Present Situation and Alternative Water Supply Solutions for Northern Vojvodina (Serbia)

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PRESENT SITUATION AND ALTERNATIVE WATER SUPPLY SOLUTIONS FOR NORTHERN VOJVODINA (SERBIA)

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Abstract

The northern part of the Autonomous Province of Vojvodina is situated in the central and southeastern sectors of the Pannonian Basin. Drinking water supply is provided by groundwater abstraction from depths of 60 to 200 m. The quality of that water is poor, especially due to high concentrations of arsenic which most water supply systems do not remove. Current planning documents call for the construction of large regional water supply schemes on the banks of the Danube and Tisa rivers, aimed at improving the quality and ensuring sufficient quantities of water. The proposed concepts are 20 years old and based on unrealistic water consumption levels, compared to current EU water-related legislation. The paper reviews these strategic solutions and highlights the importance of the current demographic situation, characterized by population migration over the past ten years. The population drain, especially pronounced in the border zones, requires new water supply concepts and more efficient solutions, whose primary objective should be to improve drinking water quality as set forth in the EU Water Framework Directive. One such solution is discussed in the paper.

Key words: groundwater, regional water supply schemes, arsenic

Introduction. The northern part of the Autonomous Province of Vojvodina, which borders on Croatia to the west and Hungary to the north, hosts an ethnically diverse population of about half a million (Fig. 1). The area is situated between the Danube River, the Tisa (or Tisza) River, and the Danube-Tisa-Danube (DTD) Canal, where there are 12 municipalities that not long ago used to be among the most developed in Serbia.

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The study area is a spacious plain, part of the Pannonian Basin, with thick Tertiary sediments whose depth is in places greater than 2500 m. Largely sandy and clayey strata spread continuously over vast surfaces and extend into the territories of neighbouring countries. Along the vertical, the permeable parts of the geologic complex contain a number of transboundary aquifers. Cold groundwater with low levels of total dissolved solids (TDS) are found in Quaternary and younger Tertiary sediments up to a depth of $\sim$ 200 m. In the older strata there are thermal and mineral waters of varying physical properties and chemical compositions. The transboundary aquifers feature slow groundwater circulation and are recharged from distant mountainous regions of the eastern Carpathian mountains (Ukraine and Romania), the Tatra Mountains (Slovakia), the northwestern mountain range in Hungary (Mecsek), and Mt. Fruška Gora on the southern fringe of the basin in Serbia [1].

The Danube and Tisa rivers abound in water, which recharges shallow aquifers in the alluvial plains. The study area is known for the DTD Canal, which comprises a system of canals that are 960 km long, extends across Vojvodina, and connects the two rivers (Fig. 1). As a result of lacklustre maintenance, over time DTD gradually lost is irrigation and drainage functions and became the main recipient of municipal and industrial wastewater.

Drinking water supply relies solely on groundwater resources, whose reserves are limited. In the 1980s, this led to a permanent regional drawdown in both Serbia and Hungary. In addition, the quality of the groundwater is poor, often with elevated concentrations of organic substances, ammonia, and arsenic.

Future water supply solutions for the study area data back 20 years. The Water Management Master Plan of Serbia through to 2021 [2] assumes an unrealistically high water demand that cannot be met solely by groundwater abstraction. This planning document calls for the development of two regional schemes: one on the Danube near Apatin and the other on the banks of the Tisa in the northern part of the country (Fig. 1). The basic idea is to provide sufficient quantities of water, but bank filtration and mixing with groundwater from the hinterland would also improve drinking water quality. Although the concept is sound, its implementation has not begun to date. There are multiple reasons for this, the most important being military operations in the former Yugoslavia at the end of the past century; impoverishment and economic crisis leading to decreased industrial activity; and a significant population drain from the area. This has resulted in a reduced water demand, so it is questionable whether regional schemes would be justifiable, from both technical and economic perspectives.

An efficient approach based on EU water consumption standards and a realistic estimate of the water demand, along with economic water pricing and reduced water losses in the distribution network, would warrant the implementation of new concepts, such as small water supply systems outfitted with adequate raw water treatment plants.

