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# Условия, проблеми и перспективи на водоснабдяването с подземни води в Сърбия

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Serbia is relatively rich in groundwater reserves, which are found in different types of aquifers, unequally distributed along the territory of the republic (Polomčić et al., 2011). Considerable reserves of groundwater are found within the Quaternary and Neogene sediments as well as in the karst massifs of East and West Serbia. Most of these reserves are used for the supply of fresh water for the population of Serbia. Today, more than 90% of the inhabitants of Serbia have access to public water supply systems (the Water Management Basis of the Republic of Serbia). Of the total quantities of water used for public water supply, about 80% originate from groundwater (Polomčić et al., 2011). According to the data taken from the Water Management Basis of Serbia, a total of 23 $m^3/s$ of groundwater is abstracted for the purposes of water supply (Table 1).

Taking into account the results presented in Table 1 and the regional overview of water supply that is executed at the expense of groundwater of a certain type of aquifer, we can generally distinguish three regions by their specificity. These are: Autonomous Province of Vojvodina in the north (water supply at the expense of the Basic Water Complex and water from alluvial deposits), then there is Central Serbia (alluvial deposits and Neogene deposits) and the third one covering East and West Serbia (mainly at the expense of karst aquifer waters).

The north portion of Serbia is covered by the **Autonomous Province of Vojvodina**. In geotectonic terms, the area belongs to the southeast part of the Pannonian Basin, where, during the Tertiary period, sand and clay layers were deposited down to a depth exceeding 2500 meters. The water supply in Vojvodina is virtually exclusively carried out by exploitation of groundwater. About 5.5 $m^3/s$ of groundwater is abstracted at the sources used for public water supply. A fewer number of settlements use the water from the "first" aquifer, within the younger Quaternary sediments, the quality of which is significantly compromised by anthropogenic influences. Contrary to them, the largest number of settlements abstract groundwater up to the depth of about 200 m, from the aquifer formed in the deposits belonging to the youngest Pliocene and the older Quaternary (Plio-Quaternary deposits). Due to its importance in water supply, this aquifer is known as the "Basic Water Complex" (Hajdin, 2014). Many more problems in water supply arise in towns and settlements that are supplied with groundwater abstraction from the deeper aquifers, the Basic Water Complex. In terms of quality, the biggest issues relate to the occurrence of arsenic in the groundwater, which is genetic in origin, but due to expensive technology, its removal is only carried out in a few major towns. 653 000 inhabitants of Vojvodina drink water with increased concentrations of arsenic. In addition to arsenic, concentrations of ammonia and organic matter are also elevated in such groundwater, with microbiological irregularity also being common. Physical and chemical irregularity of water samples ranges from 25% of samples (in Srem) up to 100% samples (in middle Banat), whereas microbiological irregularity ranges from 0.5% (in Srem) to 72% (in middle Banat). The most common form of treatment is the disinfection of water by chlorination, which certainly does not comply with criteria set by modern European water management legislation. The most critical areas with high arsenic content are Novi Bečej with a maximum of 273 μg/l, Zrenjanin with up to 194 μg/l, and Subotica with up to 99 μg/l. In addition to quality, the problem is also the decline in groundwater levels within this aquifer, which has a regional character. The intensive process of decline in the water levels began in the 1970s, with the opening of new wells,

*Table 1. Capacities of groundwater sources in Serbia by type of aquifer medium (l/s) (Polomčić et al., 2011)*

| Hydrogeological unit | Alluvial deposits | Basic water complex (Vojvodina) | Neogene deposits | Karst medium | Cracked-porous mediums | Total |
|---|---|---|---|---|---|---|
| Bačka and Banat | 1454 | 3.570 | 431 | 0 | – | 5455 |
| Srem, Mačva, the Sava/ Tamnava | 6974 | 340 | 506 | 30 | – | 7850 |
| Central Serbia | 2585 | – | 845 | 430 | – | 3860 |
| East Serbia | 620 | – | 60 | 1711 | – | 2391 |
| South-West Serbia | 242 | – | 140 | 1614 | – | 1996 |
| West Serbia | 1051 | – | 60 | 397 | 17 | 1525 |
| Total | 12 926 | 3910 | 2042 | 4182 | 17 | 23 077 |

