Application of the principle of circular economy to the thermal groundwater, the example of the municipality of Bogatić

Marija Jovanović, Vesna Ristić Vakanjac

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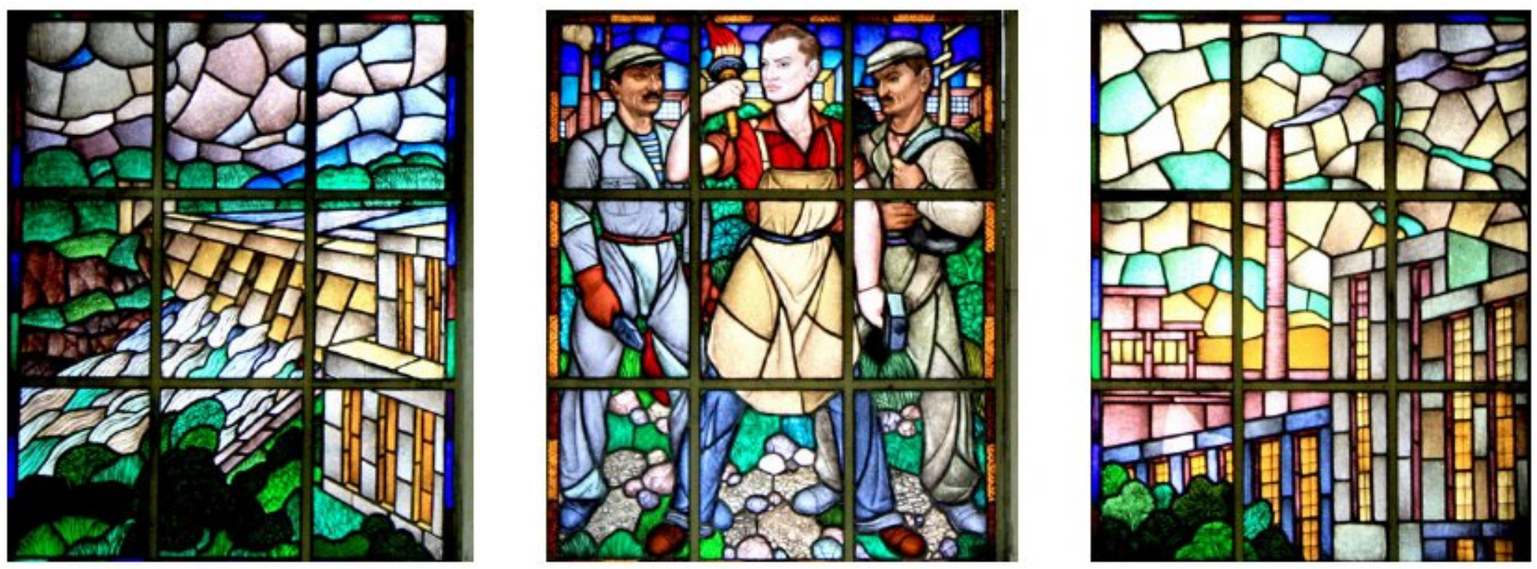

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FOREWORD

School of Engineering Management in Belgrade and Engineering Management Society of Serbia organised the third International Scientific and Practical Conference on Circular and Bioeconomy - CIBEK 21.

The Conference deals with more current topics, such as improving efficiency and reducing the use of resources; identifying and creating new opportunities for economic growth and promoting the innovation and competitiveness of cities and their surroundings as well as their companies; guaranteeing the security of supply of essential resources; fighting against climate change and limiting the environmental impact of the use of resources.

This conference brought in some different format, online, together scientists, professionals and students from Austria, Jordan, United Kingdom, Portugal, Spain, Italy, Luxembourg, Norway, United Arab Emirates, Romania, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Macedonia and Serbia due to exchange ideas and concepts of great importance for the future sustainable economic development.

The Book of Proceedings, as a result of the Conference, is published and will be available to a wider audience, scientifically and practically focused on circular and bioeconomy multidisciplinary issues.