Methods. ***Data sources.*** The insights presented in the paper with regard to water management issues stem from several international and domestic projects implemented in the past ten years. All of them complied with EU water legislation and the principles of the Water Framework Directive [3]. Official demographic reports released by national institutions were another relevant data source.

The 2007–2008 project "*Sustainable development of Hungarian-Serbian transboundary aquifer* (*SUDEHSTRA*)" [4] investigated the transboundary aquifer used by both countries for water supply, because of declining groundwater levels caused by long-term groundwater abstraction and poor groundwater quality.

Extensive and detailed hydrogeological investigations have been conducted in northern Bačka [1] to study groundwater management options. Data was collected on the operation of all groundwater sources and central water supply services and the ways in which water was supplied to and used by industry. The unchecked use of groundwater for irrigation was also examined.

A monitoring network consistent with WFD standards and guidelines has been set up in the study area according to a national project prepared in 2015 [5]. For the first time, monitoring included the deep Pleistocene aquifer, also referred to as the Basic Water Complex (BWC) because of its water supply significance.

More attention has recently been devoted to this area known for its drinking water quality issues. There have been several programmes aimed at assessing the situation and defining best available techniques (BAT) for drinking water production per EU legislation [6]. The information gathered in this regard is also presented in the paper.

Demographic data on this part of Serbia was studied from 1948 to 2018, including data up to and including the last census in 2011 and more recent data up to 2018 [7]. The extent and rate of demographic changes were determined and the municipalities with the largest population drain identified.

Water supply. Drinking water supply in the study area relies solely on groundwater [1]. Industries use both surface water and groundwater, but because of the poor condition of the DTD Canal, these resources are also used for irrigation. Relatively small quantities of groundwater are withdrawn from the shallow ("first") aquifer, because it is polluted by human activity. Most of the municipal and industrial water supply comes from the Basic Water Complex (BWC), because of the need for high-quality water. BWC is formed in Lower Quaternary (Pleistocene) and Upper Pliocene (Paludian) sediments. Its depth in the study area is up to ~ 200 m and it spreads into Hungary, Croatia and Romania.

The main water supply issues are associated with quality, but also quantity. The poor groundwater quality of the shallow aquifer is generally due to pollution by municipal and industrial wastewater, as well as long-term contamination by fertilizers applied on spacious farmland. The quality of the deeper BWC groundwater is adversely affected by elevated concentrations of arsenic, ammonia, and organic substances. In most cases it is also bacteriologically inadequate because of mesophilic and coliform fecal bacteria.

The water quantity problem is caused by very slow groundwater circulation and exchange in the Pannonian Basin, but also many years of inefficient use. The development of new groundwater sources and growing industry in the 1980s, as well as groundwater abstraction with no continuous monitoring of the groundwater regime, have led to a considerable permanent drawdown. Groundwater levels are now reduced on a regional scale [4]. In the early 1990s, the drawdowns recorded in Vojvodina were 25 m in Vrbas, 13.5 m in Kula, and 16 m in Subotica [1]. Although monitoring programmes had been prepared, the situation stabilized mostly because of a sudden drop in industrial water demand as large manufacturers discontinued their activities due to the onset of a major economic crisis in Serbia at that time.

To address these issues, strategic documents in the field of water [2,9] produced in the 1990s called for the development of regional water supply sources. The first system – Bačka Regional Scheme – was proposed on the left bank of the Danube, near Apatin, which would supply the towns of Apatin, Sombor, Odžaci, Bač, Kula, Mali Ipoš, Bačka Topola, Vrbas, Srbobran, Bečej and Novi Bečej, as well as potentially several settlements in Subotica Municipality (Fig. 1). Series of riverside wells, on two locations, would provide a total of ~ 2 m^3/s of water, as determined by detailed investigations conducted in that sector [10]. The second system – Upper Tisa Regional Scheme – would comprise existing groundwater sources as well as the withdrawal and treatment of water from the Tisa River. This water supply scheme would service Subotica, Kanjiža, Novi Kneževac, Senta, Čoka, Ada, Kikinda, and Nova Crnja. The capacity is unknown because funding difficulties have so far prevented detailed hydrogeological investigations.

