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DRINKING WATER SUPPLY FROM KARST WATER RESOURCES (THE EXAMPLE OF THE KRAS PLATEAU, SW SLOVENIA)

OSKRBA S PITNO VODO IZ KRAŠKIH VODNIH VIROV (NA PRIMERU KRASA, JZ SLOVENIJA)

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Abstract UDC: 628,1;551.44(487.4)

Nataša Ravbar: Drinking water supply from karst water resources (The example of the Kras plateau, SW Slovenia)

In the past the biggest economic problem on the Kras plateau used to be drinking water supply, which has also been one of the reasons for sparsely populated Kras plateau.
Today the Water Supply Company provides drinking water to households and industry on the Kras plateau and the quantity is sufficient to supply the coastal region in the summer months as well. Water supply is founded on effective karst groundwater pumping near Klariči. Some water is captured from karst springs under Nanos Mountain as well.
In water supply planning in future, numerous other local water resources linked to traditional ways of water supply need to be considered. Eventual rainwater usage for garden irrigation or car washing, for communal activity (street washing) or for the needs of farming and purified wastewater usage for industry (as technological water) is not excluded.
Key words: karst waters, human impact, drinking water supply, Klariči water resource, Kras plateau.

Izvleček UDK: 628,1;551.44(487.4)

Nataša Ravbar: Oskrba s pitno vodo iz kraških vodnih virov (na primeru Krasa, JZ Slovenija)

Na Krasu je bil od nekdaj največji problem oskrba s kakovostno pitno vodo, ki je omejevala poselitev in gospodarski razvoj območja.
Sodobna oskrba ne zagotavlja zadostne količine pitne vode za gospodinjstva in gospodarstvo le na Krasu, temveč jo v poletnem času oddaja celo na Obalo. Oskrba s pitno vodo temelji na črpanju kraške podtalnice iz vrtin pri KlaričIh in na dveh izvirih pod Nanosom.
Pri snovanju vodne oskrbe kaže v prihodnosti vključiti številne lokalne vodne vire v povezavi s tradicionalno obliko vodne oskrbe. Pri tem ni izključena morebitna uporaba kapnice za potrebe namakanja vrtov, pranje avtomobilov, za komunalne dejavnosti (pranje ulic) in v kmetijstvu ter ponovna uporaba odpadnih voda za tehnološko vodo v industriji.
Ključne besede: kraške vode, človekovi vplivi, oskrba s pitno vodo, Klariči, Kras.

INTRODUCTION

Kras is about 40 km long and up to 13 km wide limestone plateau, that lies between Trieste bay on the west and southwest, alluvial Soča River valley on the northwest and flysch Vipava valley on the north and northeast. Further on the east it is bordered by Pivka basin, towards southeast by Brkini and the Reka river valley, only towards karst Čičarija, Podgorski Kras and Materija dry valley the passage is less noticeable (Kras 1999). It reaches height from 200 to 500 m above sea level and descends towards northwest.

As it is mainly made of carbonate rocks, there is no surface running water and underground water flow prevails. On the north by the Vipava valley, and on the southwest by the coast, the Cretaceous carbonate rocks pass into less permeable layers of the Tertiary marl flysch and limestone, however on the south Paleocene limestone passes into Eocene flysch. On the southwestern edge of the plateau, where limestone contacts flysch, waters from Brkini sink underground. The biggest of the sinking rivers is the Reka River. When the underground water level is high, the Raša river, that gets low inflows only from the right side, uses tectonic fault and periodically runs towards Vipava valley. Waters are flowing underground towards the Trieste bay. They reappear in submarine springs under Nabrežina (Aurisina) or in springs of the Timav river (Civita et al. 1995). Because these springs are the only large water springs in the area, in the past they were used for drinking water supply of the town of Trieste.

Kras is an area, where the cave density is the highest in Slovenia. But only in some of them several hundred meters under the surface it is possible to reach the underground water level.

Kras is a typical Slovene border area that was marked by mass depopulation in the past. Natural possibilities for agriculture are low, because cultivation is limited to small fields at the bottom of several karst depressions. Growing is therefore directed in self-providing agriculture. Wine producing, meat remaking, quarrying, wood and construction industry are important in the region.

