ASSESSMENT OF RIVER WATER QUALITY IN THE MORAVIAN KARST, CZECH REPUBLIC

Assoc. Prof. Ing. Jitka Malá, Ph.D.[1]

Ing. Bc. Kateřina Schrimpelová[1]

RNDr. Antonín Tůma[2]

Assist. Prof. Ing. Zuzana Bílková, Ph.D.[1]

Assist. Prof. Ing. Karel Hrich, Ph.D.[1]

[1] Brno University of Technology, Faculty of Civil Engineering, **Czech Republic**
[2] Protected Landscape Area Administration Moravský kras, **Czech Republic**

ABSTRACT

The Moravian Karst, situated in the eastern part of the Czech Republic, is the most extensive and most developed karst area in the Bohemian Massif. To protect its unique environment, the Moravian Karst was declared a Protected Landscape Area in 1956. Despite the protection, pollution occurs in some disappearing streams both on the earth's surface and underground, in caves formed by karst processes. The aim of the study was to assess the hydrochemical status of several selected streams and identify the sources of the pollution affecting them.

Three streams were monitored, one in each hydrological part of the karst area. Volume flow rate, dissolved oxygen, pH, COD, BOD, NH_4-N, NO_2-N, NO_3-N, total Kjeldahl nitrogen and total phosphorus were determined.

The study showed deteriorated water quality at most sampling points, especially in the case of parameters such as organic substances, nitrates, and total phosphorus. Inadequate management methods, the excessive recreational use of ponds located on the studied streams, and the phosphorus load from treated domestic wastewaters are among the main causes. However, the studied stretches were found to have retained their self-purification ability.

The stream water quality was already deteriorated when entering the karst area. Thus, it would seem necessary to protect karst streams right from their very source.

Keywords: Moravian Karst, karst stream, hydrochemical status, organic pollution, nutrients

INTRODUCTION

The Moravian Karst, situated in the eastern part of the Czech Republic and extending north from the city of Brno, is the most extensive and most developed karst area in the Bohemian Massif. This region of fully developed karst relief is formed from an approx. 25 km long and 5 km wide area of limestone. It contains more than 1,100 caves and karst phenomena, formed mainly in high-purity limestone from the Devonian period. The karst area is divided into three parts by its hydrology – a northern, a central and a southern part. To protect its unique environment, the Moravian Karst was declared a

https://doi.org/10.5593/sgem2017/52

Protected Landscape Area (PLA) in 1956. The PLA has an area of 92 km², of which nearly half is also included in the Natura 2000 network. Pollution occurs in some disappearing streams both on the earth's surface and in the caves of the PLA. Therefore, the aim of the study was to assess the hydrochemical status of selected karst streams and identify the problems.

The cave systems and connected waterways drain the individual hydrological parts of the karst. The northern part is drained by the Amatérská Cave system and the Punkva River, with corridors extending to a total length of about 34 km [1]. The central part is drained by two systems: the Rudické propadání – Býčí skála system, where the total length of all corridors is about 13 km [1], and the mostly unknown system of Křtinský Brook with Výpustek Cave, where the known corridors stretch for about 2 km [1]. The southern part is drained by the system of Hostěnický Brook and Říčka Stream with Ochozská Cave; the known length of the corridors is about 1.8 km [1]. Most caves are filled to different levels by Pleistocene clastic sediments. The hydrology of the karst area is quite complicated, because of the unknown parts of underground watercourses. Dense settlement and human activity in the karst and surrounding area has a negative impact on the quality of karst water. Despite this, autochthonic karst water is relatively clean and is a source of drinking water for some towns.

