DIRECTIONS OF GROUNDWATER FLOW AND POSSIBILITIES OF THEIR CONTAMINATION IN ONE PART OF DOBRA AND KUPA RIVER BASIN.

SMERI PODZEMELJSKIH TOKOV IN MOŽNOSTI NJIHOVEGA ONESNAŽENJA V DELU POREČIJ DOBRE IN KOLPE

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Darko Mihljević: Smeri podzemeljskih tokov in možnosti njihovega onesnaženja v delu porečij Dobre in Kolpe

S pomočjo injiciranja natrijevega fluoresceina v požiralnik s požiralnostjo okoli 50 l/s pri vasi Luke, 3 km južno od Vrbovskega, je avtor želel ugotoviti smer podzemeljskega toka ne le proti izvirom Gojačke Dobre in drugim bližnjim izvirom, ampak tudi proti enako oddaljenim izvirom ob Kolpi. Na podlagi dokazanih in verjetnih podzemeljskih vodnih zvez je moč predvidevati onesnaževanje izvirov, ki so že oziroma ki so potencialni vodni viri.

Ključne besede: hidrologija krasa, podzemeljska vodna zveza, sledenje vode, Hrvaška, Dobra, Kolpa.

Abstract UDC 556.38(497.13)

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Having put natrium fluorescein into a swallow hole with capacity over 50 l/sec., near the village Luke, 3 kilometers south of Vrbovsko, we would like to determine the direction of underground flow, not only towards the springs of Gojačka Dobra, and other nearby springs, but also towards the equally distant springs near the Kupa river. On the basis of proved and probable underground flow connections we assume a possibility of springs contamination, which have been used or which could be captured for water source menagment.

Key words: karst hydrology, underground water connection, water tracing, Croatia, Dobra river, Kupa river.

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INTRODUCTION

The area of research, in its more specific sense has been limited by the river Kupa, in the north, by the river Dobra of Ogulin towards south-west and south and by the Dobra of Gojak and its tributaries, the brook Bistrac, to the east (Fig.1). As for the relief, it consists of the four morphographic entities: mountain region in the south-west (3 mountain ranges: Klek (1182 m),Smolnik (1219 m) and Crna Kosa (1004 m), of the more or less Dinaric orientation); the river Dobra valley of Ogulin; the central hilly region; and the extensive karst plain in the north-east.

Natrium fluorescein (50 kg) was put into a permanent swallow-hole of Luka with a capacity of 50-100 l/sec, situated about 3 km towards south-east from Vrbovsko, right by the left Dobra shore of Ogulin.

We organized observation spots for the possible outflow of fluorescein at the springs within the immediate Kupa river basin (the spring Jezerce,by the village Ponikve, 210 m above sea-level), at the springs along the Kupa (the captured spring Umolac near Severin, 170 m above sea-level, the spring Prikrajnik, 165 m above sea-level and the Jezerine, 170 m above sea-level in the village Fratrovci, and the spring Potok in Pribanjci),also at the Dobra springs of Gojak (the main spring of the Upper Dobra within the hydro-power plant "Gojak", 190 m above sea-level, the spring Bistrac, 3 km towards north-west from Tounj, 220 m above sea-level and the spring Ribnjak by the village Trosmarija, 210 m above sea-level) (Fig.1).

GEOLOGIC AND HYDROLOGIC RELATIONS

The area under study consists in its major part of Jurassic and Cretaceous carbonate deposits. Only towards the north-west from Vrbovsko we may find clastic and dolomite Triassic deposits in a reverse contact with the clastics of the youngest Paleozoic members. The younger Paleozoic and Triassic deposits, could be considered, due to their lithologic composition and tectonic position, as impervious (Bahun 1968). The Dobra flow of Ogulin is hydrologically very stable in this section, since there are almost no water losses by sinking. From the Paleozoic-Triassic complex of deposits near Vrbovsko, towards the south-east, the Dobra of Ogulin enters into the Dogger limestones and dolomites; however, since they form an anticline limb with a core of impervious Lias

