Karst wastewater as a high quality, renewable and within the circular economy water resource

Jovana Nikolić, Vesna Ristić Vakanjac

FAKULTET ZA INŽENJERSKI MENADŽMENT

Proceedings of the 3rd International Scientific Conference on Circular and Bioeconomy “CIBEK 2021”



Belgrade School of Engineering Management
Belgrade, 2021

The Third International Scientific Conference

CIRCULAR AND BIOECONOMY

Book of Proceedings

School of Engineering Management

Belgrade, 2021

BOOK OF PROCEEDINGS

The Third International Scientific Conference

CIRCULAR AND BIOECONOMY

Publisher

School of Engineering Management, Belgrade

For the Publisher:

Vladimir Tomašević, PhD

Editor:

Brankica Pažun, PhD

Number of copies

100

Printed by:

Black and White, Beograd

978-86-89691-21-4

SCIENTIFIC COMMITTEE

Vladimir Tomašević – School of Engineering Management, Chairman

Ana Ristevska, BAS Institute for Management Bitola, Macedonia

Anamarija Pisarović, Institute for Development and International Relations – IRMO, Zagreb, Croatia

Branko Latinović, School Of Information Technology, Pan-European University "Apeiron", Banja Luka, Bosnia and Herzegovina

Brankica Pažun, School of Engineering Management, University Union Nikola Tesla, Serbia

Duško Tomić, American University in the Emirates, UAE

Eldar Šaljić, American University in the Emirates, UAE

Ilija Životić, School of Engineering Management, University Union Nikola Tesla, Serbia

Magdalena Nikolić, School of Engineering Management, University Union Nikola Tesla, Serbia

Magdalena Stevanović, Institute of Technical Sciences, SANU, Serbia

Malči Grivec, Faculty of Business, Management and Informatics, Novo Mesto, Slovenia

María Begoña Peña Lang, University of the Basque Country-University School of Engineers of Bilbao, Spain

Marija Maksin, School of Engineering Management, University Union Nikola Tesla, Serbia

Milica Gerasimović, School of Engineering Management, University Union Nikola Tesla, Serbia

Momir Čelić, School of Electrical Engineering, University of Banja Luka, Bosnia and Herzegovina

Nikolina Ljepava, American University in the Emirates, UAE

Rade Slavković, School of Engineering Management, University Union Nikola Tesla, Serbia

Sanja Tišma, Institute for Development and International Relations – IRMO, Zagreb, Croatia

Senhorinha Teixeira, University of Minho, Portugal

Slobodan Živković, School of Engineering Management, University Union Nikola Tesla, Serbia

Smilja Marković, Institute of Technical Sciences, SANU, Serbia

Srđan Tomić, School of Engineering Management, University Union Nikola Tesla, Serbia

Stanko Bulajić, School of Engineering Management, University Union Nikola Tesla, Serbia

Stefan Grbenic, Graz University of Technology, Graz, Austria

Tatjana Ilić Kosanović, School of Engineering Management, University Union Nikola Tesla, Serbia

Tina Vukasović, International School for Social and Business Studies, Celje, Slovenia

Valentina Janev, Mihajlo Pupin Institute, University of Belgrade, Serbia

Vladica Ristić, School of Engineering Management, University Union Nikola Tesla, Serbia

ORGANISATIONAL COMMITTEE

Brankica Pažun (School of Engineering Management, Chairperson)

Tatjana Ilić Kosanović (School of Engineering Management)

Jelena Rajković (School of Engineering Management)

Veljko Ćalasan (School of Engineering Management)

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, Editor

July, 2021 Brankica Pažun, PhD

CONTENT

KARST WASTEWATER AS A HIGH QUALITY, RENEWABLE AND WITHIN THE CIRCULAR ECONOMY WATER RESOURCE

Jovana Nikolić, Vesna Ristić Vakanjac

University of Belgrade, Faculty of Mining and Geology, Belgrade, Serbia

Abstract: High quality drinking water in it's natural state is becoming less and less available to the human population. Based on the expected climate changes, it is considered that this resource will be less in the world but also in our region. Also, the accompanying polluting components that exceed the maximum allowable concentration are increasingly present in the waters. Even after the water treatment, it happens that some components are still in the drinking water, which adversely affects human health. One of the highest quality waters used for water supply of the population is groundwater, within which karst spring waters are separated. Karst massifs are mostly uninhabited areas without industry, while roads are laid mainly along their perimeter so that there are almost no potential contaminants of karst aquifer water. This is also the reason why some local karst water works capture these waters in their natural state for their own needs, id without prior treatment. This paper will present how this important renewable, high quality water resource can be used through the circular economy, and in addition to the mentioned water supply, it can also be used for aquaculture, irrigation, hydropower production, recreation and tourism, etc.

Keywords: water resource, groundwater, karst aquifer, water supply, irrigation.

