zones. However, tourism oriented function of the spas is secondary due to a rooted traditional treatment concept of spas in Serbia (Jovičić, 2008; Marković, 1980, Doljak & Jojić Glavonjić, 2016).

Before the year 2000, all natural resources in Serbia were state owned, and only governmental companies could utilize natural resources such as geothermal energy. After year 2000 and a period of transitions, all companies, private or governmental, could utilize geothermal energy according to the new regulations. For the last 20 years, state investments in all geological exploration have decreased from 40 million euros (year 1988) to less than 1 million euros (year 2007) per year.

Exploration of the geothermal energy in Vranjska banja in the past was linked to the possibility of its use for the therapeutic purposes and heating of settlements. Thermo-mineral springs in Vranjska banja did not attract the attention of researchers because of their peripheral position in relation to the main sources of geothermal energy in Serbia (Luković, 197[illegible]).

The aim of this paper is to examine the possibility of using thermal mineral waters in Vranjska banja for economic, biological and tourism purposes. In this regard, the paper analyzes the effect of the geological conditions on occurrence of the thermal mineral waters of Vranjska banja, given the classification and systematization of their origin on the basis of the physical, chemical and therapeutic qualities. It also gives an overview of the existing and potential utilization of thermal mineral waters for business, therapeutic and tourist development of Vranjska banja.

Study area

On the territory of Serbia, old tectonic masses of the Rhodopes and Pannonian land and younger fold orogenic zone of the Dinarides and the Carpatho-Balkan mountains touch, converge and clash. On these contacts, in fault zones, there are thermal and mineral springs, where the tectonic lines (longitudinal and transversal) have cut earth's crust to the greater depth and have reached magmatic ore deposits. Therefore, a large number of thermal and mineral springs related to the fissure lines of the Rhodopes masses are situated in southern Serbia, where Vranjska banja is located (Rodić & Pavlović, 1994) (Figure 1).

According to the geothermal potential Serbia is one of the richer countries. The current results show that the intensive research and development program in Serbia until 2017 could achieve replacement level of 500,000 tonnes of the imported liquid fuels per year (Dragović, Janković-Mandić, Dragović, Đorđević, & Đokić, 2012).

The density of geothermal heat flow (mW/m^2) is the main parameter for assessing the geothermal potential of any given area. The density of geothermal heat flow is the amount of geothermal heat, which in a unit of time, through the unit area, comes from the Earth's interior to its surface. However, the density of geothermal heat flow towards the surface of the Earth is not the same everywhere. It is different and depends on the composition — the material of the Earth's crust and their thermal conductivity coefficient (conductivity). The average value of the density of geothermal heat flow for the continental Europe is about 60 mW/m^2, and for the largest part of the territory of Serbia it ranges from 80–110 mW/m^2. In the Panonnian basin, the central part of southern Serbia and in central Serbia, the density of geothermal heat flow is more than 100 mW/m^2 (Pavlović, Milosavljević, & Mirjanić, 2013).

Vranjska banja is located at 42°33'11" north latitude and 21°59'19" east longitude, in the large Vranje basin in Southeast Serbia, at 420 meters above the sea level, 10 kilometers east of the town of Vranje. According to the political-administrative division, Vranjska banja is located within the Pcinja District with its seat in the town of Vranje. Vranjska banja has the Banjska river flowing through and it is the right tributary of the South Morava. According to the official census of the population, households and apartments in 2011, Vranjska banja has 5,347 inhabitants, [illegible]0% of which are the Serbs and 27.6% are the Roma minority (Marković & Pavlović, 1995).

In geotectonic terms Vranjska banja is in the Rhodope Serbia and in the west it relies on the Serbian-Macedonian massif. As part of the composite valley of the South Morava, Vranje basin is lowered in the old Rhodopes mass which is surrounded by the mountains of the medium height up to 1,500 m (Besna kobila, Streser, Orlova čuka and Čemernik) (Dimitrijević, 1994).

According to the geological structure, the space of Vranje basin is very heterogeneous. It is dominated by igneous and sedimentary rocks (schist, granite, andesite, limestone). The Neogene between Vranje and Vranjska banja is interrupted by the parts of gneiss, andesite and dacite. Mountain peaks Grot (1,323 m) and Oblik (1,310 m) above Vranje are built of rhyolite and rhyolite tuffs and have some forms of craters indicating the existence of paleovulcanism (Marković, 1966).