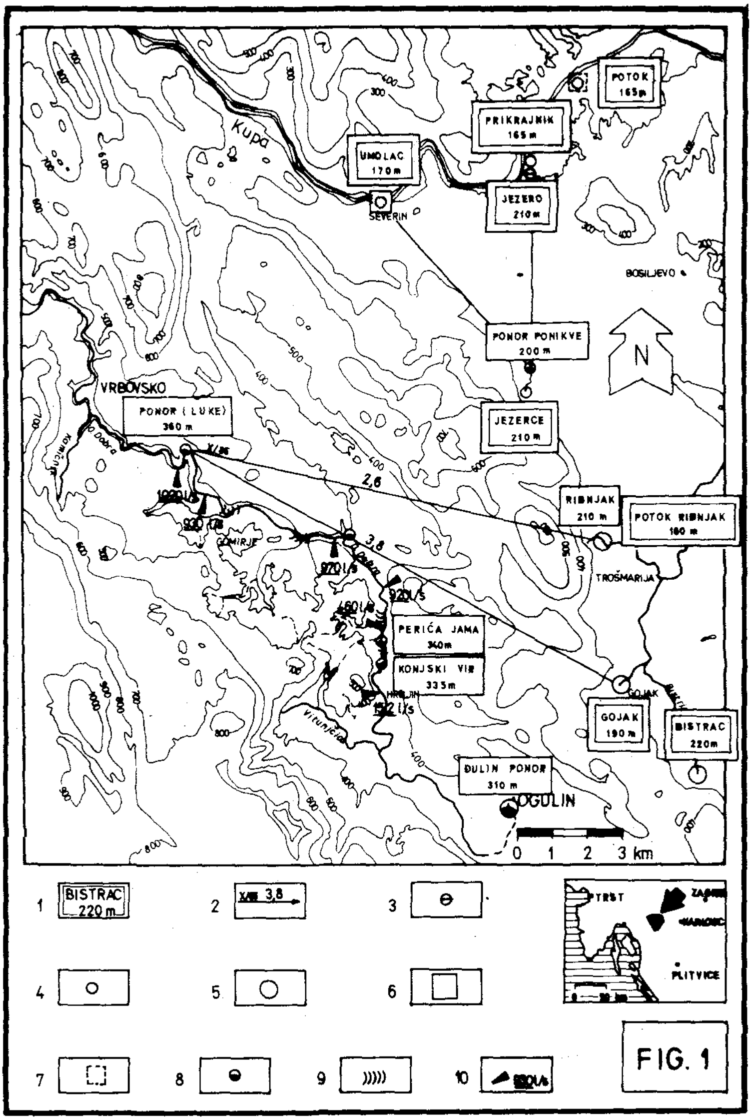

FIGURE 1. Situation map of the area under research
1. Observation place of fluorescein outflow (name and height) 2. Prooved underground water connection with an apparent velocity of underground waterflow and with date of fluorescein drop 3. Occasional spring, medium capacity 1-10 l/s 4. Permanent spring, medium capacity 1-100 l/s 5. Permanent spring, medium capacity 100-1000 l/s 6. Capture for public water supply 7. Simple spring capture 8. Swallow hole 9. Sinking zone 10. Hydrometric profile