Belgrade,

July, 2021

Editor

Brankica Pažun, PhD

CONTENT

APPLICATION OF THE PRINCIPLE OF CIRCULAR ECONOMY TO THERMAL GROUNDWATER, THE EXAMPLE OF THE MUNICIPALITY OF BOGATIĆ

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Abstract: There are about 360 locations of thermal and thermo-mineral waters in Serbia, whose water temperatures range from 14 to 98°C, which ranks Serbia as the richest European country in geothermal energy. The mentioned water resources (thermal and thermomineral waters) are used, mostly, for therapeutic purposes in spas and sports and recreational centers. The main problem that is present is the fact that they are not used in a rational and efficient way. The paper will give examples territorially related to the municipality of Bogatić, where this resource is used for various purposes. These examples have in common the fact that this resource is largely unused, or that it is a partial single use, which cannot develop the full potential of the resource. Applying a rational approach to the circular economy would encourage efficient, multi-stage use of geothermal energy. Because of this, different economic branches would satisfy their needs for space heating for different purposes, for greenhouses, balneotherapy, irrigation, etc.

Keywords: water-food-energy nexus, geothermal resources, groundwater management, sustainability, Bogatić.

1. INTRODUCTION

Groundwater is, in Serbia, a resource that traditionally reliable, in terms of meeting the needs of population for water, and most of the centralized water supply in the country uses it. In addition to high-quality waters that are used to supply water to the population and industry, Serbia also has insufficiently used potential in the field of thermal, mineral and thermo-mineral waters, which are used in our country mainly for the

needs of spa tourism. As we live on a planet of limited resources, the current economic model with existing patterns of production, consumption and trade is unsustainable. This includes the production of electricity, which, due to the mentioned imbalance, is increasingly turning to alternative methods of production based on green energy, energy produced exclusively from renewable resources (hydropower, solar energy, wind energy, geothermal energy, energy tides, biomass energy, etc.).

According to the data [1–6], in Serbia there are approximately 360 sources of thermal and thermo-mineral waters whose water temperature ranges from 14 to 98 C. Opine the geothermal potential of Serbia (calculated value is about 100 mW / m^2) in relation to the European average which is about 60 mW / m^2, it can be said that our country is one of the countries in Europe richer in this renewable resource. Although, the mentioned water resources (thermal and thermo-mineral waters) are used for therapeutic purposes in spas and sports and recreation centers, they are not used in a rational and efficient way. Precisely, if the quality of these waters allows, the circular economy could be used by other economic activities for heating residential, commercial, industrial buildings, which would reduce emissions of greenhouse gases, then greenhouses, which would increase agricultural production, as well as for irrigation of areas planted with certain crops.

In addition to the Pannonian Basin, for which there are certain strategies for the use of groundwater resources, which should be realized soon, another suitable site is the southern edge of the Pannonian Basin, around Mačva region. Specific geological conditions for the formation of a geothermal resource, as well as favorable exploitation possibilities, enable the development of an economically and ecologically sustainable model of use. It is certainly necessary to have in mind the fact that there is a chance of possible increase in needs, which are a consequence of reliable economic development, but certainly the relationship between the potential of the resource and its use is positive, in every sense of the word.

2. GENERAL CHARACTERISTICS OF THE RESEARCH AREA

The municipality of Bogatić is located in the northwestern part of the Republic of Serbia and includes the northern and northwestern part of

Mačva, in the Podrinje-Kolubara region, and is one of the less economically developed municipalities. It belongs to the border municipalities (it borders Bosnia and Herzegovina / Bijeljina municipality). On the territory of Serbia, its border municipalities are Sremska Mitrovica and Šabac. The municipality of Bogatić occupies a peripheral position in relation to central Serbia. With the construction of the bridge over the Drina, this periphery has been somewhat reduced since this bridge represents a traffic link between Serbia and the Republika Srpska in BiH.

The total area of the municipality of Bogatić is 384.31 km^2. In this area there are 14 cadastral municipalities and 14 settlements, in which, according to the 2011 census, live 28879 [1] inhabitants. All settlements in the municipality have retained their rural character, with certain urban elements in the administrative center of the municipality - Bogatić. As in other parts of central and western Serbia, the natural increase is negative and amounts to −9.7‰. Figure 1 shows a graphic presentation of the position of the municipality of Bogatić.

