SOME EXAMPLES OF THE KARST WATER POLLUTION ON THE SLOVENE KARST

PRIMERI ONESNAŽEVANJA KRAŠKIH VODA NA SLOVENSKEM KRASU

KOGOVŠEK JANJA

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Prispevek podaja primere, ko se onesnaženje na kraškem površju odraža v kvaliteti *prenikle vode*. Obravnavana je onesnažena prenikla voda z območja slovenskega krasa in sicer v Postojnski (Kristalni rov) in Pivki jami, Ponikovski dragi in v Škocjanskih jamah. Določena je bila vrsta in izvor onesnaženja, v primerih Postojnske in Pivke jame pa smo podrobneje več let spremljali posamezne parametre, kar je pokazalo tudi na postopno večletno čiščenje karbonatnega masiva po odstranitvi izvora onesnaženja.

Ključne besede: *krasoslovje, kraške vode, prenikla voda,* ponikalnice, kvaliteta, onesnaževanje, slovenski kras

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Kogovšek Janja: *Some Examples of the Karst Water Pollution on the Slovene Karst*

The paper gives some examples of karst surface pollution reflected in the quality of the percolation water in the caves. The cases of Postojnska Jama (Kristalni Rov), Pivka Jama, Ponikovska Draga and Škocjanske Jame are dealt with. Type and origin of the pollution are determined; in the case of Postojnska Jama and Pivka Jama several parameters of the pollution were monitored during many years and we assessed gradual, several years lasting cleaning up of the carbonate massif after the pollution source was removed.

Key words: karstology, karst waters, percolation water, sinking river, water quality, pollution, Slovenia

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INTRODUCTION

The study of the percolation water corrosion in the caves of the Slovene karst, in Postojnska Jama, Planinska Jama, Taborska Jama, Divaška Jama, Jama at Predjama, Vilenica, Dimnice and Škocjanske Jame yielded us the notion about the water quality. Fig. 1 presents the underground caves where our researches were carried on.

In several caves, lying below the uninhabited areas that are not intensively cultivated, no signs of pollution were registered in the percolation water as it was expected. In the course of researching infiltrating water, polluted water was encountered. This was the reason for analysing the polluted infiltration water in Pivka Jama, in Ponikovska Draga, in the Kristalni Rov of Postojnska Jama and in Tiha Jama, Mahorčičeva, Mariničeva Jama, the latter three forming part of the Škocjanske Jame system.

In all the cases studied, pollution from communal waste waters was present. In the Kristalni Rov alone there was a once-off spillage of some other pollutants which left dark stains on the flowstone.

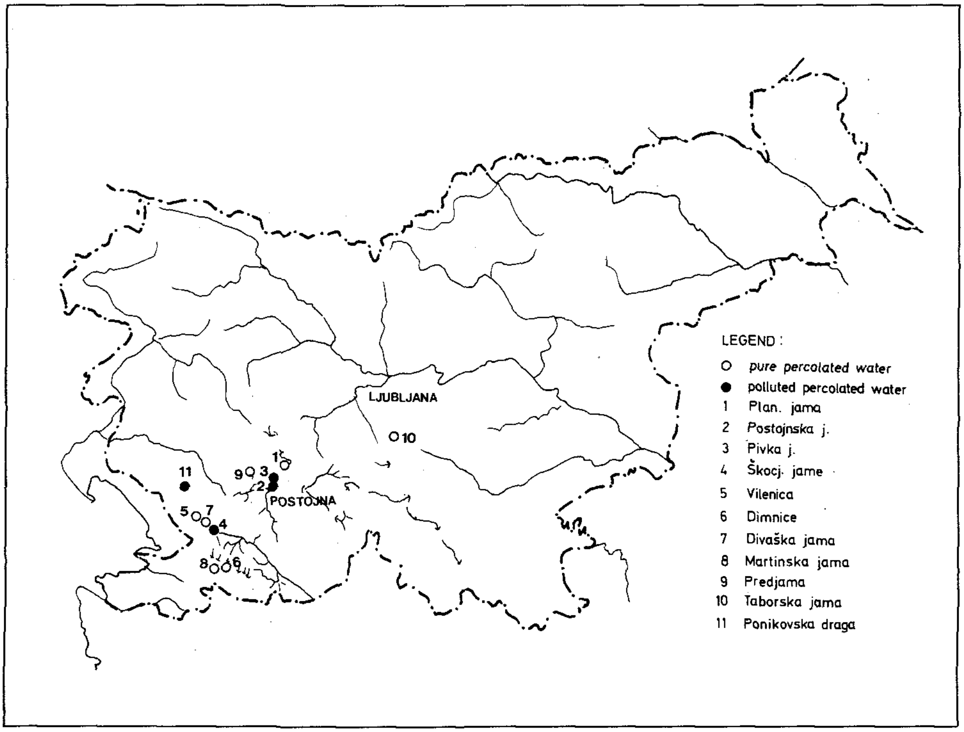
THE EXAMPLES OF POLLUTED PERCOLATION WATER