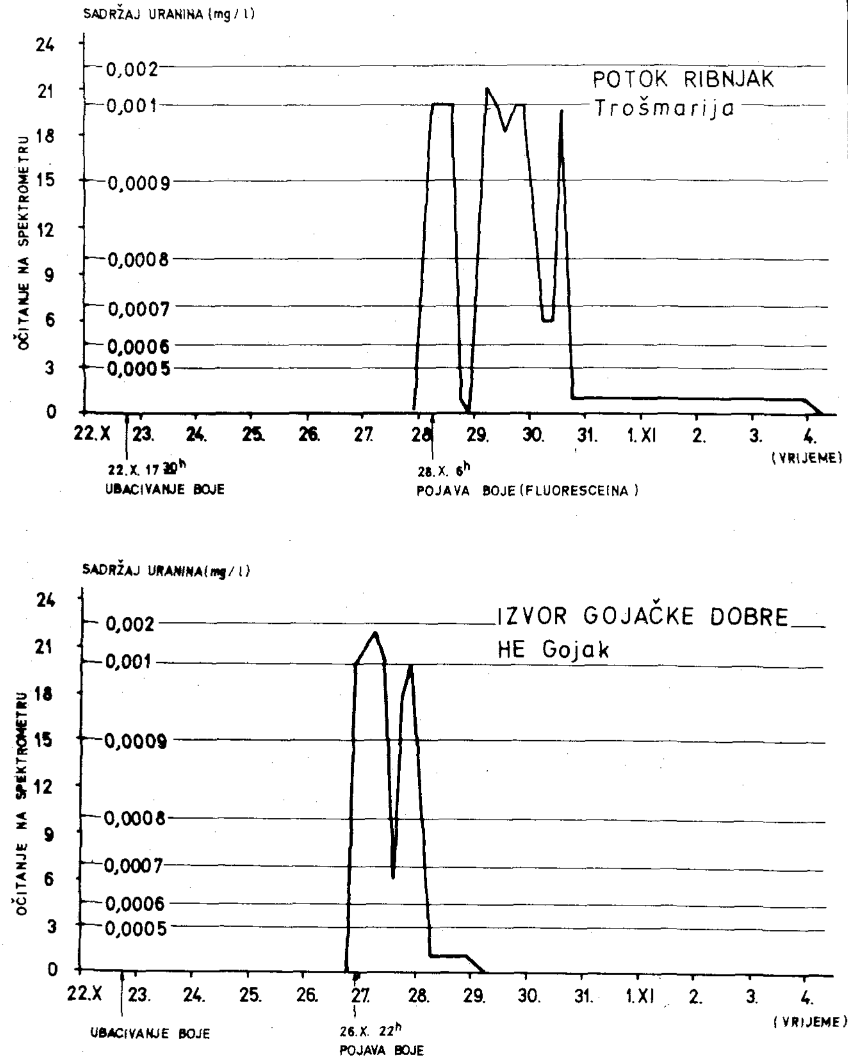

FIG. 2

FIGURE 2. Diagram of natrium fluorescein outflow

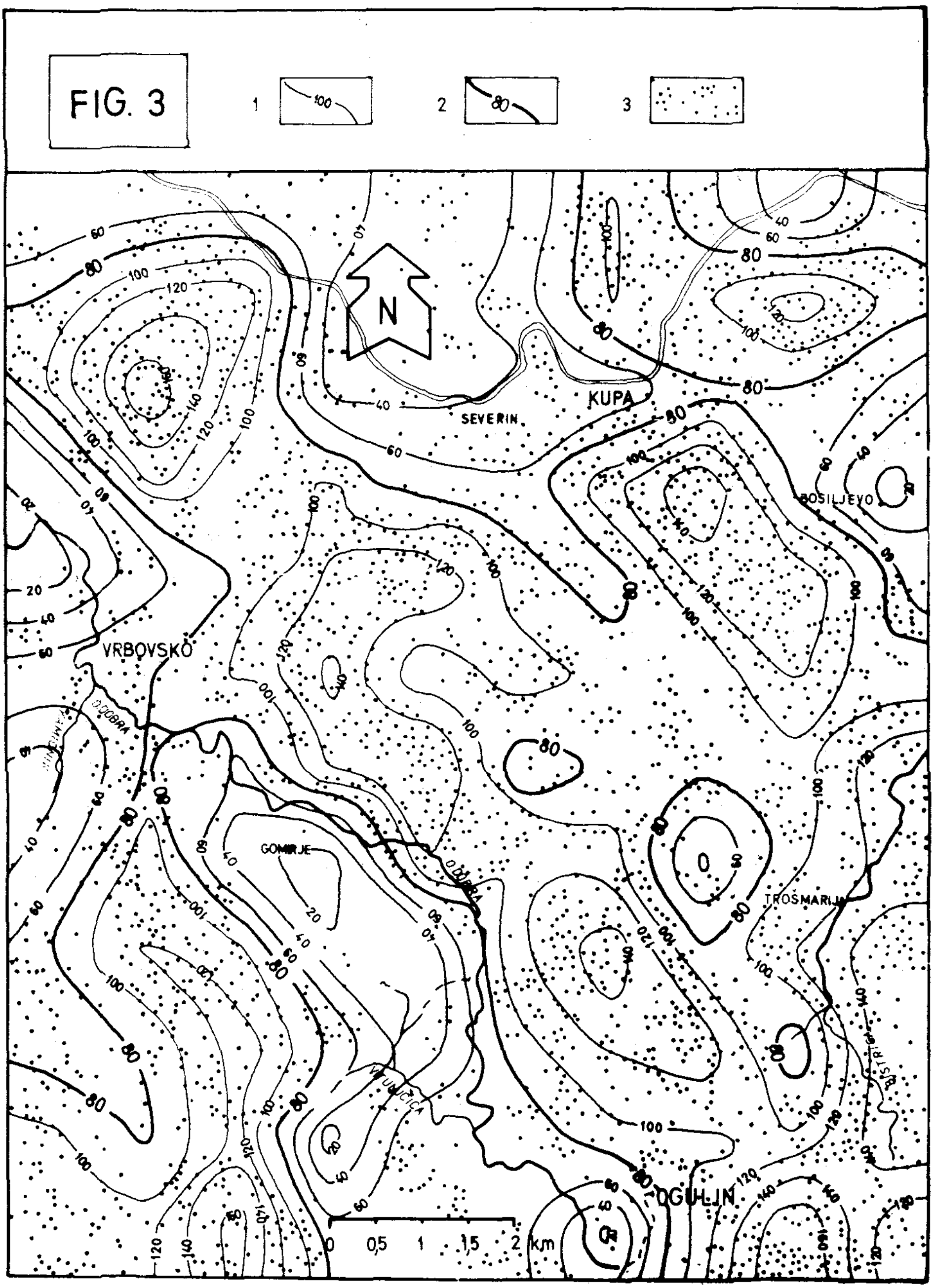

FIGURE 3. Dolina density as an indicator of permeability grade
1. Isolines of dolinas density 2. Average density 3. Spatial distribution of dolinas