Climatic characteristics were analyzed based on the existing meteorological (metro station Šabac and metro station Sremska Mitrovica) as well as seven rain gauge stations: Badovinci, Bogatić, Glušci, Lipolist, Hrtkovci, Petkovica and Štitar. Table 1 gives basic data on the stations used. According to the values of the main climatic elements and according to their change in space and time, this is undoubtedly the area with the most pronounced continental characteristics of the climate with quite warm summers and moderately cold winters. The annual amplitude of air temperature ranges from 21°C to 23°C. The mean temperature of the warmest month, July, is mostly in the range 20°C to 23°C and the mean temperature of the coldest month - January between 0.5°C and -1.5°C. Spring is slightly warmer than autumn or has approximately the same temperature conditions. The penetration of cold continental air from the northern and northeastern parts of Europe is the most common and the most intense in this subregion. As a consequence of this are present rather low ap are convolution minimal temperature of the air which are between -23°C and −32°C. A significant feature of this subregion is that during the colder part of the year there is a large frequency of strong, cold and dry wind from the southeast and east, known as košava. The average annual rainfall ranges from 6 26.0 (metric station Sremska Mitrovica) to 845 mm (rain station Petkovica) (Table 1).

Figure 1. Geological map of the municipality of Bogatić (OGK SFRY 1: 100,000 sheets Bjeljina and Šabac [1]) showing the position of the municipality of Bogatić

Table 1. List of meteorological and climatological stations in the research area and overview of basic data. [20]

Station	Station type	Ltd. φ□N	Ltd. EG R λ	Altitude (mnm)	Avg. temp. (° C)	Air humid. (%)	Avg.rainfall (mm)
Sabac	Climato logical	44.77	19.68	80	11.2	79.3	678.7
Sremska Mitrovica	Climato logical	45.00	19.55	82	11.0	77.7	626.0
Badovinci	Rainy	44.78	19.38	85	-	-	718.5
Bogatic	Rainy	44.83	19.48	85	-	-	689.7
Deaf people	Rainy	44.88	19.55	80	-		679.1
Lipolist	Rainy	44.88	19.77	80	-	-	746.6
Hrtkovci	Rainy	44.70	19.53	90	-	-	640.9
Petkovica	Rainy	44.67	19.43	100	-	-	845.2
Shield	Rainy	44.80	19.60	80	-	-	689.5

Mačva is the largest alluvial plain in Serbia between the Drina River and the Sava River and covers an area of about 860 km^2. It belongs to the region of the inner Dinarides of western Serbia and has a length from south to north of 33 km, and a width of about 27 km.

In the municipality Bogatić [4] soil is the most important natural potential, because of the intensive agricultural use. Macva is a special pedogeographic micro-region, where the arid climate and alluvial sediments and loess, as the most common lithological background, decisively influenced the structure of the pedological cover. In this region, the great differentiation of the pedological cover is reflected in the change of different types of soil, starting from alluvial, mineral - marsh through chernozem to groves and vertisol. In terms of percentage, the most common are automorphic soils (56.3%), namely groves (23.5%), and of the hydromorphic soils, the most common is alluvium (19.5%), and this is shown in more detail in Table 2.

Table 2. Land types and percentage of their presence in the exploration area *.

Soil type	Representation	
	Ha	%
Automorphic	21,600 th most common	56.3
Chernozem	1 . 740	4.5
Chernozem (degraded)	4,970 th most common	13.0
Cambisol	9,000	23.5
Cambisol (lessified)	5,800 th most common	15.3
Hydromorphic	16,797 th most common	43.7
Alluvium	7,497 th most common	19.5
Meadow (mineral-marsh)	6,300 th most common	16.4
Hydrogen mixture	400	1.0
Pseudogley	2,600 th most common	6.8
In total	38 . 431	100.0

* According to the PPO Bogatić 1986–2000., Analytical – Documentation and the basics of a "plan" Sabac, Sabac, 1986. [2]

In addition to agriculture, which is the most dominant economic activity in the municipality (about 50% of the total population is agricultural), livestock is also developed. Even in the old Yugoslavia, Badovinci was one of the places with the largest production of pork. According to the census from 2012, it was recorded that in the municipality of Bogatić there were 3920 head of cattle, then 126954 pigs, 31327 sheep, 1368 goats and poultry 202980.

3. GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS

Knowledge of geological and hydrogeological characteristics of an area is of crucial importance in assessing the possibility of using and exploiting geothermal energy. Detailed geological research in this area was done during the preparation of the geological map, for Šabac [1]. On the surface, the entire territory of the municipality of Bogatić is covered with Quaternary sediments represented by layers of river terraces (t_1), lesoid-marsh and marsh sediments (b), sediments of the dead facies (am) and flood facies (ap), river beach facies and facies trough (a) (Figure 1). Beneath the Quaternary lie Pliocene and Miocene sediments. Pliocene sediments were found by drilling in the entire area of Macva, while they were discovered only in its southern parts. They are represented by fine dusty sands, sandy clays and clays, and in some places by sandy and clayey gravels. Within the Miocene formations, there are Pannonian gray, greenish and bluish fine-grained sands, fine clays with interlayers of medium-grained sands with characteristic vertical alternation of layers, and Sarmatian limestones, which were initially thought to be of Triassic age. In Dublje, Pannonian sediments were drilled at a depth of 170–207.5 m, while Sarmatian limestones were registered by exploratory drilling near Šabac at depths greater than 195 m. Below the Miocene, rocks of Mesozoic age have been recorded, namely the Lower and Middle Triassic and Upper Cretaceous.

From the aspect of geothermal energy, the most productive are the Triassic and Upper Cretaceous limestones and the outcrop that was formed in them, so here we will only talk about the hydrogeological characteristics of these geological formations. Thus, the karst type issued was formed in carbonate deposits of Mesozoic age which were ascertained by exploratory drilling in the bedrock of Tertiary deposits. These deposits are represented by dolomitic limestones and limestones of the Middle Triassic age, massive and layered limestones of the Upper Cretaceous age. In the area of Pocerina and in the wider surroundings of Šabac, Middle Triassic and Upper Cretaceous limestones erupt on the surface of the terrain in the form of small, isolated oases.

Limestones are intensively karstified, and smaller caverns are filled with calcite and sandstone with pyrite. Based on the exploratory drilling for the needs of the exploration of the thermo-mineral waters of Macva, it was determined that the limestones have a thickness of more than 200 m. By drilling the exploration well DB-1 to a depth of 400 m, it was found that the Middle Triassic limestones have a wider horizontal

distribution around Macva than assumed. Thus, karst released in the area of Mačva, Srem and Semberija covers an area of about 2000 km^2. The waters of this issue are replenished at the expense of infiltration of water from precipitation and surface water in the part of the terrain where limestone erupts on the surface of the earth. Top-dressing is also done by the inflow of groundwater from other aquifers. Drainage is carried out by flowing into tertiary deposits of sand and gravel as well as by underground runoff outside the boundaries of the exploration terrain. Also, the outflow waters flow to the surface of the terrain through exploratory wells and exploitation wells whose waters have a temperature of 50–78^{o}C.

4. GEOTHERMAL POTENTIAL OF THE MUNICIPALITY OF BOGATIĆ

J. Perić, M. Milivojevic and M. Martinović, were used to define the geothermal characteristics of the terrain. [11,12] Macva is in the area of geothermal anomaly of Serbia [8], which is the southern part of the geothermal anomaly of the Pannonian Basin. Therefore, the conductive and convective geothermal anomaly of Macva is a consequence of very high regional values of terrestrial heat flux density in the earth's crust of this part of the Pannonian Basin.

To assess the reserves of geothermal potential and forecast the reserves of geothermal resources, it is necessary to know the values of temperature in the shallower part of the earth's crust. Temperature field at great depths was determined based on the model budget by temperature Milivojevića and Martinovic 1998 years [13]. According to these data, the temperature at a depth of 5 km is about 230°C, at a depth of 7 km about 300°C, and at a depth of 10 km about 420°C. At the Mohorovičić discontinuity, it is assumed that the temperature value is around 800°C. [6]

The reservoir in the hydrogeothermal system of Macva is represented by the mentioned highly karstified Triassic limestones. The proportion of these limestones is unknown. According to geological data, it is a minimum of about 500 m and according to geophysical data a maximum of about 1000 m [4].

Returnable insulator over the reservoir with thermal waters - reservoirs consists of Neogene sediments with a thickness of 200 m in Dublje to 620 m in Bogatić. The temperature at the top is 35–78^{o}C.

According to hydro geothermometers and mixing models, the maximum value of the temperature in the tank should be around 100°C [6].

With the help of individual vertical or oblique wells, geothermal energy can be rationally exploited only from thermal waters, in Upper Cretaceous and Triassic limestones. [9]

In order to more reliably assess the geothermal conditions of the terrain, modeling was performed, on the basis of which all subsequent research was performed. On this topic, a hydro geothermal model was made in 1986 and enabled the simulation of both the current conditions and the prediction of the system response in the event of more intensive exploitation. Later, the original model was supplemented with new data, and in 2008 a hydro geothermal conceptual model was constructed, shown in Figure 2.