Both solutions have their deficiencies. Potential arguments would be based on the facts that the two rivers are international, that future drinking water demand projections reflect current inefficient consumption rates, and that project implementation would be costly. The paper highlights another important aspect that challenges these solutions – the recently altered demographic situation due to a considerable population drain.

National strategies that address water supply generally rely on national rivers because transboundary rivers might give rise to disputes regarding water quality and water pollution control due to the inability to influence circumstances beyond national borders. The Tisa is more problematic, given that it is a highly vulnerable river with 92 identified potential threats, 76 of which are upstream from the Serbian border [11]. There have been a number of instances of accidental pollution of the Tisa in the past [12].

The idea to implement regional water supply projects had been backed up by water demand projections, which were unrealistic even at the time they were made. The estimates presented in the Water Management Master Plan [2], a strategic document produced in 2002, were founded upon unrealistic guidelines and overestimated parameters. For example, the water demand through to the year 2021 is based on a specific consumption by urban users of 600 l per capita per day (population 230 l/cap/day, industry 170 l/cap/day, and public services 90 l/cap/day) and a specific consumption by rural users of 400 l/cap/day (population 215 l/cap/day and the remainder used for watering cattle and public services). The projected water losses in both categories amount to 18%. This led to water quantities five times larger than actual; for instance, Subotica Municipality currently uses ∼ 350 l/s, whereas the document predicts that by 2021 the population and industry would require 1709 l/s. Sombor Municipality is another example, where the current consumption rate is 220 l/s (Sombor City 145 l/s and other settlements 70 l/s). The Master Plan projects 1208 l/s of water by the year 2021. This clearly shows to what extent the water demand had been overestimated.

Demographics. The demographic situation in the past 20 years has changed considerably, compared to the time projections were made. This requires the planning documents, as well as the proposed solutions, to be revised in respect of the future water demand. Apart from a negative birth rate, the study area is experiencing migration of mostly young people, to Hungary and other West European countries. The National Statistical Office does not collect data on the so-called external migration, but between the censuses of 2002 and 2011 [7], with regard to ethnic minorities, Vojvodina's Hungarian population declined by 39 071 or 13%, the Croat population by 9153 or 16.8%, the Slovak population by 6305 or 11.1%, and the Romanian population by 5009 or 16.4%. Serbia's population drain can also be studied by analyzing data from the 1948 census to 2017 (Table 1).

The census reports produced between 1948 and 2002 show that the population of large cities has increased on account of the surrounding village population. However, since 2002, all municipalities and municipal centres have reported a pop-

Table 1

Population from 1948 to 2017 and water consumption in 2018 [1,8]

Municipality	Population				Consumption
	1948	2002	2017	2017–2002 (%)	(l/s)
Ada	22 235	18 994	16 093	−15	37
Apatin	31 145	32 813	27 107	−17	63
Bačka Topola	43 135	38 245	31 210	−18	54
Bečej	42 071	40 987	35 567	−13	120
Kanjiža	36 334	27 510	23 992	−13	58
Kula	39 488	48 353	40 055	−17	95
Mali Iđoš	17 683	13 494	11 386	−16	30
Senta	29 617	25 568	22 100	−14	60
Sombor	90 477	97 263	80 400	−17	215
Subotica	123 688	148 401	137 753	−7	337
Srbobran	20 082	17 855	15 584	−13	42
Vrbas	37 174	45 852	39 821	−13	104
Total	533 129	555 335	481 068	–	1215

ulation drain. It is especially pronounced in villages, with some now completely abandoned [1]. During that period the population drain was a result of increased "external migration" to EU countries. Between 2002 and 2017, the population in the study area was reduced by 74 200 and in all of Vojvodina by more than 100 000. As a result, today these municipalities have 52 000 fewer inhabitants than in 1948, which best illustrates the population drain from the area [7,8]. The current situation invalidates the projected population growth and economic development [2]. Consequently, the development projections (as they relate to water supply), municipal and industrial water demand estimates, and existing water supply solutions for the study area need to be re-evaluated.