Kras has large potentials for developing various forms of tourism, because it is in the hinterland of big coastal cities, among which the population of Trieste and its outskirts presents a special potential. Traditional traffic role is also important, because in the southern part of Kras there is railway connection Vienna- Trieste, which had more influence in the past. Some years ago a motorway section Ljubljana- Trieste was also built. Across Kras there are railway and road connections with Vipava valley.

The biggest economic problem on the Kras plateau in the past used to be drinking water supply, which has also been one of the reasons for the scarce settling of the Kras plateau. Main resource used to base on collecting rainwater and in some places it is still the main drinking water resource.

OBJECTIVES

As many European regions Slovenia also tries to provide sufficient amount of quality water to the inhabitants. Population and economy growth and numerous other socio-economic processes have increased needs for exploration of potential water resources for an effective and sustainable use of drinking water.

Objectives of this contribution are to present historical background of drinking water supply and to show the situation of today. Final results about the drinking water exploitation in Kras plateau, gained mostly with karst groundwater pumping, are presented: water resources, water supply extent

and drinking water distribution, number of inhabitants supplied, quantity and purpose of consumption data. Furthermore some suggestion for subsequent strategic water resources planning and management are proposed in addition to possibilities and limitations of the same.

TRADITIONAL WATER SUPPLY

Traditional water supply on the Kras plateau used to be based on captures of rainwater, which was collected in wells, called "štirna", or lakes, called "lokve". For watering the cattle special puddles, called "kal" were provided. At the end of the 19th century, when the needs for water grew, many villages in Kras built additional wells.

First aqueduct system was built about 150 years ago for the needs of the Southern railway connecting Vienna to Trieste. Every railway station was water station as well, where locomotives were supplied with water. In Gornje Ležeče for the needs of the steam railway several superficial streams were captured at the contact of karst with flysch. It was gathered in two reservoirs, storing more than 20,000 m^3 of water. From there water flowed into 35 km long pipes by gravitation towards Sežana, Divača and Prosek (Kraški vodovod Sežana 1998; Rustja 2000).

But at the beginning water was only used for locomotives. Because of constant growing of needs, the whole system was enlarged for several times and finally in 1935 an additional reservoir Draga has been built, pumping water from the Reka river. After electrification of railway, water needs dropped and aqueduct system was used for supplying people along the railway.

For strategic needs of the front during the First World War the Austrian army built the aqueduct network across the Kras plateau. They drew water from the Hubelj springs and pushed it from Dornberk in the Vipava valley 375 m higher. Below the Trstelj Mountain reservoirs were built from where water flowed towards Temnica, Kostanjevica and Opatje selo, and the second branch towards Šibelje, Škrbina, Dutovlje, Tomaj, Šepulje, Grahovo Brdo and Štore. Only for the needs of army 80 km of the network were built in a couple of months (Kraški vodovod Sežana 1998).

Defeat of the Austrian army has also stopped the construction of aqueduct network in Kras. The Hubelj aqueduct was taken over by the Italian army. Because of extremely high costs of the compression of water into Kras Italians abandoned this part of aqueduct and conditions in drinking water supply worsened until they renovated it and attached additional springs from under the Nanos Mountain. The aqueduct has not been extended until after the Second World War.

Fig. 1.: Traditional water supply on the Kras plateau used to be based on capture of rainwater (Photo: N. Ravbar).

DRINKING WATER ON KRAS PLATEAU

According to data of Kras Water Supply Company the Sežana municipality numbered 23,000 inhabitants in 1976. They were supplied with water from springs at foot of the Nanos Mountain (8 l/s), from the Hubelj springs (9 l/s) and from the Brkini stream Padež (12 l/s), which was not sufficient, especially in summer months, when the needs were the highest.

But, thirty years ago only 37 of 172 villages with approximately 10,000 people or 48 % of the whole population in the municipality were connected to this water system. During the summer dry months this percentage was much lower, because the capacity of water springs decreased altogether under 20 l/s. Therefore special preventive measures of saving water and supplying it with cisterns was introduced.