Pivka Jama

While monitoring the trickles and drippings in Pivka Jama, a narrow area of polluted water was detected, indicated by the increased level of nitrate, phosphate, chloride, and characteristically augmented specific electric conductivity and chemical oxygen demand. A lot of questions arose and we started detailed researches. We were in particular interested what was the source of the pollution, and how quickly the trickles react as it gives the velocity of the pollution transport into the karst interior, what a degree of self-purification exists during the percolation of pollutants through the cave roof and how the pollution is washed out of the cave roof, it means how long it may be retained in the carbonate rocks.

The pollution did not appear in all the trickles at the same extent due to different infiltration mode in various conduits. The reason for the polluted percolation water was waste water from showers and toilets of the camping site at the surface. It was point pollution reappearing in the cave in a radius of about 10 m after it passed through 40 m of fissured carbonate rocks. The trickles in the cave that were the most abundant during dry summer period when, on the other hand, there were most visitors in the camping, evidenced that the trickles represent an additional source of the water from the surface. Obviously this water bothered the visitors of the cave as it was falling to the tourist foot-path and the administration built a roof to protect the tourists against the drops. Hence, while planning the buildings on karst one must urgently examine the terrane and ascertain that there are no underground objects nearby.

Later adaptations of the lavatories within the camping site included blasting and as a result the pollutants have been washed off the cave roof and changed circulation occurred; some trickles almost dried up while the others increased. Obviously intensive works at the surface, blasting of upper rock layers for instance, can essentially impact on water circulation from the surface to the underground; in the mentioned case the works deepened the doline's bottom and we all know that the area of dolines intensively drains the water to the underground.



Sl. 1. Podzemeljske jame v Sloveniji, kjer smo spremljali kvaliteto prenikle vode.
Fig. 1. The underground caves in Slovenia where the quality of percolation water was measured

The results of many year researches have shown (Kogovšek 1987) that the settling of solid organic impurities in a cess-pool and their regular removal eliminate a major part of pollution from the waste water. After such sedimentation the water percolation through karstified carbonate massif is subdued to self-purification processes which are variously efficient due to percolation mode of different trickles. The chloride and phosphate level decreased to half after being filtrated through 40 m thick limestones, chemical and biochemical oxygen demand diminished by 95%. The purification is due to oxidation processes and dilution effects. With higher recharge, or when there are no sedimented solid organic impurities (that happens at direct outlet), the self-purification considerably diminishes and water remains much more polluted.

Kristalni Rov

The researches of percolation water in Kristalni Rov were provoked by visual pollution; dripping from the cave roof over the flowstone left well visible dark stains. This was a once-off spillage of some unknown pollutant obviously, as later this pollution was no more observed. The pollution was reported by the cavers and noticed by Gams (1983) who mentioned that fortunately the pollution did not spread through 100 m thick limestone roof in a bell-shape. Visible pollutions are noticed soon afterwards but most of these that we perceived till now were neither visible to eye nor smelt. Such was the case of water in Kristalni Rov near the place where black stains appeared.

The analyses showed that the water within an area of 20 m is polluted. Increased specific electric conductivity and higher levels of nitrate, phosphate, sulphate and chloride, and chemical oxygen demand (COD) were recorded. The pollution derived from the military object at the surface. Again different degree of pollution at various trickles was stated. Different conductivity of single conduits is controlled by different percolation velocity which influences the purification effect during the percolation and finally reflects in the quality of the percolation water.