Results and comments. Existing solutions for future urban and rural water supply in northern Vojvodina need to be revised following WFD guidelines. The two main guiding principles should be: (i) realistic water demand projections, based on EU consumption standards, and (ii) ensuring appropriate quality of drinking water, which requires water treatment technologies consistent with the composition of raw water.

European Union water consumption standards that should apply are from 110 l/cap/day for rural households to 150 l/cap/day for large cities. These quantities are much smaller than previously estimated. In addition, when population projections are aligned with current demographic developments and the ongoing population drain, it is reasonable to expect that the needed quantities of water will be smaller than projected in current planning documents.

This part of Vojvodina has major water quality issues, largely associated with the presence of arsenic. However, only the city of Subotica provides adequate raw water treatment. In other places, water is mostly treated only by chlorination. Treatment tends to be non-selective and is often applied in cases where it is not permissible. For instance, when groundwater with a high organic content is chlorinated, compounds that pose a health hazard are created.

Water testing has been undertaken in recent years and appropriate technologies identified for the entire territory of Vojvodina, depending on parameters that exceed drinking water standards [6]. This was a significant contribution to addressing drinking water quality in the province. Best available techniques (BAT) were identified, based on EU practices, and classified into eight treatment types, depending on the number and types of pollutants and their concentrations, but also reflecting economic circumstances and the ability to implement appropriate solutions. Waters that, inter alia, contain high concentrations of organic substances, boron and arsenic, require the most complex treatment technologies. Water treatment plants in such cases are very expensive because they require several processes, which include membrane filtration in addition to degassing, flocculation and disinfection.

In spatial and water quality terms, Subotica Municipality is the most threatened because in a large number of settlements, in addition to the presence of ammonia and organic substances, the concentrations of arsenic in the water often exceed 50 µg/l. The situation is similar in several settlements in Sombor and Kula municipalities, as well as to the northeast, in Horgoš, Kanjiža and Senta. BWC groundwater in the western part of the study area and along the Tisa River to the east also exhibits elevated arsenic concentrations (up to 50 µg/l).

Instead of the proposed regional water supply schemes, whose implementation never began and the population has been using water of poor quality for decades, small water supply systems with appropriate raw water treatment technologies are an option. They would be highly suitable because in this part of Vojvodina as many as 65% of the settlements have a population of not more than 3000 (30% with less than 1000) [7].

Complying with EU standards, given that the rural settlements are small (population up to 3000), preliminary estimates suggest that systems with a capacity of up to 10 l/s would meet their water demand. Figure 2 shows such systems by municipality.

Preliminary investigations have already been undertaken in the municipalities that were to be serviced by the Bačka Regional Scheme. Detailed investigations are still pending in the eastern and northern parts of the study area, which are represented here based on current insights into the water supply situation [1]. The systems in all the municipalities would comprise a water treatment plant that would service multiple settlements. A small number of remote settlements would continue to rely on private water supply arrangements, but water treatment would have to be provided. These are villages with a population of less than 1000.

Current water supply methods, which have not really changed over the past decade, provide approximately 1.3 m^3/s of groundwater extracted from the BWC. The main shortfall is poor drinking water quality. In the northern part of the study area, particularly in the settlements around Subotica, arsenic concentrations vary from 2 to more than 150 µg/l, which is enormously high. A proper arsenic removal technology has been implemented only in Subotica. In the other settlements, water is inadequately treated by chlorination. Along the Tisa, groundwater from the deeper aquifer (BWC) is characterized by high concentrations of organic substances, the $KMnO_4$ demand exceeds 20 mg/l, and in most parts of northern Vojvodina the concentrations of the ammonium ion are also elevated. Due to the age of the water distribution systems, water losses are greater than 20%, but often in excess of 40%.

According to current estimates, the proposed regional schemes on the Danube and the Tisa would provide 2.5 to 2.8 m^3/s of water from the riparian zones. However, there is sparse data on the Tisa scheme because there have been no detailed investigations. In addition to ensuring a sufficient quantity of water (together with existing water supply sources), the drinking water quality would be improved. Notwithstanding, the costly implementation of the two schemes, in an area where a further population drain is expected, renders this approach rather inefficient.