In the late seventies a lot of hydrogeological and speleological investigations were undertaken in order to explore caves with underground water (Krivic 1983; Habič 1984). Some boreholes have been drilled as well. It has been discovered, that the groundwater in Brestovica dol, that is about 40 m under the surface is the easiest to be exploited.

In 1984 the Kras aqueduct system in Sežana that pumped water in Klariči near Brestovica was built. The Brestovica pipeline was drawn to Lipa under Trstelj, where reservoirs that already served an old Austrian aqueduct are used. Network system continues towards Kostanjevica and Opatje selo on the one hand and on the other towards Komen, Dutovlje, Križ and Sežana. Later, section Sežana- Rodik- Kozina was attached.

In 1983 the municipality of Sežana passed a decree about water-protection zones of the Klariči borehole. In the pumping station Klariči the pumped water is relatively clean, but still suitable treatment is necessary. For this purpose construction for treatment of raw water was realized in years 1997-98 (Kraški vodovod Sežana 1998).

In addition to the karst groundwater pumping also two karst springs under the Nanos Mountain are captured for the needs of the Kras plateau drinking water supply. So 30% of whole consumed water is added (3 to 30 l/s) to the system. The only weakness of these two springs is, that they dry out during summertime, when the consumption is the highest. Because of better and cheaper water providing from the Klariči pumping station water capture Padež and water station Draga have been abandoned.

Intensive drinking water supply on Kras started in 1986, when the primary

Fig. 2.: Rainwater has been collected in wells, called »štirna« (Photo: N. Ravbar).

Fig. 3.: For the needs of the steam railway several superficial streams were captured at the contact of karst with flysch (Photo: N. Ravbar).

Fig. 4.: At Gornje Ležeče there are two water reservoirs, which could contain more than 20,000 m^3 of water. Picture presents the south water reservoir at Gornje Ležeče that could contain 14,000 m^3 of water (Photo: N. Ravbar).

pipeline across the plateau was finished and renewed. At that time also the additional network, connecting settlements without connection to the public network, was built.

In 2003 the public water supply, about 480 km of pipelines, supplies more than 22,500 people in 116 settlements. The municipalities of Sežana, Divača, Komen, karst part of Miren-Kostanjevica and partly Hrpelje-Kozina are supplied. The stage of provision already reached 92%, which has been quite a success of the past thirty years. Quantity of 250 l/s of water could be pumped in three boreholes near Klariči, which is sufficient to supply also the coastal area in the summer months. The inhabitants of Kras consume only 50 l/s on average.

But settlements on Kras are very sparsely spread out the rough terrain

Fig. 5.: When the needs for water increased rapidly, an additional water pumping station was built (Photo: N. Ravbar).

Fig. 6.: Drinking water supply of today is mainly based on karst groundwater pumping near Klariči (Photo: N. Ravbar).

and are small by their size. Consequently a long network of pipelines needs to be constructed to supply a small amount of people. Long pipelines are not easy to maintain and renovate frequently. Today more than 40% of the pipelines attain the age between 30 and 60 years, the rest is younger. Water losses in the system are nearly 35% due to old network, bad quality of pipeline, lowering of the ground and other reasons.

Average consumption of water on Kras is 100 l/person/day, which in comparison to the Slovene average 440 l/person/day is very low. The biggest consumers of drinking water on Kras are Lipica stud farm, that uses 58,000 m^3 water per year, ham-curing plant in Šepulje, glue factory and other industry. Though economic activity consumes one third of the water.

Since 1991 consumption of water decreased rapidly and varies around 1,3 million m^3 yearly. Reasons for decrease of consumption are numerous, but the most important is certainly a careful management, because price of water on Kras is one of the highest. This situation is also due to great decline of the army and economic activity, which affected numerous firms and industry in late eighties and nineties.