I. Gams (1967) reported about different reactions of the percolation water drainage to the rainfall. Later detailed researches of the percolation water in Planinska Jama evidenced that at single trickles considerable differences occur during a year. In wet spring and autumn period the trickle reactions were quick, after half an hour after the rainfall even. In dry summer months the sporadic rainfall does not cause the recharge increase. When the recharge area of trickles is filled up, or when the total rainfall quantity reaches a defined value, in Planinska Jama this is 70 mm (Kogovšek & Habič 1981) the recharges of the trickles in the cave increase. At tiny drippings the reaction to the rainfall is very suffocated this is why the trickles react to the rainfall with considerable time lag. We got similar values at water tracing test from the surface into Kristalni Rov. Through well permeable conduit the tracer has taken an hour to reappear through 100 m thick roof, while badly permeable conduits required almost three months although in this time 240 mm of rain has fallen. By such a way one may presume the movements of pollution, dissolved by water and also non-degradable pollution that is washed off the cave roof. The tracer reappeared on a narrow area due to 100 m thick roof; in Pivka Jama, where the roof is 40 m thick, the pollution spreading was much wider.

These facts may become very useful at accidental spills of harmful substances or some other pollutants at the karst surface; one may assume when the pollution will reappear in the underground (Kogovšek 1982).

Ponikovska Draga

The pollution generated by the village above the cave appears in Ponikovska Draga rather quickly on several places. Of course, certain dilution occurs. During dry periods drippings prevail indicating relatively small or diffused quantities of waste water; probably partial evaporation occurs at the surface, the pollution concentrates and accumulates in the cave roof. During the first rainfall, at the beginning in particular when the dilution is small, the pollution in the underground is the most distinctive; after abundant and intensive rain the pollution is washed off.

Škocjanske Jame

The percolation water in Škocjanske Jame is also polluted. The increased value of nitrate in the trickle at Golgota, Tiha Jama, Škocjanske Jame reached 30 $mgNO_3\,l^{-1}$ may be explained by intensively cultivated field at the surface. In other parts of Tiha Jama, in Hankejev Kanal and in Tominčeva Jama the pollution was not recorded.

Extremely polluted percolation water was detected in Mariničeva and Mahorčičeva Jama. The level of nitrate, sulphate, and chloride and chemical and biochemical oxygen demand (Kogovšek 1994) as well as increased specific electric conductivity indicated the pollution in water. The percolation water constituents were similarly as in Pivka Jama, Kristalni Rov of Postojnska Jama and Ponikovska Draga due to communal waste water.

The roof thickness is from 50 to 80 m. During and after rain more or less abundant trickles appear, providing at the same time considerable dilution and washing the pollution off the surface and off the cave's roof. The degree of pollution among the trickles varies. In dry period in the cave there are single drippings only, similar as was stated in Ponikovska Draga. At such occasions the recharge area of the trickles is not filled and inflow water remains there. Thus the concentrated pollution occurs after the first washing of the recharge area, that means during the first heavy, and in particular intensive rain.

SINKING STREAMS

Karst underground and karst waters are endangered by sinking rivers that, more or less polluted, disappear into the karst underground, some of them several times even. The springs may even be captured for water supply. Also from this point of view the protection of sinking river quality is urgent.

Due to numerous cases when the waste communal waters are not treated the sinking streams receive during their superficial flow a certain amount of pollution. During low waters the conditions are usually critical and at this time the water is even more sensitive for any additional pollution, as could be some accidental spills of waste industrial waters or traffic accidents.

During dry summer months Pivka river gradually disappears in its medium flow already and frequently the water coming to Postojnska Jama is only that of Nanoščica, its tributary. In this time the water and the pollution disappear into karst by other ways, of course. Monitoring Pivka quality at its swallow-hole to Postojnska Jama during low waters indicated increased values of the parameters, in particular chemical and biochemical oxygen demand and at the same time decrease of the dissolved oxygen level that lowered to critical 1.1 $mgO_2\ l^{-1}$ at 6 a.m. But, due to water vegetation, a considerable increase of oxygen during the day was perceived. This production does not work during the night when oxygen is consumed due to assimilation and thus the critical conditions appear early in the morning. At low water level in summer when the temperatures are high, the water treatment is very important, but more and more urgent becomes the need to treat the waste waters of other villages along the Pivka and industrial waste waters.