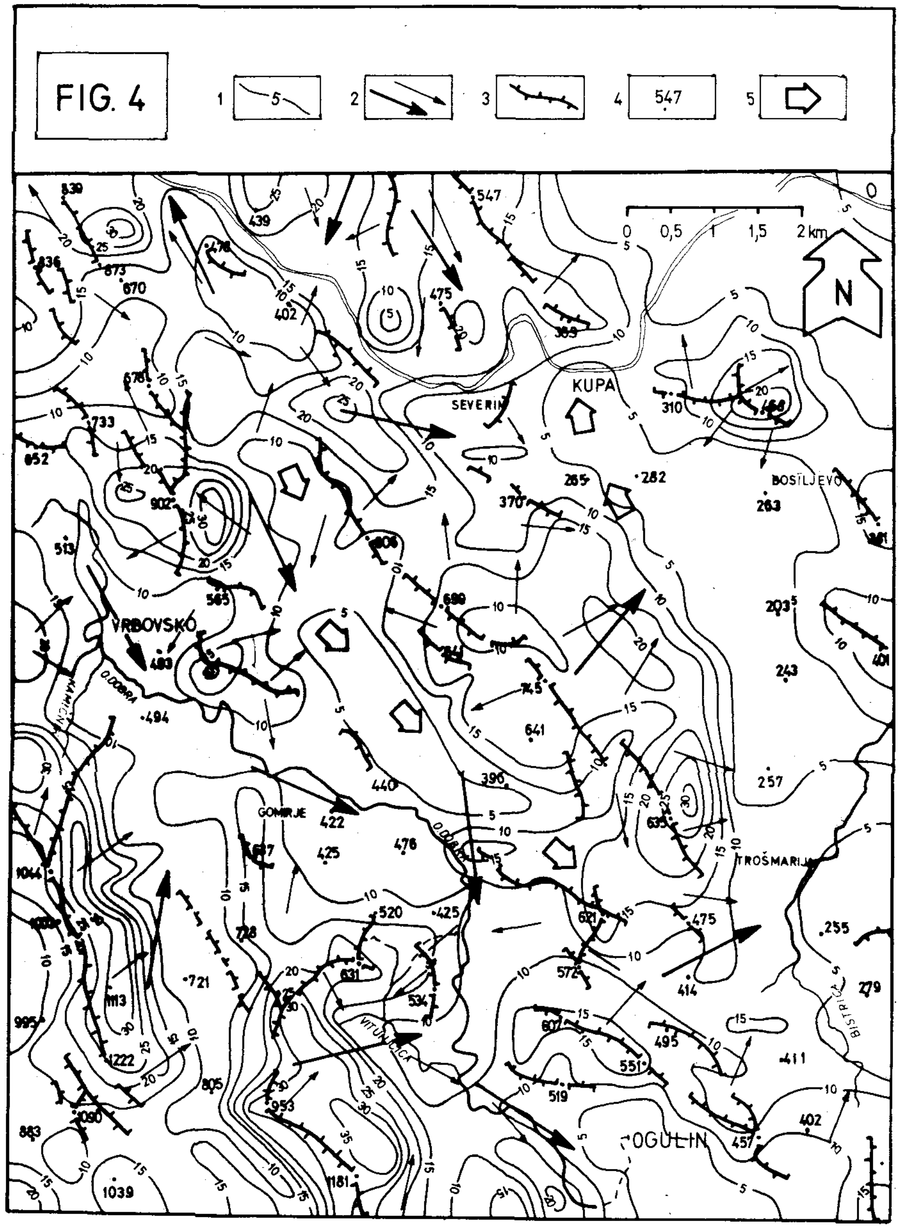

FIGURE 4. Directions of superficial and the underground water outflow
1. Average inclination of slopes 2. Directions of superficial outflow 3. Local topografic watershed 4. Peaks with marked altitude 5. Direction of the underground outflow