The risk of groundwater pollution in karst areas is very high due to the lack of overlying rocks or deposits. Thus, surface run-off may infiltrate easily into the underground conduit system. [2] Contaminants can be transmitted relatively fast over long distances. Besides human settlements and agricultural activities, the risks posed by sports and tourists as well as the road traffic related to them are major burdens on the karst environment. [3]

The carbonate rocks of the Moravian Karst belong to a group of vulnerable aquifers, especially as regards nitrates, which are often used in inorganic fertilizers. Their concentrations can reach high values due to leaching and runoff from arable land. Farmland constitutes about 45 % of the total area of the Moravian Karst, while the rest is covered with forest and permanent grass. [4–5]

In order to lower the pollution of the karst streams, a comprehensive approach is required. Multisite and tributary monitoring is essential to understand and quantify the human impact on the region and evaluate the effectiveness of adopted measures on the ecological balance. [6] Good cooperation between scientists, planners, and decision makers is needed for integral karst protection, as other authors have also pointed out. [7] The establishment of a wider influential protection zone may be advisable. It would comprise the whole catchment area and also include less karstified ground. [2]

AREA OF INTEREST AND METHODS

Streams were chosen that characterize each hydrological part of the Moravian Karst – Lopač Brook in the north, Jedovnický Brook in the centre, and Ochozský Brook in the south (Fig. 1). All of the streams originate outside the PLA in the non-karst area of the Drahany Uplands, east of the karst region.

Lopač Brook rises in woodland and flows through agricultural land before passing through an urban area with a wastewater treatment plant (WWTP), which discharges its treated water into the brook. There are two ponds along its length. The first of these is a small pool located in a forested area. The other, larger one (1.08 ha) is in an urban area. It is used for fishing and recreation. Further on, the stream disappears underground and becomes a left-bank underground tributary of the Punkva River, the largest stream in the Moravian Karst.

The springs and tributaries that form the headwaters of Jedovnický Brook are located in an agricultural area. Their confluence occurs in a system of ponds, the largest of which has an area of 42 ha. Around this pond there is a recreational area with approx. 360 chalets and a campsite with a capacity of 1,500 people. Every year, a fish harvest attended by several thousand people and international motorboat races take place there. The number of cyclists using cycling routes near the pond is continuously growing, too. [3] The stream flows through forested, agricultural and urban areas, where it receives treated domestic wastewaters. Approx. 1.2 km downstream of the WWTP the stream disappears underground and flows through the second longest cave system in the Moravian Karst: Rudické propadání – Býčí skála. After approx. 4.3 km of underground flow it rises to the surface and becomes a right-bank tributary of Křtinský Brook, which drains the central part of the Moravian Karst.

The Ochozský Brook rises in farmland and flows through a village with a small pond (approx. 0.1 ha). Downstream of the village it receives WWTP effluent. It then flows through an open channel and becomes the right-bank tributary of the Říčka Stream, which drains the southern part of the Moravian Karst. Hostěnický Brook is a tributary of the Říčka Stream, too. It rises in woodland and flows through a forested area with two smaller ponds, and then through a village, sinking underground just outside.

The sampling points on each of the aforementioned brooks are described in Tab. 1.

Tab. 1 Description of sampling points and the respective WWTPs

Location	Brook	Sampling point	Description	WWTP category, PE
northern MK	Lopač	1	upstream of WWTP	500–2,000
		2	downstream of WWTP, sinkhole	
central MK	Jedovnický	3	upstream of WWTP	2,001–10,000
		4	downstream of WWTP and 1 km upstream of a sinkhole	
southern MK	Ochozský	5	upstream of WWTP	500–2,000
		6	downstream of WWTP	
	Hostěnický	7	sinkhole	