Table 1 Pivka quality along its flow, August 20, 1992

	T	SEC	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	COD	BOD	COD/BOD
Postojnska J.	22	505	27	1,4	1,45	19	22,3	2,6	8,6
Pivka Jama	15	405	12	4,2	0,73	12	11,2	1,0	11,2
Planinska J.	12	359	8	8,0	0,40	11	8,1	1,7	4,8

T - *temperature (°C)*
SO_4^{2-} - *sulphates*
SEC - *conductivity (μS/cm)*
COD - *chemical oxygen demand*
Cl^- - *chlorides*
BOD - *biochemical oxygen demand*
NO_3^- - *nitrates*

Monitoring the Pivka quality in Planinska Jama, where the water cools during the summer and is enriched by the oxygen in the underground, recorded rather good quality. Later this water is joined by Rak tributary and the mixture is still more favourable. The Table 1 represents the Pivka river quality at low summer waters at its swallow-hole to Postojnska Jama, in Pivka Jama and in Planinska Jama. The improvement was registered with the exception of the nitrate level that increased along the flow.

For a long time the Reka river was highly polluted due to waste waters of Organic Acids factory. When the factory was closed its quality at the swallow-hole to Škocjanske Jame was gradually improving when the sedimented pollution from the bottom of the riverbed was slowly decomposed and removed. Obviously this factory of organic acids was the main pollutant but others are still present. Relatively high ratio between slowly degradable and non-degradable organic matters indicates that slowly degradable organic pollution increases. Table 2 represents the mean values of cited parameters of the measurements done from 1992 to 1995 and the values at low water level in June 1993.

Table 2 The Reka quality

	SEC	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	COD	BOD	COD/BOD
Average values 1992-95	345	3,7	4,5	0,03	14,5	6,6	1,8	3,7
June 1993	341	4,0	5,3	0,01	12,0	12,0	2,0	6,0

CONCLUSION

It was stated that the pollution of the percolation water is always due to the pollution at the surface. In most cases these are direct outlets from the houses or villages (cess-pools without bottom) without sewage system and waste water treatment plants. The pollution of karst underground and karst waters is due to waste disposal sites washed by rainwater, and to accidental spills of various liquids at traffic accidents as well as to pollutants being washed off the roads.

How such pollution is reflected deeper in the karst underground, in the karst caves and in the quality of karst water depends on type and quantity of pollution, on rock structure through which the water percolates, as the rocks control the mode and velocity of infiltration and the possibility of oxidation degradable processes which again control the self-purification of these waters which can be done by nature. We assessed that in up to 100 m thick rock oxidation processes helped by dilution effects by the rainwater may be successful; however, the pollution must be enough small and degradable.

Our researches indicate that somewhere the conduits from the surface to the karst interior are very direct and well permeable and the water passes through 100 m thick limestones in an hour already. However, such canals are frequently combined by less permeable conduits where water and liquids may be retained up to three months, in particular during the period of less intensive rain. In such cases the heavy and intensive rain is deciding as it presses the retained pollution.

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PRIMERI ONESNAŽEVANJA KRAŠKIH VODA NA SLOVENSKEM KRASU

Povzetek

Človek, ki živi na krasu, s svojo vsestransko aktivnostjo pogosto tudi ogroža kras in kraške vode. Tako srečamo najrazličnejše oblike onesnaževanja kraškega površja, od kjer padavine lahko spirajo topne komponente skozi prepustne karbonatne kamnine globlje v kras, kjer pa so tudi zaloge pitne vode, osnovne človekove surovine. V kras ponikajo tudi reke ponikalnice, ki na svojem površinskem toku sprejemajo odpadne vode naselij, ki v večini primerov še nimajo čistilnih naprav, kot tudi odpadne industrijske vode.

V okviru raziskav prenikajoče vode na slovenskem krasu smo naleteli na onesnaženo preniklo vodo v Pivki jami, v Kristalnem rovu Postojnske jame, v Ponikovski Dragi, v Škocjanskih jamah pa v Mariničevi in Mahorčičevi jami. V Pivki jami in Kristalnem rovu smo podrobneje preučevali prenos onesnaženja skozi 40 m oziroma 100 m debel jamski strop.

Ugotavljamo, da ima onesnaženje prenikle vode vedno izvor v onesnaževanju na površju, v naših primerih so bili to direktni izpusti iz hiš oz. naselij (greznice brez dna), ki nimajo urejene kanalizacije in čiščenja odpadnih voda ali pa so odpadne vode odtekale v kras po predhodni sedimentaciji trdnih nečistoč.

Kako se tako onesnaženje odraža globlje v krasu, v kraških jamah, v kvaliteti kraške vode, pa zavisi tako od vrste in količine onesnaženja, kot tudi od zgradbe kamnin, skozi katere prenika, saj le-ta pogojuje način in hitrost prenikanja ter možnost poteka oksidacijskih razgradnih procesov, od katerih pa