The public water supply network incorporates nearly 8,500 households. Nevertheless a great part

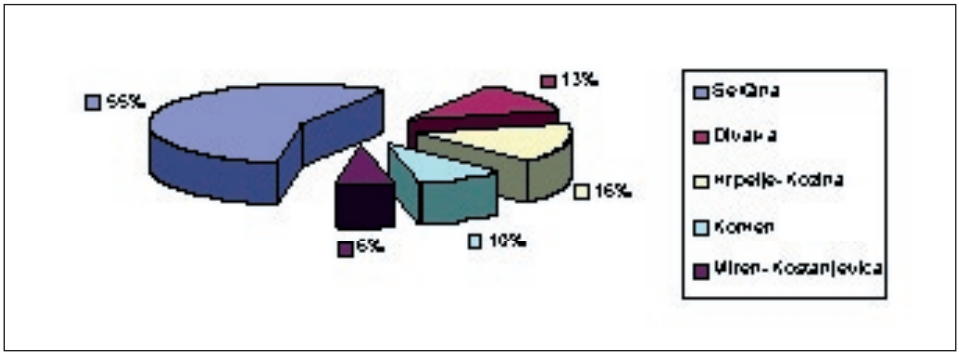

Fig. 7.: The Kras Water Supply Company regularly supplies the following municipalities (Source: Kraški vodovod Sežana 2003).

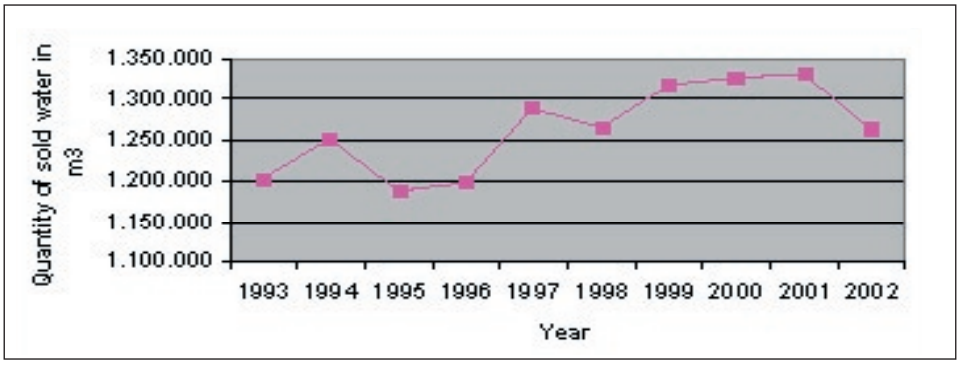

Fig. 8.: Quantity of sold water between years 1993 and 2002 (Source: Kraški vodovod Sežana 2003).

of the inhabitants partly still gather rainwater. Quantity of consumed water in households is 880,000 m^3 per year. In summertime, when the wells dry up, consumption of water rapidly increases. It is estimated, that it is even two times higher than in wintertime.

Branica is an additional source for local supply, where 0,3-3 l/s is captured. It supplies 100 to 120 households in the settlements Trebižani, Koboli, Večkoti, Dolanci, Čehovini and Kodreti. From the local water resources are supplied also the villages in Vrhe (Krtinovica, Štjak, Bogo, Mahniči, Razguri, Sela pri Stomažu, Jakovce, Vrabče and Veliko Polje).