where no necessary regime observations were set up, which made exploitation often not rational. In some settlements, a level decline of 25 m was noticed (in Vrbas), in Kula, it was 13.5 m, and in Subotica, 16 m (Fig. 1 – left). The sharp decrease in water consumption by large industrial enterprises and the interruption of their operations due to the onset of a great economic crisis affecting Serbia during this period, and after that, the large emigration of younger population from this area, contributed most to the stabilization of the situation in water supply during the 1990s. The concept by which to overcome the current aforementioned problems of water supply came about two decades ago. It was believed that the opening of regional wells at the two large rivers, the Danube and the Tisa, would overcome the current problems. The aforementioned concept has become less and less realistic, in the first place due to reduced needs of consumption due to the pronounced process of migration of the population from this border area to the countries of the European Union, followed by the decrease in industrial production, but also due to the high cost of implementation of such solution, which is currently beyond Serbia's financial reach. Therefore, more rational solutions are being considered today, such as the construction of small water supply systems with mandatory plants for adequate technological treatment of water, in accordance with European legislation in the field of water management.

The next accentuated region comprises **Central Serbia**, that is, the basin of the Great Morava. The valley of the Great Morava has always been the most densely populated part of Serbia. Heavy floods prevented settlements from being built on the very banks of the river, so the only town on the banks of this river is Ćuprija. Among other settlements, we can name (going from the most upstream part): Stalać (where the Great Morava is formed by confluence of the South and the West Morava), followed by Varvarin, Paraćin, Ćuprija, Jagodina, Batočina, Lapovo, Markovac, Svilajnac, Velika Plana, Aleksandrovac, Požarevac and Smederevo. Most of the settlements mentioned above are supplied with water at the expense of groundwater of the first aquifer formed within the alluvion of the Great Morava and its tributaries. Water supply sources are represented by shallow wells from which the required quantities of water are abstracted. Due to the good hydraulic connection between the groundwater and the surface

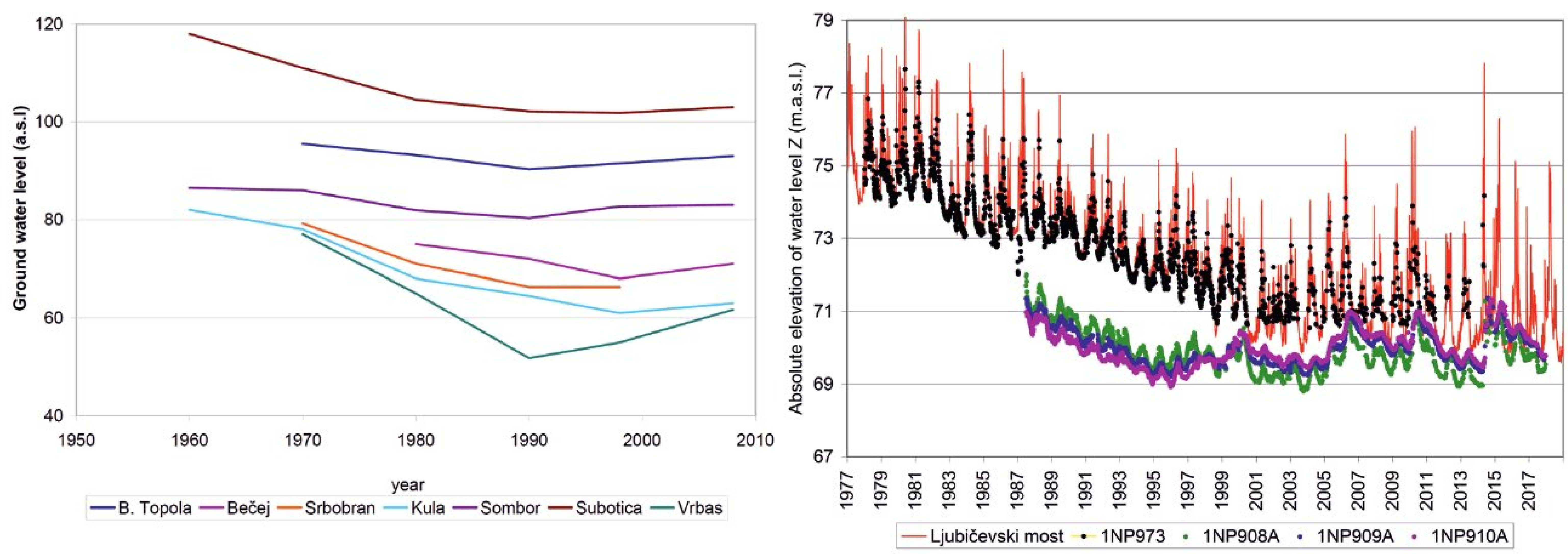


**Fig. 1.** *Left*, decrease of groundwater levels at the water supply sources of towns in Vojvodina in the period 1960–2009; *right*, absolute elevations of the Great Morava water levels at Ljubičevski Most and groundwater levels at observation wells on the right bank (1977–2017) (Ristić Vakanjac et al., 2019)