The third solution discussed in some detail reflects the authors' belief that the primary objective of the future municipal and industrial water supply in this part of Vojvodina should be to ensure good drinking water quality. Efficient groundwater extraction will require monitoring of water supply sources and raw water treatment by suitable technologies, defined separately for each water supply source depending on the physical and chemical parameters of the groundwater. As the study area develops, small water supply systems could be integrated into future regional schemes.

Groundwater contamination is a major issue in this part of Vojvodina. It is a result of natural circumstances and largely aggravated by human activity. The shallow ("first") aquifer, immediately below the ground surface, is especially difficult to protect. It is easier to safeguard the deeper BWC, but pollution might be indirect, coming for overlying deposits in which the shallow aquifer is formed. The anthropogenic impact is considerable. In addition to sewage, the primary source of pollution in northern Bačka is industrial wastewater discharged into the DTD Canal network. The section of the network running through the industrial zones of Crvenka, Kula, Vrbas, and Srbobran makes it one of the most polluted watercourses in this part of Europe. The sugar factory "Crvenka", meat processing industry "Carnex" and cooking oil factory "Vital" discharge wastewater into this section of the canal network; enormous quantities of wastewater (421 l/s), suspended substances (8.3 t/day), phosphates (166 kg/day), and nitrogen compounds (907 kg/day) have been detected. The scale of pollution is illustrated by the fact that the depth of this canal section is only 30 cm [1].

In order to reduce the load imposed on groundwater resources, primarily BWC, the entire territory of Vojvodina requires measures that will enable the use of surface water for industry and irrigation. That would necessitate the rehabilitation of the existing DTD Canal, including dredging of certain reaches, renewal of the secondary canal network, and mandatory treatment of municipal and industrial wastewater.

For industries that require high-quality water, only small quantities should be provided by public water supply systems and the majority from their own water sources, which would be continuously monitored and inspected on a regular basis by water management services.

Groundwater withdrawal from the shallow aquifer should be minimal, only where absolutely necessary. The use of BWC groundwater for irrigation should be prohibited.

In addition, a series of other measures and directives (e.g. the Nitrates Directive – 91/676/EEC) need to be implemented and monitoring of the shallow aquifer established (as well as that of the BWC in the entire area), in order to conserve water resources in this part of Serbia.

Conclusion. The paper presented new insights that resulted from extensive hydrogeological research conducted in recent years concerning the status of municipal and industrial water supply in the northern part of the Autonomous Province of Vojvodina. The main issue is poor drinking water quality, largely due to the presence of arsenic, frequently in concentrations exceeding 50 µg/l, whose origin is genetic and associated with the geology of this part of the Pannonian Basin. The concentrations of ammonia and organic substances are also elevated, and the raw water is often bacteriologically inadequate as well, because protection measures have not been implemented and the environment has for many years been polluted by agrochemical agents, sewage, and industrial wastewater.

Solutions for future water supply that date back 20 years, which propose regional water supply schemes on the Danube (near Apatin) and the Tisa rivers, are unrealistic today for several reasons. Above all, water demand projections were based on overestimated specific water consumption and population growth. As such, they no longer apply. Today, efficient water consumption is based on much lower consumption rates and there is the additional effect of a population drain from the northern border zone of Serbia to EU countries. Migration over the past 15 years has reduced the population in the study area by 74 200. Also, economic circumstances are such that it would be unrealistic to expect the implementation of regional water supply projects even in the distant future.

The development of small water supply systems is deemed to be an efficient and realistic solution for the future water supply in this part of Vojvodina, consistent with contemporary European Union legislation. The primary task of these systems would be to improve drinking water quality. The size and distribution of settlements favours such systems because it would be possible to connect multiple settlements, depending on their population and needed water treatment technologies. Most settlements (65%) have a population of up to 3000 and estimates suggest that a water treatment plant capacity of 10 l/s would meet the needs of all households.