1. INTRODUCTION

In Serbia, about 80% of the population and industry use groundwater for their own needs, in the first place is water supply. Water supply in Vojvodina is practically entirely done by exploitation of groundwater. At the sources of public water supply, about 5.5 m^3/s of water is taken. A small number of settlements use water from the "first" aquifer in the sediments of the younger Quaternary, which is significantly endangered by anthropogenic influence. The largest number of settlements capture groundwater to a depth of about 200 m, from aquifer formed in the deposits of the youngest Pliocene and older Quaternary (Plio-Quaternary deposits). Due to its importance in water supply, this issue is known as the basic aquifer complex [7]. In central Serbia and in the valleys of larger rivers, water supply is mainly at the expense of groundwater formed within the alluvial deposits (Velika Morava, Drina, Ibar, South and West Morava, ...). These waters, as well as the waters that have been captured for the needs of the water supply of Vojvodina, are mostly of problematic quality due to the fact that certain components exceed the maximum allowable concentration. Finally, the wide distribution of karst groundwater is within the southwestern part of the inner Dinarides and Carpathian-Balkanids of eastern Serbia. They are characterized by favorable physical and chemical properties. In the region of western Serbia, there are significant karst springs captured for water supply. Some of them are characterized by a minimum discharge of over 1000 l /s [10]. In the Carpatho-Balkan region, out of a large number of karst springs, 16 have a higher minimum discharge of 100 l /s [11]. Karst wastewater as a quality and renewable resource is used for water supply, then for bottling water, mineral and thermal water. If they have elevated temperatures, which is the case with Bogatić, they can also be used as natural energy sources.

The reserves of karst outflow waters of the Carpatho-Balkanids exceed the needs of this area many times over eastern Serbia, as well as neighboring areas for a longer period of time [10]. As the waters of karst springs are of good quality, for the needs of water supply, they were treated only with chlorination before being released into water supply systems. Cities such as Niš, Pirot, Paraćin, Bor, Ćuprija, Prijepolje, Novi Pazar, Zaječar and others use them for water supply. These aquifers generally follow large fluctuations in the level of aquifer and the discharge of the source. Large differences between the minimum and maximum amounts of water are a consequence of spring highs that are the result of melting snow or spring rains and summer lows when we have long dry periods that even lead to drying of certain karst springs. In addition to the above, turbidity is present during high waters, as well as an increased number of bacteria, which is why these springs are excluded from the central water supply system until the amount of turbidity and the amount of bacteria drops to the permitted level. One of the solutions for overcoming the mentioned problems is the regulation of karst issues, which will be discussed later.

2. THE REGIME OF KARST WATER

Of special importance in the analysis of karst aquifers is discharge of karst springs, i.e. the regime of discharge of karst springs. Discharge ie. the outflow of the spring can be descending (gravitational) or ascending under pressure. The regime of gravitational karst springs is conditioned mainly by precipitation (melting of snow cover and /or heavy precipitation) [9]. One of the typical significant gravitational springs is Veliko vrelo, which drains the southern rim of the Beljanički massif and whose discharge exceeds 10 m^3/s (measured by the Department of Hydrogeology of the Faculty of Mining and Geology). We mention this spring because it is known in Serbia because of the waterfall that forms downstream from the place of outflow, so it is an important tourist facility. It is protected as a monument of nature. Figure 1. shows the flow chart in the period 1995-1999. year in which fast increases of hydrograms can be stated, where from the flow in the amount of 0.5 m^3/s, in one day it increases to almost 6 m^3/s. (Figure 1, 1997).