Vranjska banja has multiple springs of geothermal water. Almost all springs are grouped in the southwest-northeast direction with the total length of 60 kilometers and follow the valley of the Banjska River. The appearance of the thermal springs is localized to the circumference of an extended Banjska River valley, volcanic rocks contact and crystalline Proterozoic shale (Protić, 1995).

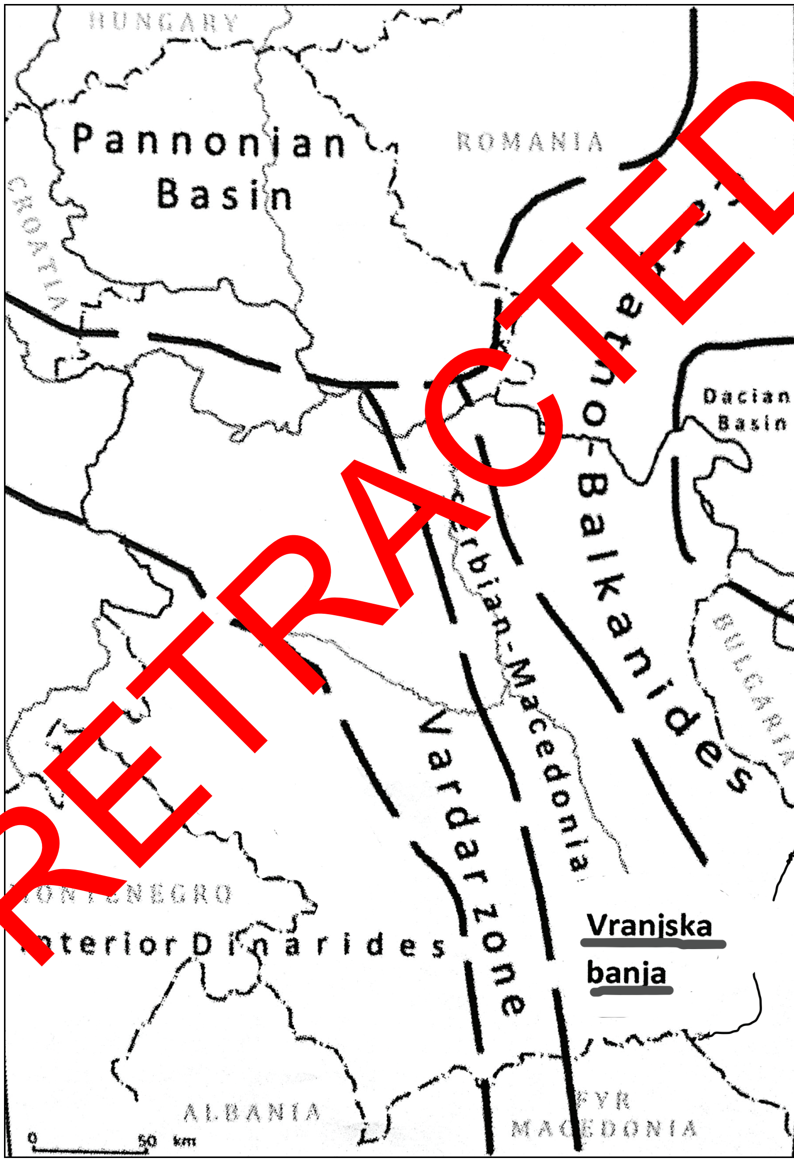

Figure 1. Position of Vranjska banja in relation to the main tectonic continent in Serbia (Source: Marković & Pavlović, 1995).

Research methods and data

Springs of Vranjska banja whose temperature ranges from 63 °C to 95 °C are among the warmest in Europe. So far 10 springs were capped, 4 of which are bigger ones with a discharge of 6–44 l/s, with different temperatures and chemical composition of the water. Based on the previous studies, the discharge of the Vranjska banja springs A-1, A-2, EX-2 and 3 VG goes up to 60 l/s. Measurements were made in the period from April to June 2018, three times a week to determine whether the strength of the source, physical and hemical characteristics change.

In this paper, ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry) device was used for the examination of the chemical composition of the geothermal water springs in Vranjska banja. The data about water springs discharge (l/s), the depth (m) and temperature (°C) are taken from the literature Stojiljković, Cakić, and Mitić (2015).