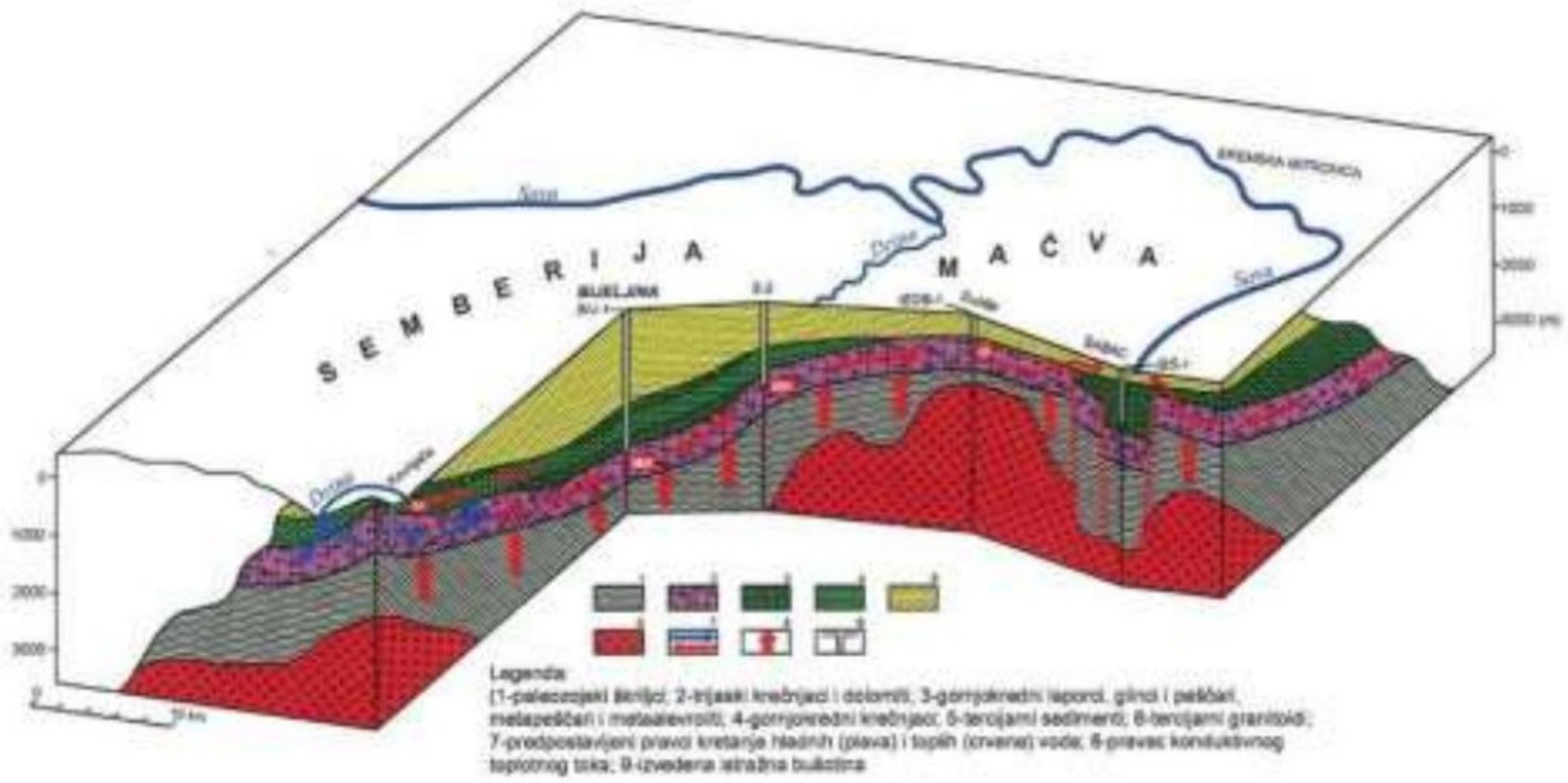

Figure 2. Hydrogeothermal, conceptual, 3D terrain model of Macva [5].