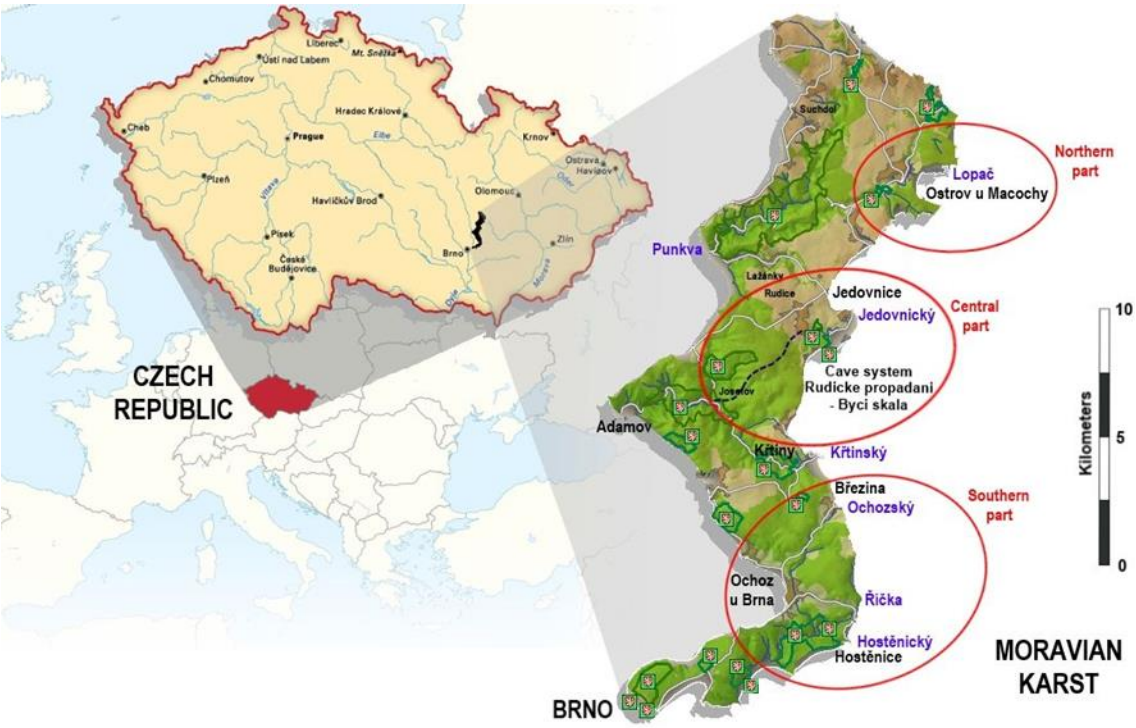

Fig. 1 Map of the Moravian Karst and studied areas

Monitoring was done over three years: Jedovnický Brook – 2014, Lopač Brook – 2015, the Ochozský and Hostěnický brooks – 2016. In the case of the Jedovnický and Lopač brooks, measurements were carried out every two weeks from March to August (a total of 13 sample collections), while in the case of the Ochozský and Hostěnický brooks, measurements were performed every month from March to November (a total of 9 sample collections).

The volume flow rates were determined using pitot tube and flow profile measurements. Dissolved oxygen (DO), oxygen saturation and pH were measured *in-situ* using a Hach HQ40D multi meter. The laboratory analyses were performed as follows: COD – semi-micro method with potassium dichromate and photometric evaluation, BOD – standard dilution method, NH_4–N – photometric method with the Nessler reagent, NO_2–N – photometric method with alpha-naphthol in the presence of sulfanilic acid, NO_3–N – photometric method with sodium salicylate, total Kjeldahl nitrogen (TKN) – acid digestion using concentrated sulphuric acid together with catalyst tablets (KJELTABS ST – Thompson & Capper Ltd), total phosphorus (TP) – mineralization with Oxisolv (Merck) and photometric determination of the released orthophosphates with molybdate and ascorbic acid. Total nitrogen (TN) was calculated as the sum NO_2–N + NO_3–N + TKN.

HYDROCHEMICAL STATUS OF THE STREAMS

As can be seen from Fig. 2–7, the only parameter that always fulfilled the criteria was pH. The average concentrations of organic compounds at most sampling points slightly exceeded the limits (26 mg/L for COD and 3.8 mg/L for BOD). However, at sampling points 1 and 7, extreme values over 100 mg/L COD and over 35 mg/l BOD were occasionally determined. DO concentrations corresponded with elevated concentrations of organic compounds and, with the exception of sampling point 5, were below the legislative limit (9 mg/L). The oxygen deficit differed among the brooks and depended on the season, too. The lowest oxygen deficits were found in the early spring, while the highest was in late summer. The highest average oxygen deficit (amounting to 33 %) was measured at sampling points 3 and 4. The average concentrations of nutrients (TN, TP) were also high and exceeded the limits (6 mg/L for TN, 0.15 mg/L for TP) at all monitored streams. Alarming TN concentrations (about 15 mg/L on average) were found in Jedovnický Brook. TP concentrations and their variance differed among the brooks. It was about 0.5 mg/L on average at sampling points 1, 3, 5, and 7. At sampling points 2, 4, and 6, it was four times higher on average and the measurements showed large variations.

