

River (non)revitalization: when the human-altered watercourse can be a better choice

DAVID HONEK¹, MILENA FOREJTŇÍKOVÁ¹, ZDENĚK SEDLÁČEK¹,
JITKA NOVOTNÁ², ROMAN HADACZ²

¹ T.G. Masaryk Water Research Institute, p.r.i., Brno, Czechia; e-mail: david.honek@vuv.cz, milena.forejtnikova@vuv.cz, zdenek-sedlacek@vuv.cz

² Czech Geological Survey, Brno, Czechia; e-mail: jitka.novotna@geology.cz, roman.hadacz@geology.cz

ABSTRACT The outcomes of watercourse revitalization are mostly evaluated as positive, depending on the implementation of the given revitalization. A potential negative aspect of watercourse revitalization was investigated via the example of an important source of groundwater for drinking purposes in Březová nad Svitavou. The aim of the research was to assess whether revitalization of the watercourse in the section upstream of the offtake point was appropriate. The assessment used long-term data from the watercourse operator as well as our own short-term monitoring. The results indicate that in this section, the risk of contamination from surface water into groundwater significantly outweighs other benefits of revitalization. Therefore, a partial, modified revitalization was proposed, which in the assessed section maintains and regenerates the existing separation between the watercourse and the groundwater. At the same time, however, it enables the formation of river sediment in the trough as a natural environment for the development of zoo- and phytobenthos and related higher organisms.

KEY WORDS river revitalization – groundwater – pollution – drinking water source – hyporheic zone – Ústecká syncline

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1. Introduction

Watercourse revitalization is currently one of the main activities of water management, landscape engineering and urban planning with the aim of returning the “degraded” parts of watercourses to their natural state and supporting natural relationships between surface water and water in alluvial and bank zones. The aim is not only to regenerate the basic cycle of water flow in the countryside (Magliozzi et al. 2019) but also to support natural biodiversity of aquatic ecosystems (Durčák et al. 2017). Biotope and morphological watercourse diversity is essential for the stability of aquatic ecosystems, as it enhances the resilience of the biota to extreme environmental events – floods, drought, pollution, etc. (Edwards et al. 2012). Revitalization, accompanied by subsequent landscape modifications, has a positive impact on the landscape water retention capacity, stabilizes ecosystems and contributes to mitigating the overall effects of climate change. (Beran 2022; Rozman, Hrkal 2020). For example, vegetation on the banks and in the immediate vicinity of a watercourse can significantly influence its microclimate by shading the water surface, which enables it to absorb daily temperature extremes (Durčák et al. 2017). Rozman and Hrkal (2020) also mention revitalization as a beneficial tool in the fight against flooding as it naturally slows down the water flow and, in suitable areas, enables a regulated water spill.

Generally speaking, revitalization enables “the return of the river to its natural state”. Nevertheless, any watercourse revitalization leads to a significant technical impact on the current water system in the given locality, affecting the current water regime and ecosystem process (Mrozinska et al. 2018, Wood et al. 2023). This tool is often used in those parts of watercourses which have been heavily influenced by human activities (Kurth, Weber, Schirmer 2015). Such watercourses might have been strengthened and their bottoms and banks reinforced with often impermeable surfaces (stone, concrete, etc.). In particular, watercourses in settlements are usually in very poor condition, where the troughs were created completely artificially to adapt to local structures and anti-flood measures, and their natural ecosystems are often severely disturbed (May 2006, Bell 2015). Pollution washed away from the surrounding reinforced surface or from sewage systems also contributes to this (Kožený, Janovská, Svobodová 2021). Revitalization is intended to help remove these maladies and return the area to its natural state, which in many cases can also cope with pollution. However, this is the case only when there is a stable and strong ecosystem in the watercourse.

Troughs influenced by human activities can be found even outside of built-up areas. Such troughs are mainly affected by watercourse alterations in agricultural landscapes, where they are straightened, often even forming a rectangular network in connection to irrigation/amelioration systems. This creates regular landscapes that are easier to manage from an agricultural perspective. Its aquatic

ecosystems are also prone to disruption, which is often caused by the application of chemical spraying to protect plants and application of nitrogen-based fertilizer, which is often washed into watercourses and groundwater (Bridhikitti et al. 2021; Filoso, Palmer 2011; Gumiero, Boz 2017).