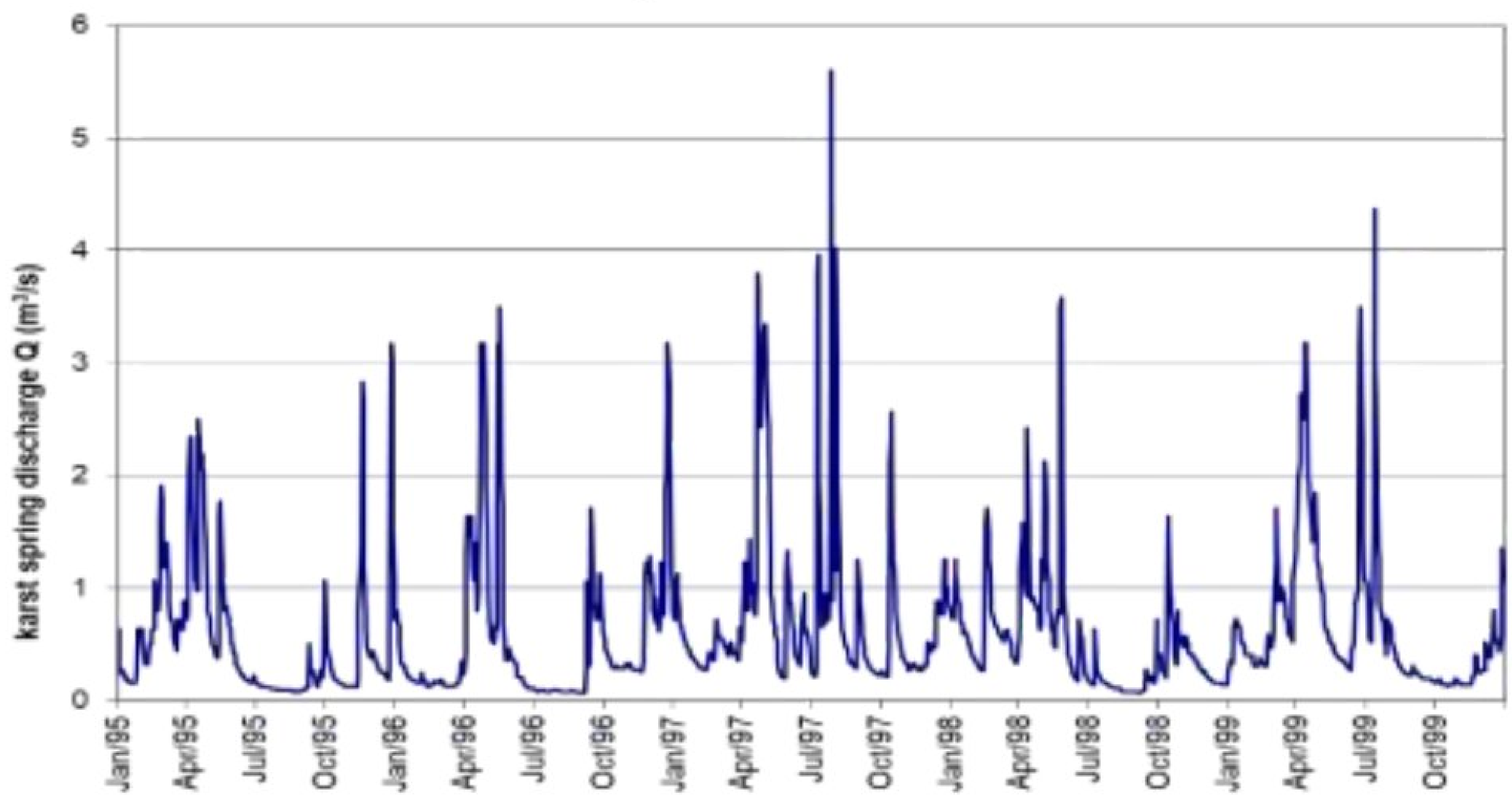

Figure 1. Hydrograph of Veliko spring for period 1995.-1999. [2]

On the other hand, we have long recession periods during the summer and autumn months when the amount of leaked water falls below 100 l/s. In addition to the problem of lack of water during dry periods, it is present during high waters and increased turbidity as well as an increased number of bacteria.

Čokorilo Ilić and co-authors (2018) believe that *during precipitation of strong intensity or long-term precipitation of stronger or medium intensity, there is a more intensive recharge of groundwater and thus an increase in groundwater levels, which creates higher hydrostatic pressure. As a consequence of this, along the predisposed directions of movement (caverns, canals, cracks), the water in the ground got a turbulent flow. This movement of groundwater is triggered by the deposited suspended sediment that the water brought into the underground in the previous period, but due to the low speeds of movement during the dry period, this material was deposited in caverns and canals. This movement of the precipitated material due to precipitation of higher intensity causes the appearance of turbidity of karst springs. If the springs are captured, during this period when turbidity occurs, the waters of these karst springs are discharged from the water supply system until the turbidity of the water drops to the permissible level.* The Banja spring, ie also called Petničko vrelo, which is also known to the general public (Figure 2). The situation is similar with the total number of bacteria (Figure 3).

In ascending springs, the regimes of quantitative and qualitative parameters are more stable. The period of recession is longer than with gravitational springs, so the dynamic reserves are more significant. The relation of maximum and minimum amounts of water is often 2: 1, or the ratio is even lower. An example of a spring with an ascending type of outflow is the Vapa spring.