The heat capacity of the water springs in Vranjska banja was calculated using the following formula (Pavlovic et al, 2013):

$$C = m \, Cp \, \Delta T \tag{1}$$

where m is mass flow rate of water (kg/s), Cp = 0,004186 KJ/kgK specific heat of water, T_2 — water inlet temperature (K), and T_1 — water outlet temperature (K). In this way obtained heat capacity is expressed in units kW.

The energy that is generated in a certain time interval is calculated using the formula (Pavlovic et al, 2013)

$$E = C \, t \tag{2}$$

where C is heat capacity of water (kW), and t — time in seconds (s) for which the energy which is obtained by means of the respective water spring is calculated. In this way, the resulting energy is expressed in units J.

Based on the data of the geothermal springs water temperature in Vranjska banja shown in the Table 1 and their discharges expressed in l/s, the paper gives two hypothetical cases of Vranjska banja geothermal water utilization. The first case considers a possibility of the utilization of water temperature of up to 37 °C, while the second case discusses a possibility of the utilization of water temperature of up to 25 °C.

Example:

I case — utilization of water temperature of up to 37 °C ΔT_1= 78 °C - 37 °C = 41 °C

II case — utilization of water temperature of up to 25 °C ΔT_2= 78 °C - 25 °C = 53 °C

Usual temperature used in the TM water calculations is given as a second case (use of up to 25 °C).

Thermomineral water springs of Vranjska banja

The first data on the geothermal water temperature in Vranjska banja were recorded in 1893 by the famous geologist Jovan Zujović. In 1974 Vujanović and Teofilović gave detailed information on the physical-chemical characteristics and the radioactivity of some water wells in Vranjska banja.

Temperature and the discharge of geothermal springs in Vranjska banja

Over time, several shallow and deep hydrogeological wells have been formed in Vranjska banja. In 1980, on the seventh meter of one water rig water temperature measured was 99 °C. Deep well rigs (2,020 m) encompass a well rig placed near the railway station in 1981. The total discharge of the spring and the water rigs of the geothermal wells in Vranjska banja were assessed to 80 l/s. Then, at a depth of 1,500–1,575 m a measured rock temperature was 124 °C. Research has shown that in Vranjska banja at a depth of 1–1.4 m there are temperature anomalies in the inner springs area temperature of 40–50 °C. This anomaly is recorded in a length of 500 m and a width of about 100 m, and extends in the south-north-west direction, which corresponds to the provision of a fault along the Banjska river (Vujanovic & Teofilović, 1983).

Based on the report of experts from France (1970), Canada and New Zealand (1981 and 1984), it can be concluded that there are possibilities of obtaining water temperature of 130–150 °C in the deeper parts of the terrain at the site in Vranjska banja.

Recent investigations have shown that all springs of geothermal water in Vranjska banja occur in the form of springs of the developed type, capped by one collecting channel — a heat pipe. The most important springs so far studied and capped are shown in the Table 1. Thermal water from these springs is of an artesian type, that is, rises to the surface of the earth on the basis of an internal overpressure so that it does not consume additional energy for its production (Stojiljković et al, 2015).

Table 1. Main features of springs in Vranjska banja.

	Name of spring	Discharge of spring (l/s)	Depth (m)	Temperature (°C)	Capacity (MW) I case	Capacity (MW) II case	Energy use (TJ/yr) I case	Energy use (TJ/yr) II case
1.	Gornji source	1.2	–	78	0.21	0.27	6.49	8.40
2.	Spring B1	2.0	26	92	0.46	[illegible]	[illegible]	17.69
3.	Spring A1	0.5	2	91	0.11	0.14	3.56	4.36
4.	VG-2	27.0	163	111	8.36	[illegible]	[illegible]	306.53
5.	Spring A3	2.1	20	91	[illegible]	0.58	14.97	18.30
6.	Spring B2	1.0	7	96	0.25	0.30	7.79	9.37
7.	Spring B3	1.5	12	87	0.31	0.39	9.90	12.28
8.	Collecting channel	50–70	–	84	13.77	17.29	434.31	545.20
9.	Spring A2	1.0	25	84	0.20	0.25	6.20	7.79
10.	VG-3	21.5	160	[illegible]	7.47	8.55	235.57	269.63
	Total	127.8						

Source: Data obtained by measuring using ICP-OES

According to water temperature on the surface from 78 °C at Gornji source and water temperature of 84 °C at A2 spring, waters of Vranjska banja belong to hyperthermiac waters. The average discharge of these two springs is 1.1 l/s. However, at greater depths, the temperature reaches 111 °C (VG-2 spring at depth of 163 m) and even 120 °C (Vg-3 spring at depth of 160 meters). Its average discharge is 24.3 l/s.