water of the Great Morava, significant reserves of good quality groundwater have been formed within the alluvial deposits, due to the natural purifying potential of the alluvial sediments. Outside the urban areas, intensive agricultural production is present within the remaining areas of land. The problem of irrigation of agricultural land has also been solved by the presence of shallow, mostly dug wells, by means of which groundwater is exploited for these purposes. The prolonged and sometimes inadequate use of fertilizers has led to increased concentrations of certain substances in groundwater, such as nitrates and other organic compounds. In addition to the industry, intensive sand and gravel exploitation is also present in this region. Long-term exploitation, which in some periods of time (mainly during the 1990s), was carried out illegally and in uncontrolled fashion, has led to the deepening of the Great Morava riverbed by as much as 5 m around the Ljubičevo Bridge (Fig. 1 – right). As a consequence, the level of the Great Morava has also decreased by 5 m, which resulted in a decline in groundwater levels in this part of the region. In addition to the decrease in groundwater levels, the illegal and uncontrolled exploitation of gravel and sand has also caused the deterioration of quality of the groundwater. More precisely, before groundwater level declined, nitrate concentrations, for example, were well below the MACs, while after the 1990s, the nitrate concentrations rose sharply and exceeded the limits of MACs. This was due to the fact that the quantities of groundwater available are much smaller, so the concentrations of certain qualitative parameters became much higher. Because of this, some of the water sources, e.g. the Ključ spring, were not used for a certain period of time, or they provided significantly smaller quantities of water, which made unimpeded supply of water to certain towns difficult (the spring of the Trnovča) (Popović et al., 2016). In addition to the alluvion of the Great Morava, a similar problem is present in the alluvion of the Drina River, where the excessive exploitation of sand and gravel causes a change in the flow of this river, which led to the situation in which some parts of the territory of Serbia are located on the left bank of this river and vice-versa, in some portions, the territory of Bosnia and Herzegovina is, on the other hand, located on the right bank of this river, which is contrary to the situation on the map. As with the Great Morava, all towns and smaller settlements here, too, supply water to the population at the expense of groundwater formed within the alluvion of the Drina. In the territory of Serbia, these are Ljubovija, Mali Zvornik, Loznica, and Bogatić. An important difference between the lower part of the Drina and the Great Morava is that there are a number of hydroelectric power plants on the Drina which, by forming reservoirs, have regulated the flow of the Drina in its lower portion. Thus, the frequent floods that occur in the basin of the Great Morava are here significantly reduced.

With regard to **West and East Serbia**, in this section, water supply is mainly carried out by abstraction of karst aquifer groundwater. About 150 karst springs with a minimum yield greater than 5 l/s have been recorded within the Carpatho-Balkanide terrenes; while in West Serbia, 11 springs have the lowest yield greater than 1,000 l/s. Since in most cases basin areas of karst springs are formed within uninhabited karst massifs, these waters are of high quality, due to the absence of potential anthropogenic pollution factors. Of the significant springs in East Serbia, it is worth to mention the Mlava spring, which represents the strongest spring in Serbia, then the Krupaja spring, the Great spring, the spring of Grza, Crnica, the spring of St. Petka, then Beljevinska springs, the spring of the Black Timok, the Radovansko spring, the Mrljiš spring, the Modro Oko, the Studena spring, the Upper Dušnik spring, the Ljuberađa spring, the Mokra, the Divljana, the Bela Palanka spring, the Kavak, the Krupac, the Gradište, the Protopopinac and many other springs. Within West Serbia, the following springs are distinguished by their importance: the Petnica spring, the Paklja spring, the Gradac spring, the Orlovac spring, the Perućac, the Sušica, the Sopotnica, the Vapa, the Sjenica, the Raška spring, etc.

In water supply, the greatest problems are present during high waters when short-duration turbidity occurs at certain springs. During these periods, such sources are generally switched off from the central water supply system. Also, water shortages occur during dry periods. The problems of turbidity during the rainy periods as well as the deficit of water during the dry periods can be overcome by regulation of the karst aquifer or by formation of springs which would exploit karst aquifer groundwater at the expense of static reserves (if there are any within the karst aquifer).

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