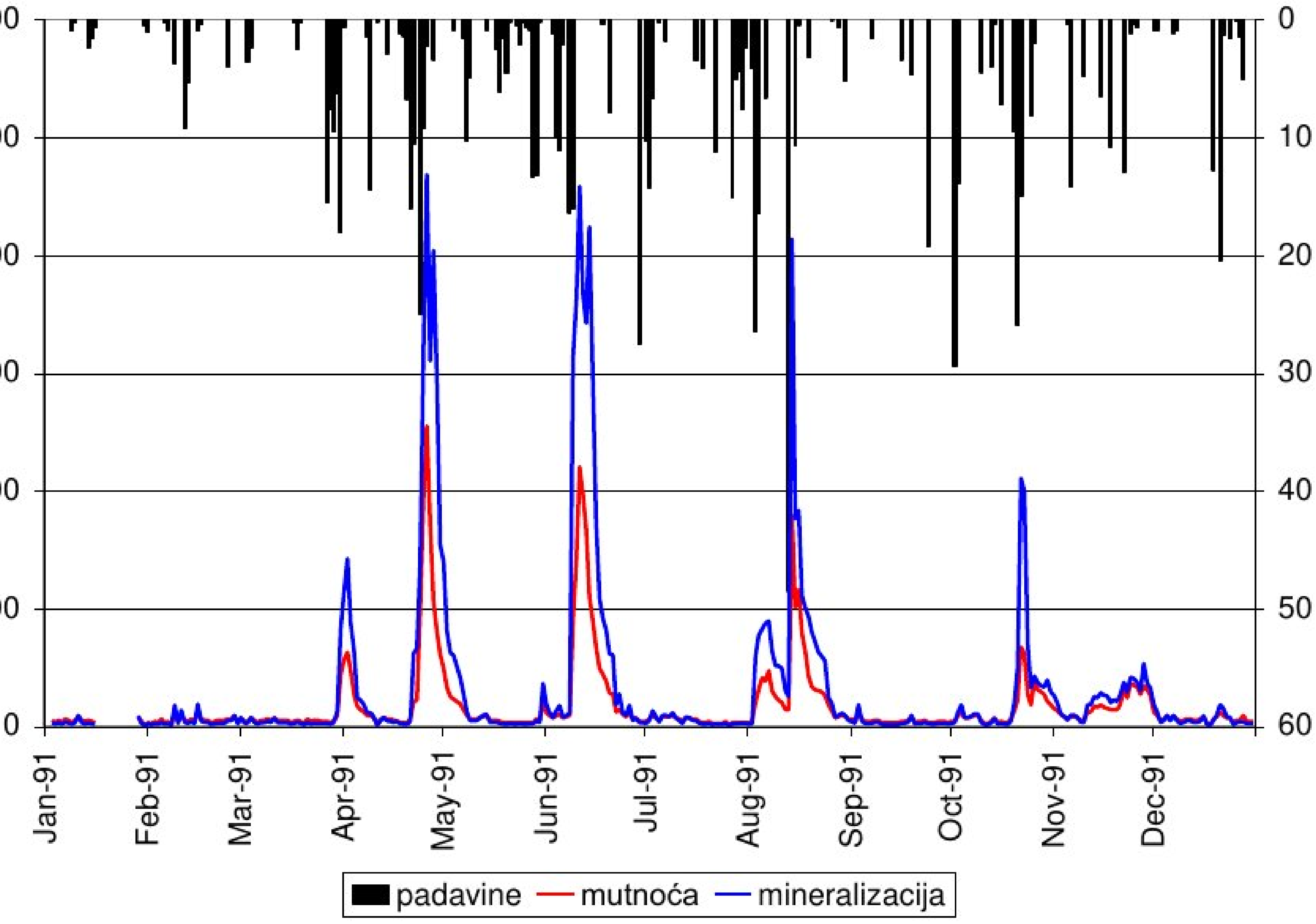

Figure 2. Comparative diagram of turbidity in the waters of the karst spring Banja and precipitation recorded in the basin for 1991 [1]

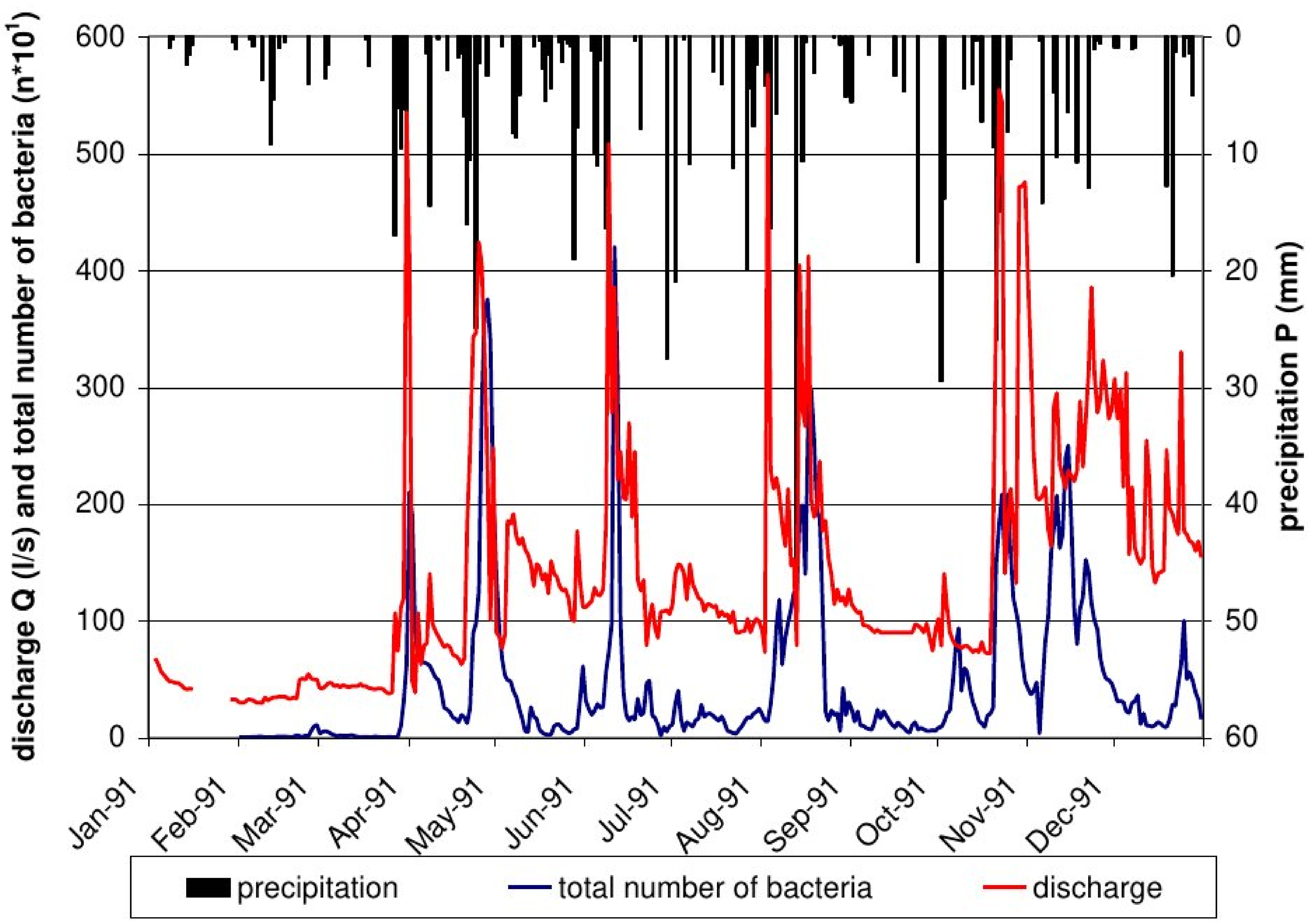

Figure 3. Parallel representation of discharge, total bacteria at Banja karst spring and precipitation recorded in the catchment in 1991. [8]