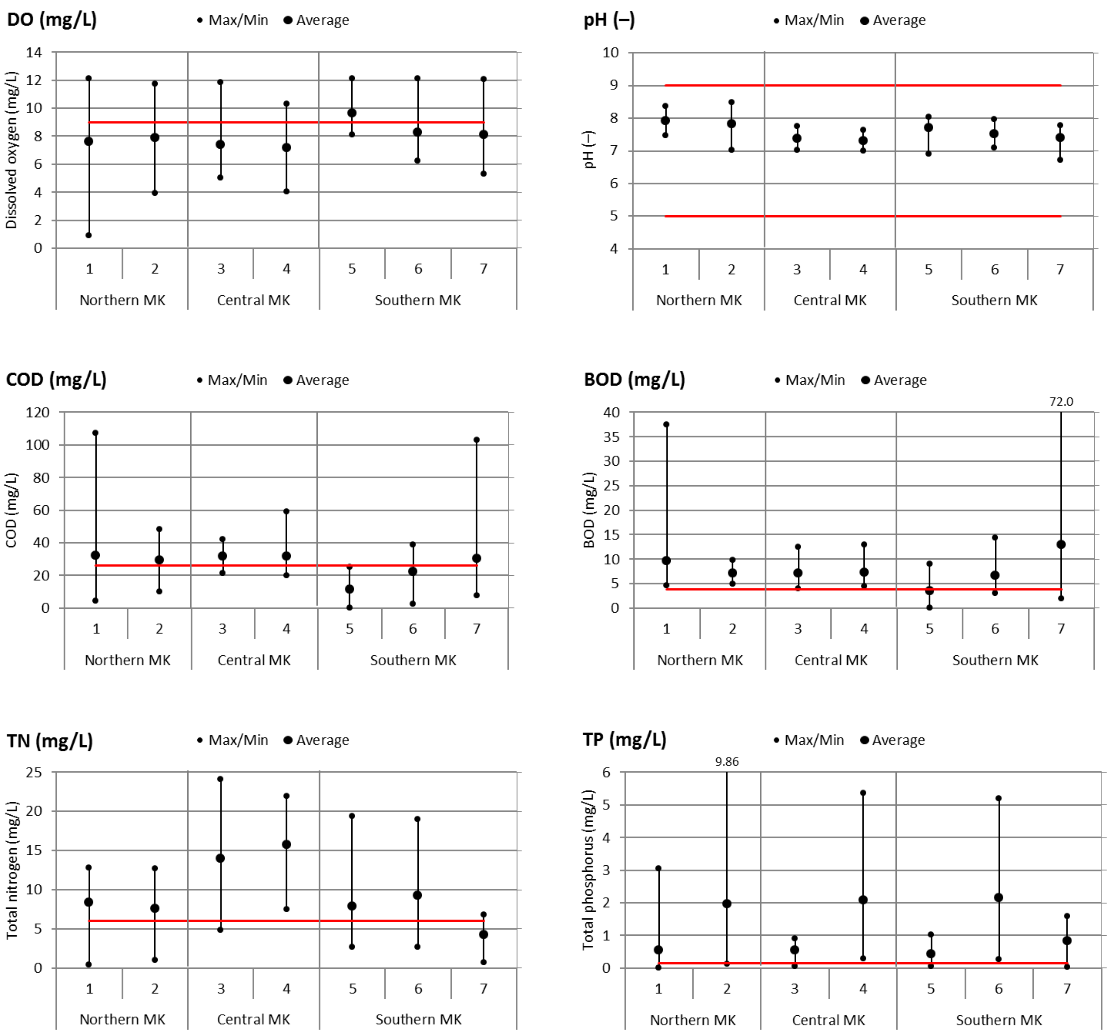

Fig. 2–7 Selected quality parameters of the monitored brooks. The red lines indicate the limits – permissible contamination values (annual average) according to Czech legislation. [8]

POLLUTION SOURCES

The selection of sampling points enabled the assessment of the effect of treated domestic wastewaters from three WWTPs on the water quality of the monitored brooks.