5. POSSIBILITY OF USING RESOURCES AND POSSIBILITY OF APPLYING CIRCULAR ECONOMY IN GIVEN CONDITIONS

Use in spa tourism, as the only and most common option, although undoubtedly one of the most important is becoming obsolete. If we assume that the average temperature of underground thermal waters exceeds 70°C , then spa tourism and use for recreational purposes leaves as, practically, another link in this chain of use. However, even in this case, it is necessary to cool the mentioned resource, and this process can take place in favor of heating the greenhouse. This was attempted with

less success in Dublje, the IEDB-1 well, which was drilled in 1985 for the needs of the sports and recreation center and the spa complex "Macvansko vrelo". [15] This complex consisted of three outdoor and three indoor pools, and they served, according to the original idea, to cool the water, which in practice, however, proved worse, because it lost a large amount of energy, which would, for example. could heat greenhouses or heat a residential or industrial complex. The irrational approach led to the rapid closure of this center as early as the early 1990s. The closure and collapse of this center were influenced by sanctions, which resulted in the economic crisis in Serbia. [14]

The imagined "Chain" begins, in fact, with the use of geothermal energy for heating, which would solve the issue of heating Bogatić as a settlement and enable the use of resources in the next stage, but also the heating of greenhouses and hothouses. Currently, most of the inhabitants of the mentioned settlement, for now, use solid fuel as a heating resource, which, apart from the immediate satisfaction of needs, does not achieve anything more, even the greenhouse effect of gases resulting from the use of solid fuels. After cooling the resources in the heating systems, in accordance with the growing needs, this water can be used in greenhouses and hothouses, and the cycle of use is closed by direct use in the irrigation of agricultural land.

An example of good practice is the well for heating the EOL Radljevo greenhouse in Dublje. The greenhouse was put into operation and currently uses water at a temperature of 32.5°C from a depth of about 350 m. They heat a greenhouse of 4650m^2. Aeolus produces flowers intensively with a million seedlings a year. For complete profitability of thermal waters obtained from the well, at least 3 ha with intensive production are needed in a short period of time. [18, 13]

The next example is the well BB-2, it was drilled in the settlement of Beljište near Bogatić, in 1989, the depth of the well is 618 m, the self-discharge gives 60 l/s with a temperature of 78°C. Currently, the water flows freely, forming the surface flow of thermal water. Downstream, some 500 m from the formation of the thermal water flow, the locals formed a small barrier on the flow, so that a smaller swimming pool was formed. This location is known as Jokin Grab Spa.

Among the newer works in that direction, the aqua park "Thermal Riviera" stands out, for the needs of which exploitation wells BT 1 and BT 2 are planned, while BT 1 was drilled .It was found that at a depth of 525 m there is a flow of water yield of 30 l/s at 70°C. At a depth of between 600 and 771 m, 5 more small inflows of water were registered in

the well, which were filled with sediment. It is expected that after the second rinsing, the BT1 well could give over 40 l of water per second with a temperature of 75°C to 80°C, which would also cover the waters of the aforementioned hypsometric inflows of water in the well. [19]

Figure 3: "Spa Jokin Grab" -p regrad in the course of thermal water and the formed pool for swimming (photo Vesna Ristić Vakanjac [20])

6. CONCLUSION

Through all these examples, the common fact is that the resource is largely unused, or that it is a partial single use, which cannot develop the full potential of the resource and that it is necessary to apply a rational approach to prevent further deterioration, because such treatment not only the question of use is raised, but also the consequences that its non-use has on quality. Certainly, by applying the principles of circular economy, whose basic principles are presented in the paragraph above, it is possible to set good foundations for the formation, at least outline, of something that could be the first green municipality in Serbia in the future. There are opportunities to form an economically and environmentally viable chain, which would cover both material needs (in terms of heating, use for spa tourism, after cooling, as irrigation water), and create the necessary environmental sustainability.

In the light of the above, the conclusion is that something like this is achievable, even in our climate. Relying on the resources that are available to us, and now we either don't know how or we are not able to use them, will contribute to the development of new ideas, and enabling some kind of energy independence, which is an immeasurable wealth in the time we live in. Certainly, a gradual transition is necessary, because

the so-called "green technologies" are mostly unaffordable, but with gradual investments, this investment, both in terms of material and environment, is more than profitable. As mentioned above, the economic model currently in use is unsustainable, because soon the first variable in that model, its initial basis, namely the raw materials used to produce energy in the form in which it is now used, will become significantly limited. From this we see that the application of the above principles is practically the only way to survive, either economically or ecologically.

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