2.1. POTENTIAL OF KARST AQUIFER WATER

Groundwater karst terrains of Serbia as high quality water can be used for different purposes: water supply, aquaculture, geothermal energy, irrigation, tourism, recreation. As the quality of karst waters is on high level, they can be used in their natural state for the needs of water supply of the population. In the western part of Serbia, for the needs of the Tamnava-Kolubara area, karst waters from deeper structures are used, e.g. Valjevo uses the waters of the karst outflow waters of the Paklje spring, all larger settlements in the central belt of the Dinarides use the karst outflow waters, Priboj uses the waters of the Čečinica spring. The strongest spring in this region of western Serbia is the gravity spring Perućac, a smaller part of which is captured for the settlement of the same name. Discharge of this spring varies from 0.45 m^3/s to 10 m^3/s [6]. As far as the eastern part of Serbia is concerned, the waters of the Golubac mountain deposits, for the Aleksinac zone of Ozren, Leskovik and the Velepojska river basin can be used for water supply of the population of the municipality of Golubac. The karst waters of Svljiška and Suva planina, the deposits of the Kučajsko-beljanički massif can be used, for the needs of the city of Zaječar, the waters of the spring Barbaroš, Bora spring Gaura Mika, Gaura Mare, Rnić, Melajnić, Surdup, Banjica are used. Over 70 karst springs important for regional water supply (with a lower limit of minimum discharge in the average hydrological year of 10 l/s), of which 16 have a higher registered minimum value of 100 l/s [6].

Due to the good quality, low temperatures and rich oxygen content downstream from the source of the spring, these waters are suitable for **aquaculture.** Downstream of all major springs, these waters are used to produce parsnips. For example, in almost all springs that drain Beljanica, trout ponds have been built (Mlava spring, Krupaja spring, Belosavac, Veliko Vrelo). As there are significant reserves within the reservoir of karst wastewater that exceed the total needs for water supply and aquaculture, a significant part goes downstream unused, which can be used for **irrigation** of agricultural areas of the local population. In addition to the above, within the karst terrains, as well as the karst springs themselves, they form morphological forms that are mainly protected by the state, and which become target objects for **geotourists, hikers**, or casual passers-by. Within the fast streams and later the river, mountain trout are inhabited, which is a real attraction for **sport fishermen**. Having all this in mind, it is necessary to mention that **rural tourism** is present here, which can be combined with **ethno tourism** and **eco-tourism**, depending on the possibilities. As these are mountain rivers with large falls, in some parts the power of the river can be used to **run mills** that would grind grain in one part, and in the other part could produce the necessary **electricity** for the surrounding households. In this way, the existing environment would not be disturbed, water would remain in its beds and all water users could be satisfied. Finally, it should be noted that in relation to the potential and water resources in Serbia, the use of **geothermal energy** is very modest. In western and eastern Serbia, there are several phenomena and deposits of thermal and thermo-mineral waters that have a very significant geothermal potential. At a distance of 50 m from the mentioned Krupaja spring, there is a thermal spring whose water temperature is 26°C with a constant flow of about 2 l/s, which is a potential source for the use of geothermal energy.

3. THE ROLE OF KARST SPRING WATERS WITHIN THE CIRCULAR ECONOMY

3.1. INVESTIGATION AREA

One of the most important springs that belongs to eastern Serbia is Krupaja spring. It is located on the northwestern edge of the Beljanica massif and is an ascending spring. This spring is one of the most deeply researched karst springs in Serbia. The elevation is at 215 m above sea level, and represents the drainage zone of the western part of Beljanica. According to S. Milanović (2010), water erupts from a cave opening, whose channels are predisposed by the NE-SW fault. The shallower channels lie to a depth of 20 m, and after a length of 70 m they exit into a dry siphon hall. The deeper channel is vertical and has been explored to a depth of 133 meters by speleological research. The spring belongs to the group of deep siphon springs whose change in the vertical morphology of the channel in the hinterland of the spring significantly affects the flow regime itself. Thus, the Krupaja spring, depending on the piezometric level, ie the general groundwater level of the Beljanica massif, may at one point have a significantly higher protrusion than the Mlava spring [3]. Since 2009, water levels and flow measurements have been monitored at this spring by the Department of Hydrogeology (Faculty of Mining and Geology), while since 2014 they have also been performed by RHMZ. According to the data of the Department of Hydrogeology, the amounts of water that are drained at this spring vary seasonally (251 to 8776 l/s), and the maximum flow was recorded in the flood wave in 2014, when about 31 m^3/s flowed at the spring. According to RHMZ data, the maximum flow of this spring does not exceed 2.7 m^3/s, while the minimum flows are as much as 150 l/s (recorded in the period from 22-25 November 2015.) (see Figure 4). The average perennial flow of this spring is about 0.788 m^3/s.