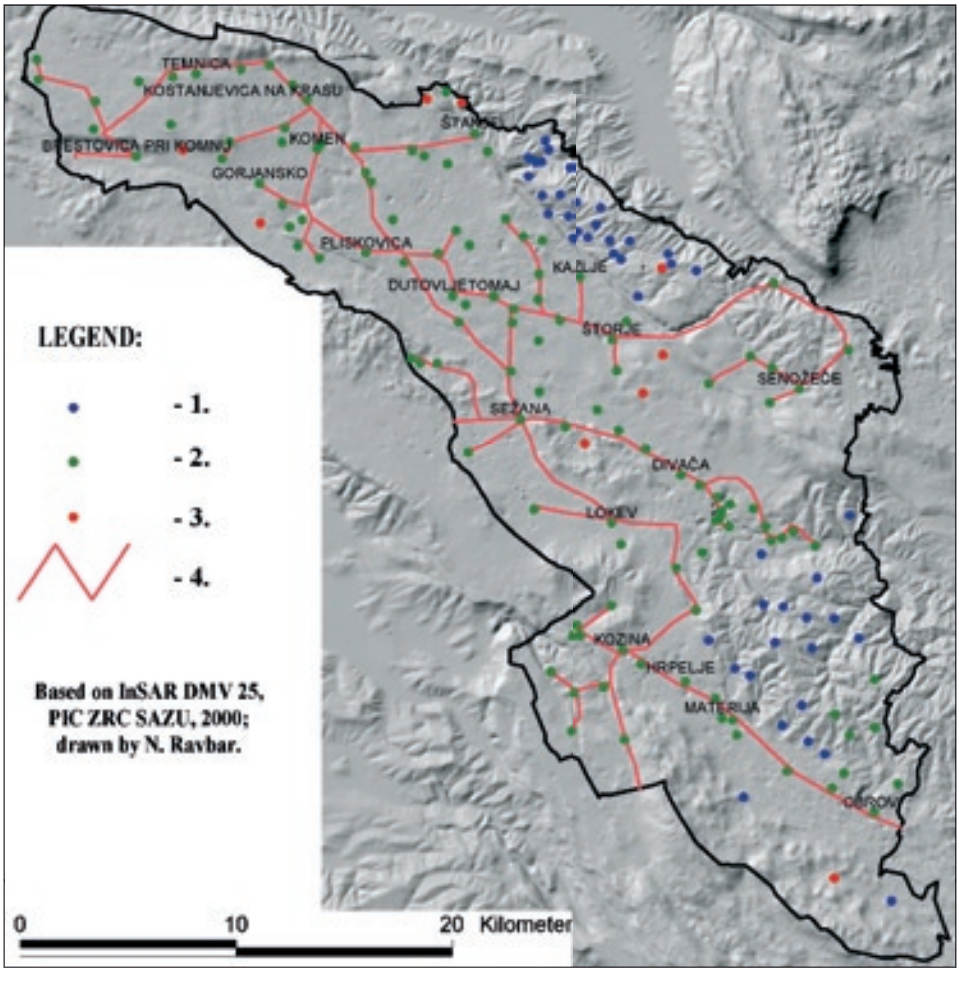

Fig. 9.: Sketch of drinking water supply situation in the Miren-Kostanjevica, Komen, Sežana, Divača and Hrpelje-Kozina municipalities, SW Slovenia (Source: Kraški vodovod Sežana 2003).
Legend: 1. local water supply, 2. public water supply, 3. rainwater supply or supply from springs, 4. main public water supply network.

Before the Kras and Bistrica network were connected in 1990, the settlements from Obrov to Kozina in Matarsko podolje have been supplied from the Bistrica karst spring (Kovačič 2001). After 1997 only Obrov, Javorje, Tatre and Brezovo brdo receive water from that spring. Some villages in Brkini (Podgrad pri Vremah, Ostrovica, Artviže, Slope, Brezovica, Gradiščica, Mrše and Hotična) are still supplied by local resources. In the villages in Brkini (Rjavče, Kovčice, Ritomeče, Velike Loče, Slivje) people are supplied with local aqueducts. These local systems have not been connected to the system of the Kras network yet, because the existent system provides enough of water.

Without connection to the public network there is still around 2,000 inhabitants in the studied area left. It is necessary to assure them to have access to the quality drinking water as well. In some remote settlements with few inhabitants (Senadolice, Vale, Brje pri Komnu, Lukovec, Plešivica, Brestovica pri Povirju, Nova vas, Tabor and Golac) or in secluded houses drinking water supply still bases only on capture of rainwater.

DRINKING WATER SUPPLY FACING NEW CHALLENGES

Since the drinking water supply with pumping underground water near Klariči has been established, gradually the rest of the settlements are being connected to the public network. In future building of pipelines to the villages Brje pri Komnu, Brestovica pri Povirju, Plešivica, Senadolice, Vale, Lukovec on Kras, to the villages Golac, Poljane pri Podgradu and Skandarščina in the Hrpelje-Kozina municipality and to the villages in Vrhe is foreseen.