It is evident from Fig. 2–7 that the hydrochemical status of the monitored brooks was already poor upstream of the WWTPs. WWTP outflows in the northern and central part of the Moravian Karst only had a minimal effect on the water quality in the streams, with the exception of an increase in TP concentrations. The southern WWTP outflow deteriorated the water quality of the Ochozský Brook to a larger extent, but it must be noted that the hydrochemical status of the brook was the best of all monitored streams. In any case, attention should be paid to TP. Czech emission standards do not set any limits for WWTPs with capacities of up to 2,000 PE, and set an average outflow TP concentration of 3 mg/L for WWTPs catering for 2,001–10,000 PE. These limits cannot fulfill the protection requirements of such vulnerable areas as karst regions.

The main difference among the streams was the presence (or not) of big ponds and tourism, as treated domestic wastewaters were discharged into all of the brooks and the land use in each of their surroundings was similar. The monitoring showed that the streams with large recreational ponds (Lopač and particularly Jedovnický Brook) had a worse hydrochemical status than the other brooks. This suggests that attention should be paid to the management of ponds and tourism in general, as they can become significant sources of contamination.

SELF-PURIFICATION PROCESSES

Two stretches of Jedovnický Brook were selected for self-purification ability assessment, i.e. an approx. 1.2 km long surface stretch above Rudice sinkhole and an approx. 4.3 km long underground stretch in the Rudické propadání – Býčí skála cave system. Fig. 8 and 9 show changes in selected parameters expressed as concentrations and as balances of material flows, respectively.

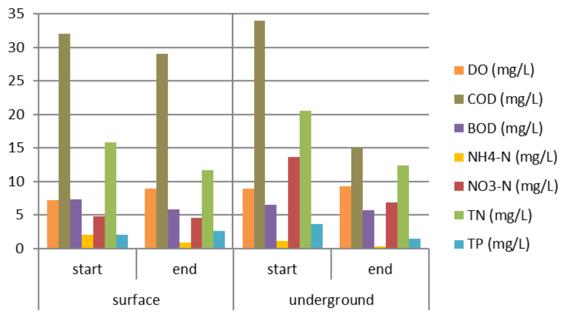

Fig. 8 Concentration changes in two sections of Jedovnický Brook

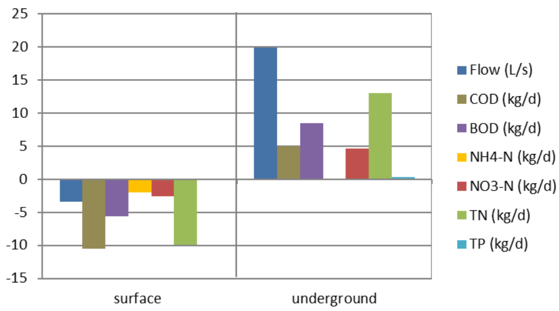

Fig. 9 Mass balances of two sections of Jedovnický Brook

In the surface stretch of the brook, average concentrations of organic compounds, TN, NO_3-N, and NH_4-N decreased; only TP concentration slightly increased. The DO concentration grew. There are no tributaries to the surface stretch and the stream flow decreased by 3.4 L/s on average (20 %). The mass balance showed a decrease in the mass flows of all assessed parameters, including TP. This suggests that this stretch of the brook has a well-preserved self-purification ability.