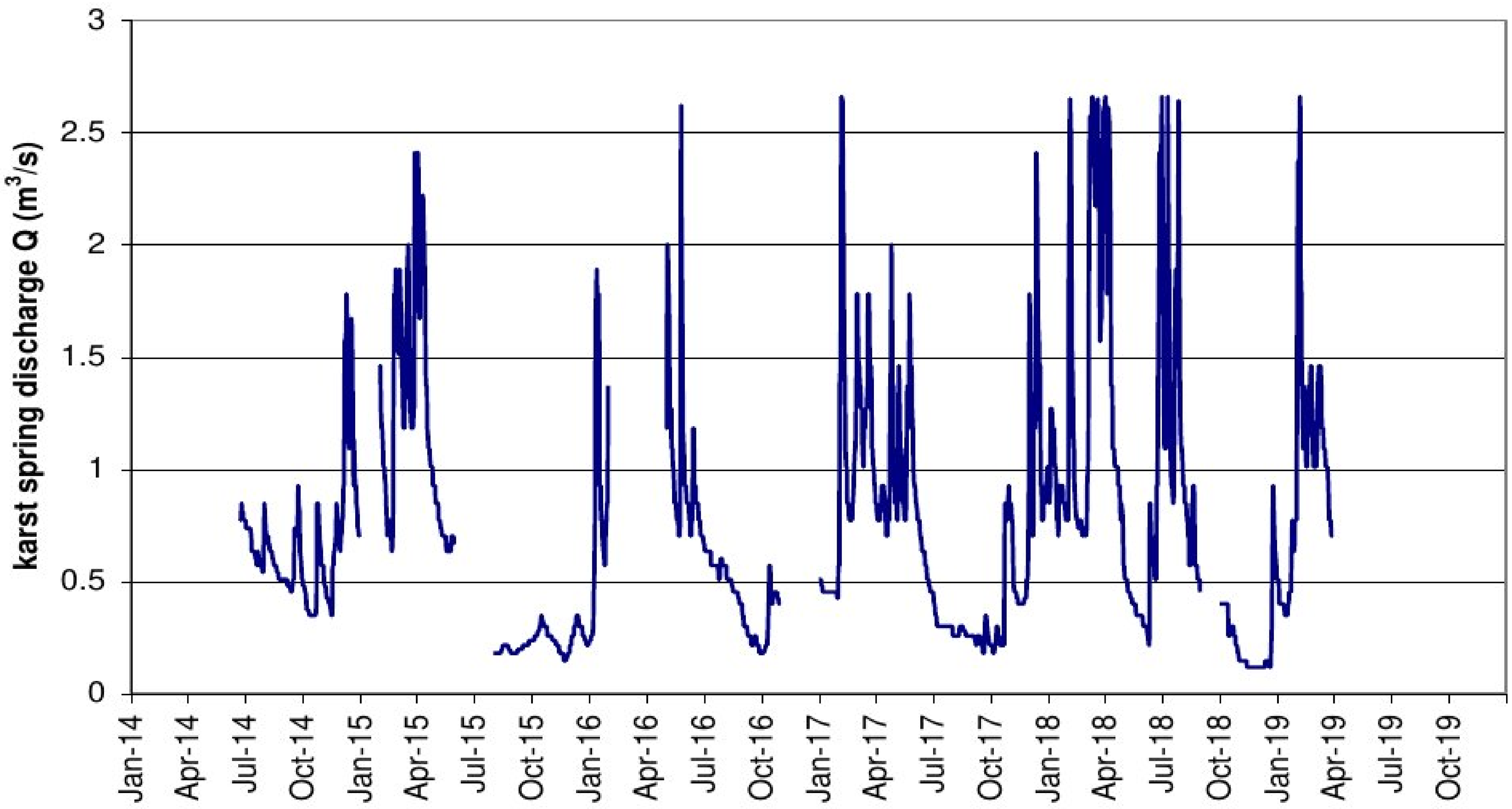

Figure 4. Hydrograph of discharge Krupaja spring for period 2014. -2019. [5]

3.2. CIRCULAR ECONOMY

We have already listed which users can use karst aquifer water. Here we will state how the karst waters of Krupaja springcan be used through the circular economy, without disturbing the water quality and the environment. In the first place, it is necessary to provide sufficient amounts of water for water supply. In the region of Krupaja spring, there are four settlements with about 3,000 inhabitants. If we assume that each inhabitant needs about 200 or 220 l/day/inhabitant, it would mean that for these settlements it is necessary to provide on average 7 or 7.5 l/s. It is mentioned here that in the vicinity of Krupaja spring there are mostly rural households, and that each household has a certain number of cattle, the number of which was unknown during the preparation of this paper. For this reason, the mentioned amount of water that needs to be provided is much higher, ie let's say that 20-25 l/s can satisfy the needs of the inhabitants and households of this part of Serbia.

According to the observed data, the minimum discharge of this spring in the amount of 150 l/s and more than satisfies the mentioned water needs. Therefore, even during long recession periods, in the bed of the formed Krupaja river, after the catchment, over 100 l/s would remain. Near the spring there is a trout pond, so part of the water is used for this purpose.