The conservation of groundwater resources also requires a series of other activities and measures, such as the construction of wastewater treatment plants and the establishment of a groundwater monitoring network for the shallow aquifer and BWC (Basic Water Complex) across Vojvodina. In addition, the function of the Danube-Tisa-Danube Canal would have to be fully restored, to prevent any further use of groundwater for irrigation. That would include the rehabilitation of threatened canal reaches and repair of the secondary canal network.

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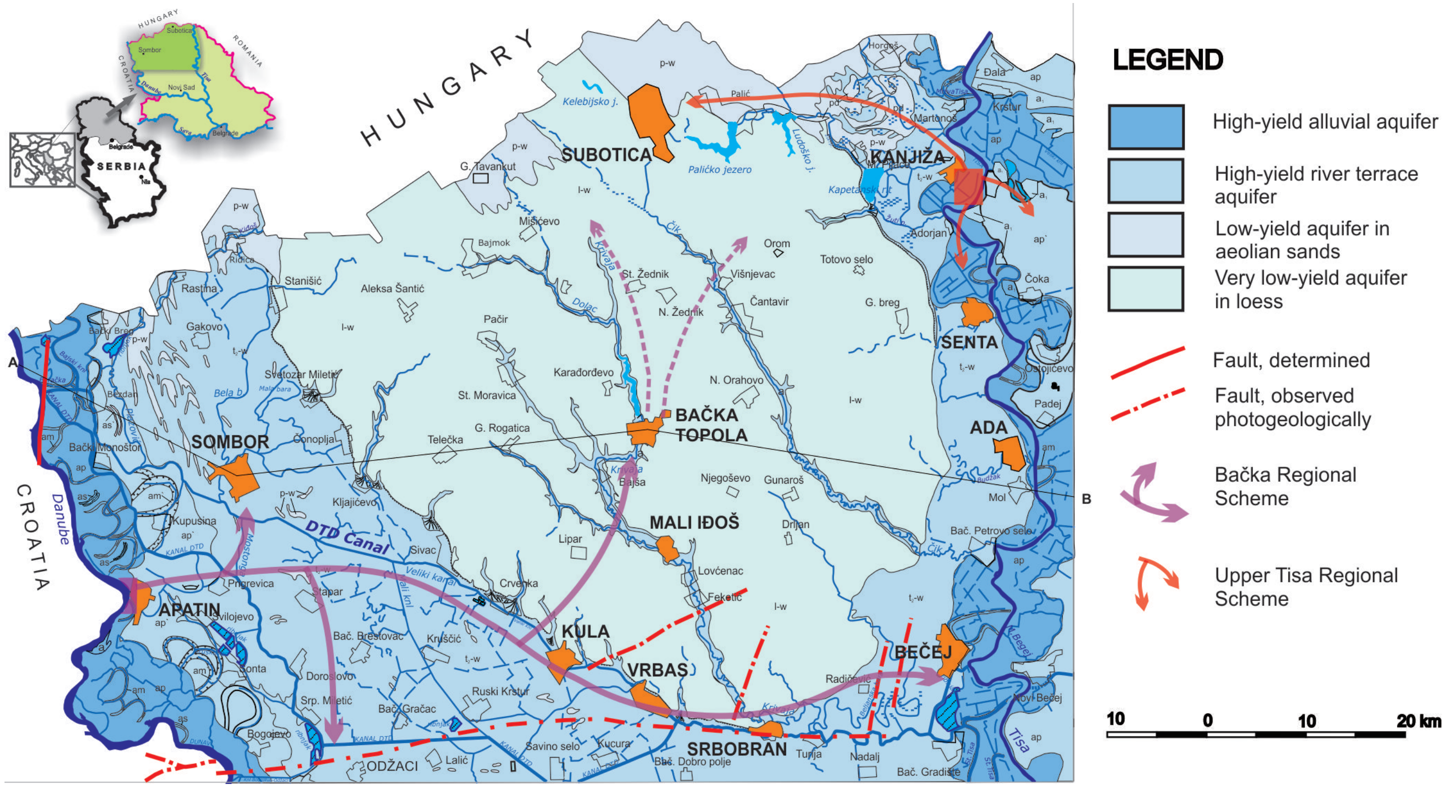