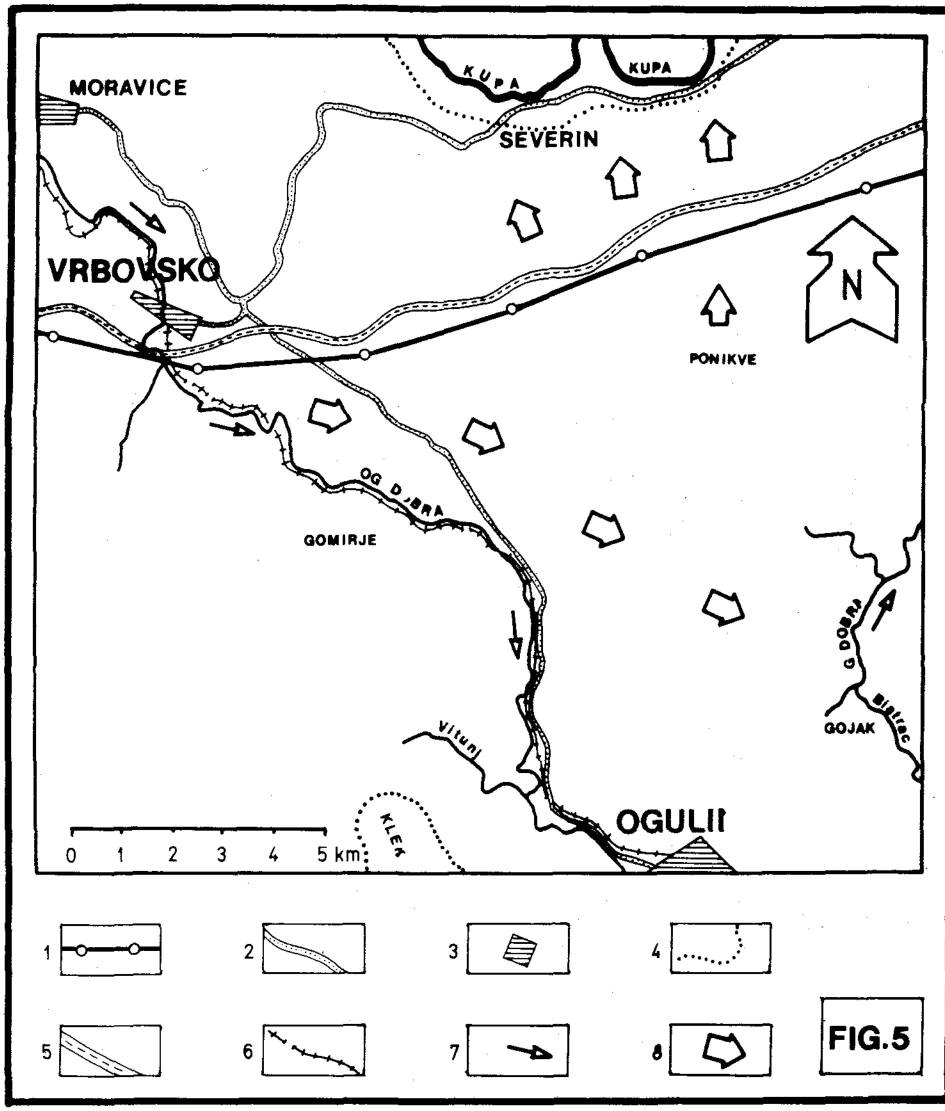

FIGURE 5. Map of possible contaminations in the Dobra and Kupa catchment area 1. Pipe-line route 2. Main and local communications 3. Industrial plants 4. Areas under protection 5. Future highway route 6. Railway 7. Contaminents with a possibility of superficialy outflow 8. Contaminents with a possibility of underground out flow

dolomites, in this section, again, Dobra would not loose any considerable quantities of water by sinking. The first bigger swallow-hole has been registered by the village Luka, where we had dropped fluorescein, at the reverse contact of the Lias dolomites and the Low Cretaceous limestones. The swallow-hole has developed due to the already-mentioned reverse contact of the pervious Low Cretaceous limestones and a transcurrent fault crossing the quoted contact. Its capacity has been estimated at about 50-100 l/sec and also later confirmed by hydrometric measurements. The measurements were carried out during the hydrologic minimum (after a long-lasting summer aridity and before abundant autumn rains).In the section where the Dobra of Ogulin does not lose much water, the average flow was 970 l/sec.

An increase in flow values between the hydrometric profiles 3 and 4 (Fig. 1) resulted from the inflow of right tributaries into the Dobra and from the Dobra flow through the still impervious or at least partially impervious Lias dolomites. However, entering into a zone of Cretaceous limestones, water sinks more and more through the active, periodically active, morphologically very distinct or dispersed swallow-holes (swallow-hole zones), situated in or by the river bed of the Ogulin Dobra. A zone of the most intensive water sinking is at the extreme south-west limb of the Cretaceous syncline, cut by a whole range of parallel faults in direction of its axis and lowered along the regional fault Vrbovsko-Ogulin. The mentioned geologic and hydrologic situation affects the striking of subterranean waters towards the nearby profuse springs of the Gojak Dobra, to the north-east.

According to the hydrogeologic classification by Herak, Bahun and Magdalenic (1966) and by Bahun (1967), the area of research represents a contact zone between the pervious regions in the south-west,with possible retentions of subterranean water, and the region with definitely slowed down subterraenean waters, coming up as the abundant springs of the permanent surface flows.

THE RESULTS OF INVESTIGATION OF UNDERGROUND FLOWS

With reference to the seven springs under observation, fluorescein appeared in only two springs: at the spring of the Gojak Dobra and at the Ribnjak. The result is completely reliable since the observations at the springs lasted long enough (24 days); sampling has been carried out 3-5 times a day and the fluorescein content or absence in the samples were determined by the state-of-art laboratory instrument (Fluorescent spectrometer "PERKIN-ELMER") (Šarin, Mihljević, Singer 1987).

At first, fluorescein appeared at the spring of the Gojak Dobra (within the water power plant Gojak), 100 hours after putting in. It was flowing out for 56 hours. A maximum concentration was 1.5x10-3 mg/l. There was also another, slightly lower maximum,about 16 hours later (Fig. 2).

At the spring Ribnjak, fluorescein appeared 132 hours after being put in.

It was flowing out for about 160 hours, which is three times longer than the flowing out at the spring of the Gojak Dobra. Here, too, we had two maximums, but the second one was bigger, namely 1.3x10-3 mg/l. The fluorescein concentration maximums were similarly shifted apart, at both springs. The apparent velocity of the subterranean flow, between the swallow-hole with the fluorescein and the Gojak Dobra spring is 3.8 cm/sec, and to the Ribnjak spring 2.6 cm/sec. The occurence of two maximums might be explained by the existence of the subterranean water pulse, caused by the first profuse rains that fell immediately before and after the injection of fluorescein, on 22. October 1986 (the first considerable precipitation were registered on 20. October (20.5 mm) on 23.October (73.9 mm) and from 26. to 27. October (100.5 mm).