As a conceptual solution, we suggest that a dam be built on the spring itself (which already exists - Figure 5) and that the formed accumulation be used for trout production. A village guide would be built under the dam, which should fit into the ambience and which would grind grain.

Figure 5. Krupaja spring [4]

In addition to this function, the drop in water flow could also be used to produce electricity that the surrounding residents could use. All the mentioned users (pond, mill and electricity production) are not pollutants and they are also not consumers of water, i.e. downstream from the mill there should still be at least over 100 l/s of water in the riverbed. Further, downstream, these waters can be used for irrigation of agricultural areas. As at some 50 m distance from Krupaja spring there is a thermal spring whose temperature is about 26°C and which has a constant flow of about 2 l/s, these waters can be used to heat the greenhouse during the winter months, so agricultural production could be done Throughout the year.

In this particular case, the potential of karst waters is reflected in the fact that the development of its infrastructure can serve multiple functions: it offers a green area, supplies clean water, provides energy and transport opportunities and creates new economic and environmental development [9]. Finally, it is mentioned here that only one karst spring is presented, while the total amount of water which discharge through all springs in Serbia is on average 44.5 m^3/s, of which 18.85 m^3/s flows in the Carpathian-Balkan and 26.65 m^3/s in the Dinarides [10].

Finally, it is mentioned here that only one karst spring is presented, while the total amount of water which discharge through all springs in Serbia is on average 44.5 m^3/s, of which 18.85 m^3/s flows in the Carpathian-Balkan and 26.65 m^3/s in the Dinarides [10].