Struggle for water of the people of Kras has always been in the forefront of their concern. Normal progress in rural economy and individual cities began after construction of drinking water network on Kras. Thus also Kras could compete with other Slovene regions in the second half of the past century. Especially quick economic growth attained the city of Sežana.

Karst groundwater, which is pumped, is organically polluted due to its vast recharge area. It is also endangered by contamination because of unsuitable transport system and hazardous spills of dangerous substances in its catchment area and dumping in a direct recharge area. Water capacities of the source are not yet completely exploited though.

While planning water supply in the studied area in the future it would be convenient to include numerous local water resources in connection to traditional way of water supply. Water resources that have been abandoned in the past century could be refreshed, thus intensifying a care for environment protection. Qualification and modernization of local water supply systems, wells and rainwater tanks could contribute to better quality and quantity of drinking water at the same time. Eventual rainwater usage for garden irrigation or car washing, for communal activity (street washing) or for the needs of farming and purified wastewater usage for industry (as technological water) is not excluded.

CONCLUSION

About 10 to 20% of the land area is represented by karst. In Slovenia 44% of land is karst, so it belongs to the countries with a considerable part of karst. For karst also numerous very efficient springs are characteristic, which may supply extensive areas with drinking water. This is the main reason why karst in Slovenia and in many other places in the world bears mainly economic significance. Almost a half of Slovenia is karst and more than half of the water comes from karst aquifers.

For the time being Slovenia still has enough water resources, which are of good quality. This is an important heritage that will play an important role in the future. The experts believe, that by the year of 2025 already 80 percent of drinking water will be derived from the karst aquifers (Forti 2002).

Today Kras plateau is not a deserted land, where people lack water. The hydrological researches have shown, that the storage of underground water is sufficient to pump up to 1000 l/s of water (Krivic 1984). Kras aquifer of today can already supply more than 170,000 people and presents an alternative source for drinking water supply of the vast area.

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OSKRBA S PITNO VODO IZ KRAŠKIH VODNIH VIROV (NA PRIMERU KRASA, JZ SLOVENIJA)

Povzetek

Na Krasu je bil od nekdaj največji problem oskrba s kvalitetno pitno vodo, ki je omejevala poselitev in gospodarski razvoj območja.

Boj Kraševcev za vodo je bil nenehno v ospredju. Šele z dograditvijo vodovodnega omrežja na Krasu je bil zagotovljen normalen razvoj gospodarstva, podeželja in posameznih mest. Oskrba s pitno vodo temelji na črpanju kraške podtalnice iz vrtin pri Klaričih in na dveh izvirih pod Nanosom.

Tako je šele v drugi polovici preteklega stoletja tudi Kras lahko konkuriral drugim slovenskim območjem. Posebno hiter ekonomski in gospodarski vzpon je doseglo mesto Sežana. Sodobna oskrba ne zagotavlja zadostne količine pitne vode za gospodinjstva in gospodarstvo le na Krasu, temveč jo v poletnem času oddaja celo na Obalo.

Le še nekaj je belih lis na zemljevidu vodovodnega omrežja na Krasu, kar kaže, da je preskrba z vodo precej urejena, saj je zagotovljena številnim gospodinjstvom tudi na odročnih območjih. Potrebe se po oskrbi z naraščanjem prebivalstva in krepljenjem gospodarstva večajo, zato je tudi za vodovodna omrežja poglavitno, da bi zagotavljala zadostno količino in kvalitetno pitno vodo preko

celega leta. Vendar pa še vedno vse premalo pozornosti posvečamo ohranjanju kvalitete pitne vode in njeni dejanski ogroženosti.

Pri snovanju vodne oskrbe kaže v prihodnosti vključiti številne lokalne vodne vire v povezavi s tradicionalno obliko vodne oskrbe. Pri tem ni izključena morebitna uporaba kapnice za potrebe namakanja vrtov, pranje avtomobilov, za komunalne dejavnosti (pranje ulic) in v kmetijstvu ter ponovna uporaba odpadnih voda za tehnološko vodo v industriji.