When assessing the change in the concentration values, all of the water quality parameters of the underground section of the brook were seen to have improved. However, the mass balance results paint a different picture. The pollution load increased, and quite significantly in the case of TN – by 13.1 kg/d (50 %). It was also found that the stream flow almost doubled (increasing by about 20 L/s). This was due to the mixing of the brook with its underground tributaries with a flow rate of 11–52 L/s, depending on the water level [9]. Some of these tributaries have high pollution concentrations, especially of nitrates. The results suggest that self-purification processes such as sedimentation, adsorption, and ion exchange also act to a limited extent in the underground streams, especially those not hampered by the special conditions present (low temperature, darkness, low oxygen concentration, etc.). However, the rates at which such processes as organic matter decay or nitrification take place are reduced by unfavorable conditions. The self-purification processes in the underground sections of the brooks need further study despite difficulties with sampling and the lack of knowledge regarding their hydrology. Regardless, our results clearly show that the mass balance of the pollutants enables a more accurate assessment of the self-purification processes acting in the streams then a simple comparison of pollutant concentrations.

CONCLUSION

The study showed deteriorated water quality at most sampling points, especially in the case of parameters such as organic substances, nitrates, and total phosphorus. The contamination determined in the Lopač and Jedovnický brooks poses a great risk to the aquatic environment of the caves, with its rare and vulnerable organisms and limited self-purification ability.

Our study identified the following main causes of the deteriorated hydrochemical status of the streams:

- the inadequate management and extensive recreational use of large ponds located on the streams outside the PLA;
- the inflow of treated domestic wastewaters from small WWTPs, which raises phosphorus concentrations.

Despite these negative influences on water quality, the studied stretches of the streams (both surface and underground) did retain their self-purification ability, although this was reduced in the underground sections due to the unfavorable conditions present there. The mass balance of the pollutants was found to be the most appropriate method for the assessment of self-purification processes.

Our results show the necessity of protecting the karst streams right from their very source, even before they enter the PLA. State financial support in matters such as a high degree of phosphorus removal at small WWTPs seems to be necessary for the effective protection of the karst ecosystem.

ACKNOWLEDGEMENTS

Funding for this work was provided by Institutional Support for the Development of Research Organization ID 22738 and by Heineken Česká republika, a.s.

REFERENCES

[1] Krásný J., Podzemní vody České republiky: regionální hydrogeologie prostých a minerálních vod, Czech Republic, 2012. (in Czech)

[2] Kaçaroğlu F., Review of Groundwater Pollution and Protection in Karst Areas, Water, Air, and Soil Pollution, vol. 113, pp 337–356, 1999.

[3] Hubelova D., Chalupa P., Pavlik I., Selected Risks of Karst Deterioration by Human Activity in Protected Landscape Area of Moravian Karst, 11th International Conference on Topical Issues of Tourism, Czech Republic, pp 126–138, 2016.

[4] Kadlecova R., Buzek F., Zak K., Nitrate Contamination in Karst Aquifers in the Czech Republic, 13th International Congress of Speleology and 4th Speleological Congress of Latin América and Caribbean and 26th Brazilian Congress of Speleology, Brazil, pp 401–406, 2001.

[5] Ekmekci M., Pesticide and Nutrient Contamination in the Kestel Polje – Kirkgoz Karst Springs, Southern Turkey, Environmental Geology, vol. 49, pp 19–29, 2005.

[6] Glavan M., Pintar M., Impact of Point and Diffuse Pollution Sources on Nitrate and Ammonium Ion Concentrations in the Karst-influenced Temenica River, Fresenius Environmental Bulletin, vol. 19, pp 1005–1014, 2010.

[7] Kovačič G., Ravbar N., A Review of the Potential and Actual Sources of Pollution to Groundwater in Selected Karst Areas in Slovenia, Natural Hazards and Earth System Sciences, vol. 5, pp 225–233, 2005.

[8] 401/2015 Sb. Nařízení vlády o ukazatelích a hodnotách přípustného znečištění povrchových vod a odpadních vod, náležitostech povolení k vypouštění odpadních vod do vod povrchových a do kanalizací a o citlivých oblastech. (in Czech)

[9] Zeman O., Bruthans J., Skapové vody a přítoky v Rudickém propadání – Býčí skále: Vliv využití území nad jeskyní a otázka původu vod, Speleofórum 2007, Czech Republic, pp 105–108, 2007. (in Czech)

Reproduced with permission of copyright owner. Further reproduction prohibited without permission.