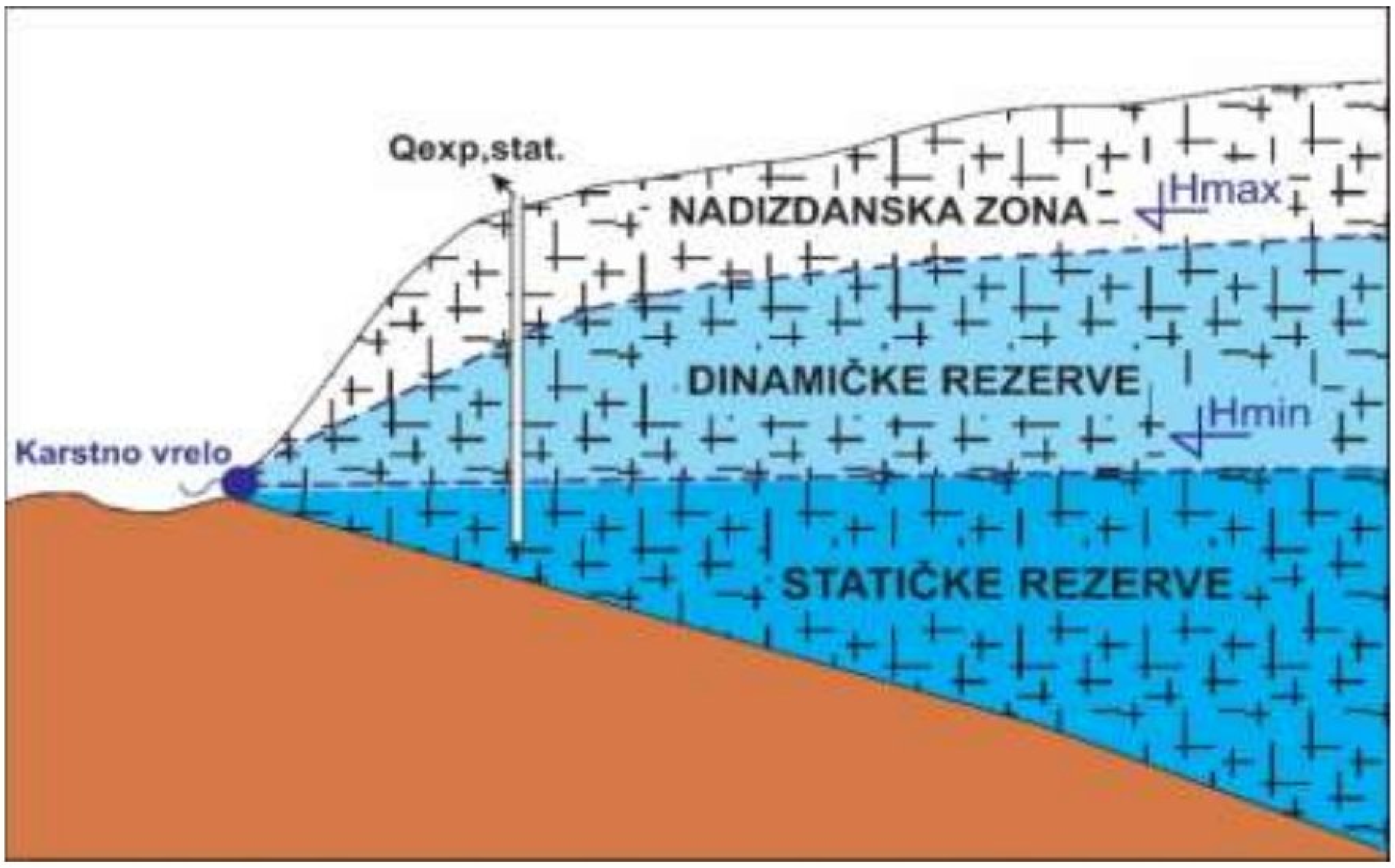

Figure 6. Schematic representation of regulation

4. CONCLUSION

Karst waters are high quality waters that can be used to supply water in its natural state. In addition to water supply, these waters can be used for aquaculture, irrigation, sport fishing, tourism, electricity generation, etc. The use of these waters is conditioned by their regime of quantitative and qualitative parameters. The most common problem occurs during the period of high waters when there is occasional turbidity of karst waters, which results in the exclusion of these sources from the water supply system. Also, water shortages can occur during the summer months and wet periods. This can be solved by regulating the karst aquifers. In order to clarify how the regulation of karst aquifers can be performed, it is first necessary to clarify what static, dynamic and exploitation reserves are. Dynamic reserves represent a renewable amount of free water that is limited by the maximum and minimum aquifer level (Figure 6), while static ones are below the multi-year minimum aquifer level (these reserves are missing in the release of some karst aquifers, Figure 6). In addition to these reserves, we also have exploitation reserves that represent the amount of water that can be used for certain purposes. In order to rationally use karst aquifer water in accordance with the potential and increasing needs of the population, it is necessary to properly regulate or manage karst aquifer. This requires the application of artificial interventions of aquifer, especially in the discharge zone, in order to equalize the quantitative and qualitative properties of the aquifer water. Regulation of karst aquifers enables us to use aquifer water evenly, the possibility of using reserve water reserves, reducing turbidity, opportunities to improve quality and economic effects. Therefore, in the specific case, it is possible to exploit static reserves by making a well in the hinterland of the karst spring. This would avoid potential turbidity of wastewater, compensate for the lack during dry periods and provide quality water for various types of its use. In this way, the uninterrupted use of these waters through the circular economy would be ensured throughout the year.

REFERENCES

[1] Čokorilo Ilić, M., Ristić Vakanjac, V., Papić, P., Golubović, R., Polomčić, D., Bajić, D. 2018. Uticaj padavina na kvalitativne i kvantitativne parametre karstnih izdanskih voda, *Zbornik radova nacionalne konferencije sa međunarodnim učešćem: Ekoremedijacija i ekonomska valorizacija vodnih resursa – modeli i promena*, Fakultet za primenjenu ekologiju Futura, pp 51-56, ISSN 978-86-86859-57-0

[2] Kocić D. 2019. *Analiza režima isticanja Velikog vrela,* završni rad, Rudarsko-geološki fakultet, Beograd

[3] Milanović S. 2010. *Formiranje fizičkog modela karstne izdani na primeru Beljanice (Istočna Srbija),* doktorska disertacija, Rudarsko-geološki fakultet, Beograd

[4] Nikolić J. 2019. *Analiza režima isticanja Krupajskog vrela,* završni rad, Rudarsko-geološki fakultet, Beograd

[5] Nikolić, J., Nikolić, J., Ristić Vakanjac, V., Nikolić, I., 2019: The condition and needs of monitoring the quantitative status of groundwater bodies un Serbia, *Proceedings of the national conference*

with international participation „Geosciences 2019“ , pp. 179-181. Bulgarian Geological Society Sofia

[6] Polomčić, D., Stevanović, Z., Dokmanović, P., Papić, P., Ristić Vakanjac, V., Hajdin, B., Milanović, S., Bajić, D., 2011: Vodosnabdevanje podzemnim vodama u Srbiji - stanje i perspektive, Poglavlje u monografiji "*40 godina hidrogeologije*", Rudarsko-geološki fakultet (*Ed. Polomčić D i Ristić Vakanjac V*), Beograd, pp 45-78, ISBN 978-86-7352-260-9

[7] Ristić Vakanjac, V., Hajdin, B., 2019: Condition, problems and prospects of water supply from groundwater in Serbia, *Proceedings of the national conference with international participation „Geosciences 2019“ , pp. 185-187* . Bulgarian Geological Society, Sofia

[8] Ristić Vakanjac, V., Golubović, R., Polomčić, D., Čokorilo Ilić, M., Štrbački, J., Bajić, D., Ratković, J., 2017: Autocorrelation and cross-correlation analyses of total bacteria: Case study of Banja karst spring in Valjevo, Serbia, *Proceedings of the national conference with international participation „Geosciences 2017“ , pp.145-146.* Bulgarian Geological Society Sofia

[9] Ristić Vakanjac, V., Vujičić Trkulja, M., Čokorilo Ilić, M., 2019*:* Potentials for sustainable usage of karst aquifers in Serbia, *Fifth international scientific conference FINIZ, Digitization and smart financial reporting*, Singidunum University, Belgrade, pp 108-112

[10] Stevanović Z., 1995: Karstne izdanske vode Srbije – korišćenje i potencijalnost za regionalno vodosnabdevanje, Poglavlje u monografiji „*Vodni mineralni resursi litosfere Srbije“*, Rudarsko-geološki fakultet, Beograd, pp 77-119, ISBN-86-80887-17-X

[11] Stevanović, Z., 1995: Vodni mineralni resursi litosfere Srbije – korišćenje, zaštita i potencijalnost, Poglavlje u monografiji *„Vodni mineralni resursi litosfere Srbije“*, Rudarsko-geološki fakultet, Beograd, pp 3-30, ISBN-86-80887-17-X