Physical-chemical properties of Vranjska banja water

The Table 2 shows physical — chemical characteristics of Vranjska banja waters measured on springs VG-1, VG-2, VG-3 and A-1 respectively, obtained by ICP-OES device.

According to the mineral composition, waters are of hydro-carbonate-sodium type (HCO_3 Na) and almost neutral at the VG-2 source whose pH value is 7.3. In other observed springs water is slightly basic and the pH ranges from 7.7 to 8.1. As dominant elements one allocates sodium (900 mg/dm^3), calcium (30 mg/dm^3), magnesium (17 mg/dm^3) and potassium (350 mg/dm^3). By chemical composition bicarbonates HCO_3 stands out as the macrocomponent in the amount of 430 mg/dm^3.

Table 2. Physical-chemical properties of springs VG-1, VG-2, VG-3 and A- 1

	Characteristics/ spring	VG-1	VG-2	VG-3	A-1
Ingredient mg/dm^3	Sodium (Na)	320	880	900	290
	Calcium (Ca)	30	21	19	20
	Magnesium (Mg)	2,4	2.1	1.5	17.0
	Potassium (K)	9	230	350	12
	Iron (Fe)	0.30	0.12	0.09	0.40
	Barium (Ba)	55	–	–	50
	Strontium (Sr)	1.7	–	–	7[illegible]0
	Lithium (Li)	158	–	–	–
	Ammonia (NH_3)	0.60	0.04	0.04	0.[illegible]0
	Chloride (Cl^-)	57	42	44	62
	Bicarbonate HCO_3	384	409	42[illegible]	414
	Sulphate SO_4	365	360	[illegible]2	368
	Dry resident	1,269	1,05[illegible]	1,08[illegible]	1,291
Size	pH	7.7	7.3	8.1	7.9
	Conduct. µS/cm	1,700	1,240	1,300	1,503
	Total hardness °DH	3.40	3.41	3.04	2.90
	Constant hardness °DH	0.60	0.61	0.67	0.60
	Fuzziness, NTU	1.6	1.3	1.3	1.5

Source: data obtained by measuring using ICP-OES

The water contains also a high concentration of fluorine (8–8.5 mg/l). At the beginning of the 20th century, many scientists linked fluorine with several disorders of the central nervous system, respiratory diseases, as well as arthritis and musculoskeletal disorders (Varga, 2010).

Apart from these, medical benefits of Vranjska banja waters are derived from potassium, lithium, rubidium, cesium, strontium, barium, cobalt and sulfur. In the waters of Vranjsk banja there is no sulfur-hydrogen. In the dry residents of Vranjska banja waters one finds mostly iron, aluminum, strontium, lithium, manganese and rubidium, and a gas part is dominated by 70% of nitrogen (Lund, Freeston & Boyd, 2011).

Possible utilization of thermomineral water springs of Vranjska banja

Balneology

Due to the high temperature, waters of Vranjska banja are used for spa purposes, after some cooling for bathing and inhalation. Thermomineral waters of Vranjska banja are important for the treatment of the locomotor apparatus, degenartive rheumatism, discopathy, sciatica, lumbago, muscle atrophy, extraarticulary rheumatism, states after bone fractures, surgery to bone and joint pain, neurological disorders, gynecological disorders and diseases of the digestive tract, the intestines, stomach, liver, kidney, diabetes, lymphoid and anemic states, etc. (Joksimovic et al, 2013).

Modern methods using mud packs of treating patients with degenerative rheumatism and post-traumatic conditions are carried out in the *Institute for prevention, treatment and rehabilitation* in Vranjska banja. The institute has its own accommodation capacities. (Dragović et al, 2012).