DISCUSSION

Absence of fluorescein at the spring Jezero near Ponikve could be explained in two ways. Firstly, that the subterranean water level, caused by the hydrologic minimum (drained subterranean), has due to the long-lasting summer and autumn aridity(1), temporarily made impossible a subterranean connection, which is quite common under the "normal" hydrologic conditions, during fairly high or high subterranean water levels. Secondly, that the assumed connection does not exist, irrespective of the actual subterranean water-level.

In order to determine more closely the outflow of surface waters, we analysed the relief properties and constructed a map of the surface and a (presumed) subterranean water flow (Fig. 3). We described the regions where, due to the lithologic composition, a tectonic disarrangement grade and rock fissures, a pronounced surface outflow occurs,actually, a stronger infiltration of precipitation into the subterranean.

A mountain region, to the south-west from the Ogulin Dobra valley This consists of two elongated ranges of ridges; the south-west range includes: Crna kosa (1044 m), Smolnik (1222 m) and Tisovac (1039 m) and the north east: Klek (1181 m), Kobeljak (953 m), Trovrh (885 m) and Gomirska kosa

(1) A period from 24th July to 20th September could be considered as especially arid, since in that period only 176.6 mm precipitation has fallen, which makes some 11% of the average annual precipitation at the station Ogulin (Source: RHMZ (The Republic Weather Service Institution), Daily precipitation in mm at the meteorological station of Ogulin for the year 1986)

(2) Fluorescein was dropped on 22nd September 1986 at 17:30 o clock. Two days before, 24.4 mm of precipitation fell whereas up to the day of the first registered outflow of fluorescein, some 78.6 mm fell.

(728 m). Their slopes are rather steep (over 25 grades) but are covered with forests, with a predominant linear outflow in rills and gulleys, towards the two topographically lower catchment areas; to the first one, the karst valley of Kujina and Jasenova draga with intensive infiltration of precipitation into the subterrain, either because of the prevailing limestones or because of the gentle inclination of the valley bottom, whereof we have an indirect evidence in the terrain morphology, characterized by the larger sink holes density; and to the second one, the valley of the Ogulin Dobra, where due to the prevailing dolomites and an anticline position of layers,there is a pronounced surface outflow in gulleys and temporary flows. At the north-east overthrust contact defining the north-east boundary of this morphostructural zone with mostly impervious dolomite deposits of the next entity, there is a whole range of big and small springs, marking the beginning of the "upper impounding area"(Bahun 1968).

Valley of the Ogulin Dobra

Due to the relatively small slope inclinations and impervious deposits in anticline position, there is mostly a superficial water circulation. At the south-west edge of the zone, there is a rise in the subterranean water level, partially accumulated in the former entity, and they occur on the surface as the profuse springs (Vitunj, Kamicnik) or smaller temporary springs, creating short permanent or periodic currents, flowing into the Ogulin Dobra.

The central hilly region of Severin and Gojak

Due to its syncline structure and limestones, this is most probably the area of major accumulation of subterranean waters, coming to the surface at the contact zone between this area and the anticline dolomites and limestones, to the north-east. Since the dolomites in an anticline position force the subterranean waters to rise, they come up to the surface in a line of abundant springs (Kukaca, Tounjščica, Bistrac, the spring of the Gojak Dobra, Ribnjak). Sinking of the syncline structure axis towards south-east could be one of the reason for non-occurrence of fluorescein at the spring Jezero. Sinking of folds intensifies a subterranean outflow towards structure sink, namely towards southeast or towards the springs where fluorescein appeared. Running of subterranean waters (in direction SW-NE) between the swallow zone of the Ogulin Dobra and the northeast springs, is getting weaker and weaker towards northwest, which is also proved by reduction of profuse springs on the line, in this direction (the extreme northwest spring on the line is the spring Jezero of a much smaller capacity).