Fig. 1. Geographic position and hydrogeological map of the study area in Vojvodina, showing planned regional water supply schemes

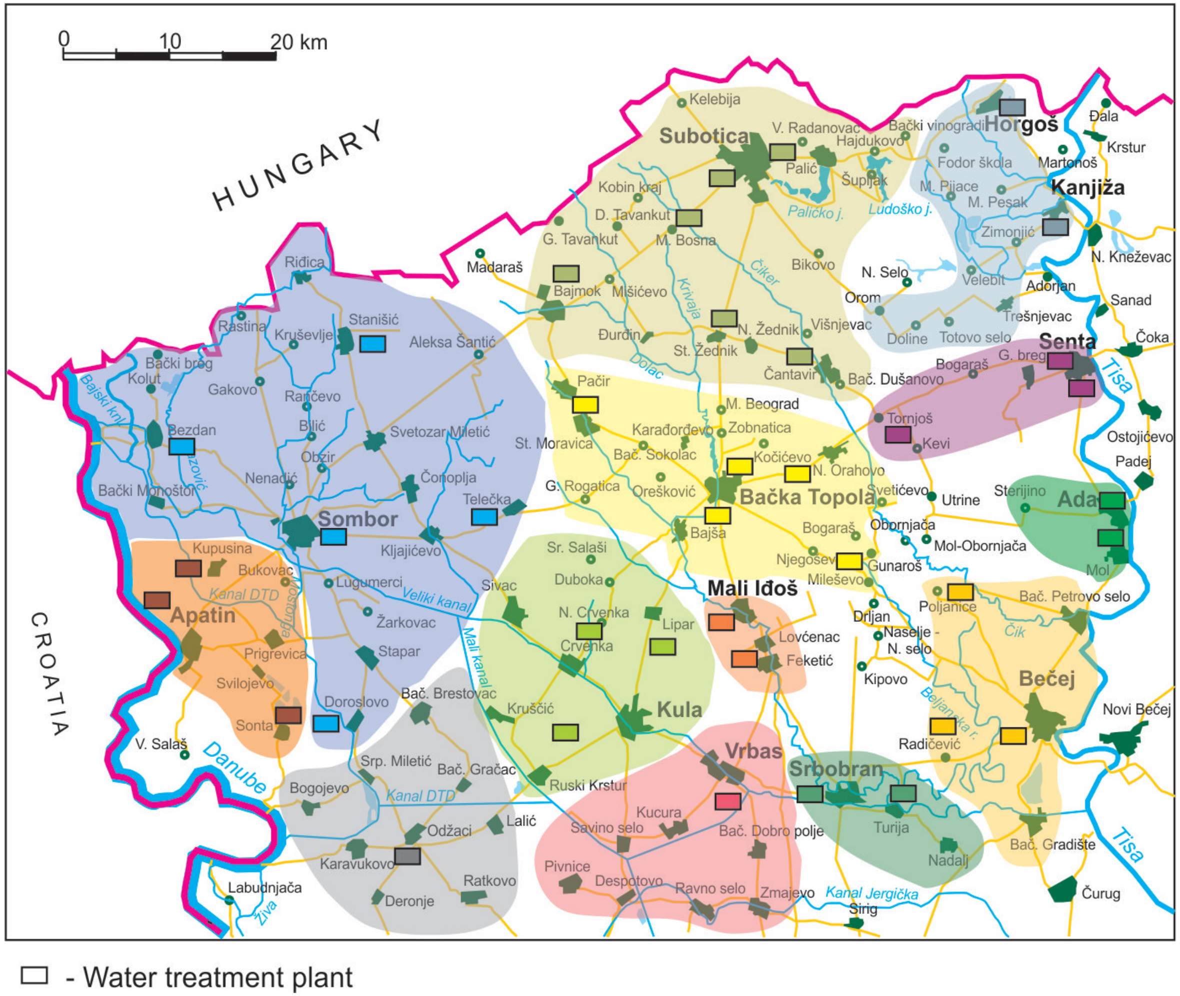

Fig. 2. Distribution of small water supply systems in northern Vojvodina municipalities [1,6]