Tourism

Although Vranjska banja has a large balneological potential, there is not enough accommodation capacity. The development of the material base of tourism in Vranjska banja is divided into two distinctive periods: the period of the liberation of Vranjska banja from the Turks in the First World War, and the second period after the Second World War. Development of Vranjska banja and construction of the first accommodation and infrastructure facilities began after the liberation from the Turks in 1878. At that time, the old building which was built by Hussein Pasha was restored. The building had three rooms. In addition, on the left bank of the river Banjska, two more buildings with bathrooms were built (Dokmanović, Krunić, Martinović, & Magazinović, 2012).

For the purpose of the spa treatment and tourism now there are more facilities in Vranjska banja which include *Railway Resort* (built in 1931, rebuilt in 1946 and 1997, when it was converted into a hotel *Sofka*), *stationary Vranjska banja, villa Balkan* and private households. In the period between the two World Wars, Vranjska banja had the highest number of overnight stays than all spas in Serbia.

Shortly before the Second World War in 1939, when Vranjska banja was excelling on its reputation for healing and richness of content, it was visited by 4,800 tourists who made 76,926 overnight stays. It was then ranked fourth in Serbia by the number of tourists, and by the overnight stays - second. In 1971, there were 16,000 registered tourists, making 77,727 overnight stays. Over the next few years the number of tourists and overnight stays increased slightly and Vranjska banja ranked tenth among the most visited spas in Serbia. In 1978 there were 27,376 tourists, a year later 96,436 overnight stays were realized (Varga, 2010).

After the Second World War a larger number of visitors was registered. In the period from 1959 to 1966 there have been increased visits to Vranjska banja, due to organized tourist attractions and cultural events. It also attracted a large number of visitors from Italy, West and East Germany, Switzerland, Greece, Poland, France, Great Britain, Austria and Japan. From 1988 to 1996 in

Vranjska banja not a single room was built, which was reflected in tourism development. Spa tourism is neglected, new hotels are not built, and for that reason the number of visitors decreased. Since 2000, tourist traffic recorded a gradual growth. The highest number of arrivals and overnight stays are realized in the summer months — July, August and September, when it is the most pleasant time to visit Vranjska banja. Beside these months, higher turnover is also recorded in April (Čomić, Jović, & Popović, 2008).

Regarding the number of arrivals and overnight stays, of both domestic and foreign tourists between 2010 and 2012 there was a slightly downward trend, but that number increased drastically in 2013. Tourism in Vranjska banja as compared to 2013, doubled during 2015 and 2016 (Table 3). This happened due to the improvement of transport infrastructure, tourism services, infrastructure arrangement of Vranjska banja, as well as an increase in accommodation facilities.

Table 3. Tourist turnover in Vranjska banja in 2015 and 2016

Year	Arrivals			Overnight stays			Average Overnight stays	
	Domestic	Foreign	Total	Domestic	Foreign	Total	Domestic	Foreign
2015.	3,762	200	3,962	22,761	905	21,856	6.1	4.5
2016.	5,489	614	6,10[illegible]	34,975	2,234	32,741	9.4	7.1

Source: Statistical Office of the Republic of Serbia Municipalities in Serbia (2010)

The formation of the *Natural History Museum* with various types of insects, plants and animals would contribute to a significant extent to the promotion and development of Vranjske banja.

Economy

The use of utilized and unutilized TM waters within the spa cycles may have a different, more convenient and more economical model. The practice of spas in Serbia has shown that partial use of thermal water energy represents a loss of energy, and direct discharge of thermal water in nature can create environmental problems.

Utilization of water with a temperature of up to 37 °C

If, on the basis of the data shown in the Table 1, one implies the utilization of geothermal water in Vranjska banja with temperatures of up to 37 °C, the conditions are created for the heating of the greenhouse complex surface of 32 ha, and flower cultivating during the winter months when the ambient temperature is –18 °C. For example, great importance would have the cultivation of carnations, spanning over 300 species, which are not resistant to low temperatures. It would certainly be of great use both for domestic and foreign markets.