Another fact which makes questionable a subterranean connection between the swallow hole of the Ogulin Dobra and the spring Jezero is a relatively small coefficient of sinking in the section, in which such assumed connection might be established (Fig. 1). A more sizeable sinking starts only from the village Ljubosina downstream, so running of subterranean waters should be perpendicular to the direction found out by tracing, in order to make a connection with the spring Jezero. This is also supported by the data obtained on the fluorescein outflow diagram (Fig. 2). Fluorescein occurred first at the more remote spring of the Gojak Dobra (14 km air-distance from the swallow hole), and only later at the closer spring Ribnjak by the village Trosmarija (12 km air-distance from the swallow hole). Outflow of fluorescein at the spring Ribnjak lasted much longer than at the spring of the Gojak Dobra, thus indicating that a subterranean connection between the swallow hole and the Gojak Dobra spring was more rapid and more direct in spite of the larger distance, than was the case with the northwest situated spring Ribnjak.

A POSSIBILITY OF CONTAMINATION OF SPRINGS AND UNDERGROUND WATERS

In the karst region, possibilities of contamination result from the well developed subterranean water circulation in impervious carbonate deposits, due to remarkably pronounced connections between the swallow-hole zones and the springs. Construction of facilities and of industrial sites within the spring inflow zones utilized for a water supply system, increase the contamination possibilities greatly. One of the examples of the already registered disruptions of the natural spring regime (which is likely to occur again) is a location of pipeline on the section between the settlements Vrbovsko, on the west and Bosiljevo, to the east.(Fig. 5) By the analysis of hydrologic situation Delić, Lukas (1074), Delić (1986), Šarin, Mihljević, Singer (1987), there are critical spots where oil might possibly enter the subterrain, like the zone Senjsko, with contamination of the spring Ribnjak (this research work found out about the links with the swallow holes by the Ogulin Dobra), and the zone Ponikve, with contamination of numerous springs along the Kupa (whereof the spring Umolac was captured for the water supply system of Severin on Kupa), since a subterranean link of the swallow hole in Ponikve with the springs by the Kupa has been proved (Delić 1986).

Apart from this, here we deal with the especially striking problem of oil entering into the Dobra. The pipeline leakage has been registered so far at the section Vrbovsko-Bosiljevo, by the air outlet station Dobra II, near the swallow zone in Ponikve (Delić 1986), which consequently contaminated the captured spring Umolac (Severin on Kupa) and an oil outflow into the river Dobra, which consequently contaminated the water wells for the settlement Duga Resa.

CONCLUSION

Having put natrium fluorescein in to the permanent swallow hole of capacity over 50 l/s, near the village of Luke, the exsistence of the underground connection between the Ogulin Dobra with the spring of Gojak Dobra and the source Bistrac have been confirmed. An expected connection with the source Ponikve was not realized, and we tried to explain the situation by means of the underground water level at the time when the fluorscein was inserted, namely, we attempted to elaborate the hydrological circumstances due to wich the presumed connection could not have been realised. On the basis of archieved and available results of underground connections marking, and on the basis of spatial distribution of the available, and potential contaminents, the regions of possible undergroundwater contamination have been displayed.

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Povzetek

S pomočjo injiciranja natrijevega fluoresceina v požiralnik s požiralnostjo 50 - 100 l/s pri vasi Luke, tri kilometre južno od Vrbovskega, je avtor želel ugotoviti smer podzemeljskega toka ne le proti izvirom Gojačke Dobre (190 m n.m.) in drugim bližnjim izvirom, ampak tudi proti enako oddaljenim izvirom ob Kolpi. Ta kraški svet grade predvsem jurske in kredne kamnine. V izviru Gojačka Dobra se je sledilo pojavilo po 56 urah, ob maksimalni koncentraciji 1,5 x 10^{-3} mg/l (ob navidezni hitrosti 3,8 cm/s). Sledilo se je po 132 urah (navidezna hitrost 2,6 cm/s) pojavilo tudi v izviru Ribnjak. Na podlagi dokazanih in verjetnih podzemeljskih vodnih zvez je moč predvidevati onesnaževanje izvirov, ki so že oziroma ki so potencialni vodni viri. S pomočjo morfostrukturne analize je avtor skušal opisati tudi značilnosti podzemeljskega vodnega toka.