Utilization of water with a temperature of up to 25 °C

In this case, an opportunity would be created for sports and recreation complex and the Olympic swimming pool heating that would enable swiming in the winter months without additional electricity heating. Aslo one could cultivate fish such as carp, grass carp, crucian carp, pike, chub, or other fish that are not characteristic for our region and live in water with a temperature of 20–30 °C. It is possible to cultivate exotic aquarium fish like the Oscars, Ancitrus, Blue Akara, etc. Specific use of geothermal energy for agricultural purposes and industrial processes, in addition to its use in greenhouses and for space heating purposes, includes chemical processes, heating kilns of fruits and vegetables, drying of tobacco, cultivation of medicinal plants, paper production, distillation, etc. (Borović & Marković, 2015).

Potential of Vranjska banja waters is partly seen for therapeutic purposes. Health infirmary Vranjska banja provides hydrotherapy, massages, drinking water, underwater massage and pearl baths. Thermal energy is utilized to heat the dispensaries accommodation capacity, hospitals and the Železničar hotel. In most cases, space heating is accomplished by means of heat exchangers. Heat exchanger stations are located in manholes along the route of direct heat source. If we also take into account the collection channel, which draws a quantity of water of 50–70 l/s with an average temperature of 84 °C at a distance of 2 km, it can be concluded that it reaches the user, with a temperature of 40 °C. From the consumer unused water goes to the Juzna Morava river with a temperature of 35 °C (Varga, 2010; Kostić, Jovanović, Tončev, & Vukadinović, 2014).

Taking into account that energy sources are limited, and that the environment is compromised and polluted, it is necessary to observe more complete utilization of geothermal energy for the business tourism development of Vranjska banja and the Republic of Serbia as well.

Conclusions

By its geothermal potential Serbia is one of the richer countries. Research over past 50 years have indicated the existence of significant quantities of thermal mineral waters that appear in different tectonic zones and on faults of the Rhodopes massif in Southern Serbia, which accommodates the Vranjska banja.

Vranjska banja has a number of sources of geothermal water whose temperature is between 63 °C and 95 °C and a total discharge of 127.8 l/s. Almost all sources are grouped in a zone which extends in the southwest-northeast direction, in the total length of 60 kilometers, and follows the valley of the river Banjska. Recent investigations have shown that all sources of geothermal water in Vranjska banja occur in the form of springs that are of the developed type, capped by one collecting channel — heatpipe.

Based on the results obtained in this study, the following conclusion were made:

- the waters of Vranjska banja contain sodium (90[illegible] mg/dm^3), calcium (30 mg/dm^3), magnesium(17 mg/dm^3) and potassium (350 mg/dm^3), which provides the opportunity for multiple use in the rehabilitation and balneotherapy.
- according to the temperature of water on the surface of 78 °C at Gornji source and a water temperature of 84 °C at A2 source, Vranjska banja waters belong to hyperthermiac waters. The average discharge of these two sources is 1.0 l/s. However, at greater depths, the temperature reaches 111 °C (VG-2 Source at a depth of 163 meters), and records 120 °C (Source Vg-3 at a depth of 160 meters). The average discharge is 24.3 l/s.
- by mineral composition waters are of hydrocarbon-sodium type (HCO_3 Na) and almost neutral at the source VG-2 whose pH value is 7.3. In other observed sources water is slighly basic and the pH ranges from 7.7 to 8.1. By the chemical composition bicarbonates HCO_3 stand out as macro component (430 mg/dm^3).

In order to highlight the possibilities for economic development by using geothermal energy of Vranjska banja, the paper concludes that:

- with geothermal water in Vranjska banja with temperatures of up to 57 °C, the conditions are created for the heating of the greenhouse complex surface of 32 ha, and flower cultivating during the winter months when the ambient temperature is –18 °C. For example, great importance would have the cultivation of carnations which are not resistant to low temperatures. It would certainly be of great use both for domestic and foreign markets. The formation and heating of the *Natural History Museum* with various types of insects, plants and animals would make it accessible to the public all year round.
- water with a temperature of 25 °C can heat sports and recreation complex and the Olympic swimming pool in the winter months without additional electricity heating. Aslo, one could cultivate

fish such as carp, grass carp, crucian carp, pike, chub, or other fish that are not characteristic for our region and live in water with a temperature of 20–30 °C. It is possible to cultivate exotic aquarium fish like the Oscars, ancitrus, Blue Akara, etc. Also, it is possible to use hot water for agricultural purposes and industrial processes, for heating kilns of fruits and vegetables, drying of tobacco, cultivation of medicinal plants, paper production, distillation, etc.

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