In agricultural landscapes, larger revitalizations are relatively more common than in built-in areas since the former naturally enable greater alterations to the watercourse's surrounding landscape. The trough is often spread to the whole inundation area, creating meanders and branching into more troughs together with water surfaces etc. (Beran 2022, Richter 2023). In built-up areas, the watercourses are usually modified within the extent of the troughs/bank edges and the modification is more likely to occur within the existing trough, where artificial impermeable surfaces are replaced with naturally permeable surfaces (Kurth, Weber, Schirmer 2015). It is highly advisable to combine the watercourse revitalization with landscaping around the watercourse, which brings a number of other benefits, such as creation of areas for recreation and relaxation, contamination reduction, etc. (Gumiero, Boz 2017). There are countless examples of revitalizations ranging from small projects of a local nature, comprising tens of meters (Rozman, Hrkal 2020), to large multi-kilometer projects on important watercourses (Vizina et al. 2018). Revitalizations are generally a frequently discussed topic by both professionals and the general public for many reasons. Nevertheless, a positive response to revitalizations prevails. But is watercourse revitalization suitable everywhere?

From an ecological and social perspective, watercourse revitalization is beneficial, it improves the quality of the environment, increases the value of the ecosystem itself and ecosystem services and, moreover, has an aesthetic value (Palmer, Filoso 2009; Shackelford et al. 2013). It always naturally depends on the actual implementation of the revitalization and the defined objective that is to be achieved. A rarely (or hardly ever) discussed issue is the impact of the revitalization on the potential spread of contaminants from polluted water. As aforementioned, water is often contaminated by human activities, especially when settlements, industry and agricultural activities are accumulated in the vicinity of a watercourse (Filoso, Palmer 2011; Gumiero, Boz 2017; Magliozzi et al. 2019; May 2006). Problematic zones are those areas where a watercourse has a strong connection to groundwater which could thus be degraded (Hörchner et al. 2024). Revitalizations generally have a major impact on the groundwater in the vicinity of watercourses, which can also be caused by the intensification of bank and bottom infiltration (Rozman, Hrkal 2020). A number of studies point to the fundamental influence of the interaction between groundwater and surface water on the river chemistry, biochemical processes (water oxygenation, denitrification, etc.) and the ecological status of the river environment itself (Haase et al. 2013; Kurth, Weber, Schirmer 2015; Magliozzi et al. 2019; Hörchner et al. 2024). In principle,

this interaction is seen as positive, especially in terms of climate change measures which increase the retention capacity of the river floodplain (Magliozzi et al. 2019). Nevertheless, there is a lack of targeted discussion regarding the potential exchange of pollution between surface water and groundwater in the vicinity of the intake area of groundwater for drinking purposes, which in conjunction with an unstable ecosystem can be very problematic to catastrophic.

From this point of view, a major problem is the potential infiltration of pollution into a source of high-quality groundwater within the research area of Cretaceous plateau geological formation, the degradation of which would have an extensive impact on the environment as well as on human society (Illes et al. 2025). The geological structure of the area, characterized by significant fracture permeability, is particularly susceptible to accelerated interaction between surface water and groundwater. This dilemma was considered by the professionals working on the Březová nad Svitavou water source, especially in the 1970s and 1980s during the construction of the 2nd Březová conduit (Viščor 2013). This water source is crucial for hundreds of thousands of inhabitants of Czechia and its protection against pollution has been and should be a priority. From the point of view of protection against pollution, attention was paid in the past to the potential penetration of pollution from the highly polluted Svitava River, which runs through the center of the whole area. For this reason, the five-kilometer-long bed of the river and its tributaries has been made impermeable. The water in the river thus passes through the area without any contact with the surroundings. In recent years, there have been discussions regarding a possible revitalization of this section of the Svitava River since the water quality in the river itself has significantly increased since the 1990s. This paper further addresses aspects of possible revitalization in such a specific area, focusing on the following questions: (1) What risks can be expected when revitalizing a watercourse in the vicinity of a groundwater intake for drinking purposes? And, (2) What form of revitalization would be acceptable with regard to the protection of the intake area? The aim is to identify a suitable method of watercourse revitalization that, on the one hand, supports the development of aquatic ecosystems and, on the other hand, maintains protection against potential groundwater contamination.

2. Research area

The research area (Fig. 1) is located north of Březová nad Svitavou, Pardubice District, Czechia, and constitutes a five-kilometer-long section of the Svitava River, which since the 1970s has had a stone-concrete bottom and trapezium-shaped banks (some parts of this modification date back to 1913). Under the concrete reinforcement there is an impermeable foil and the bottom layer is a clay bed. The

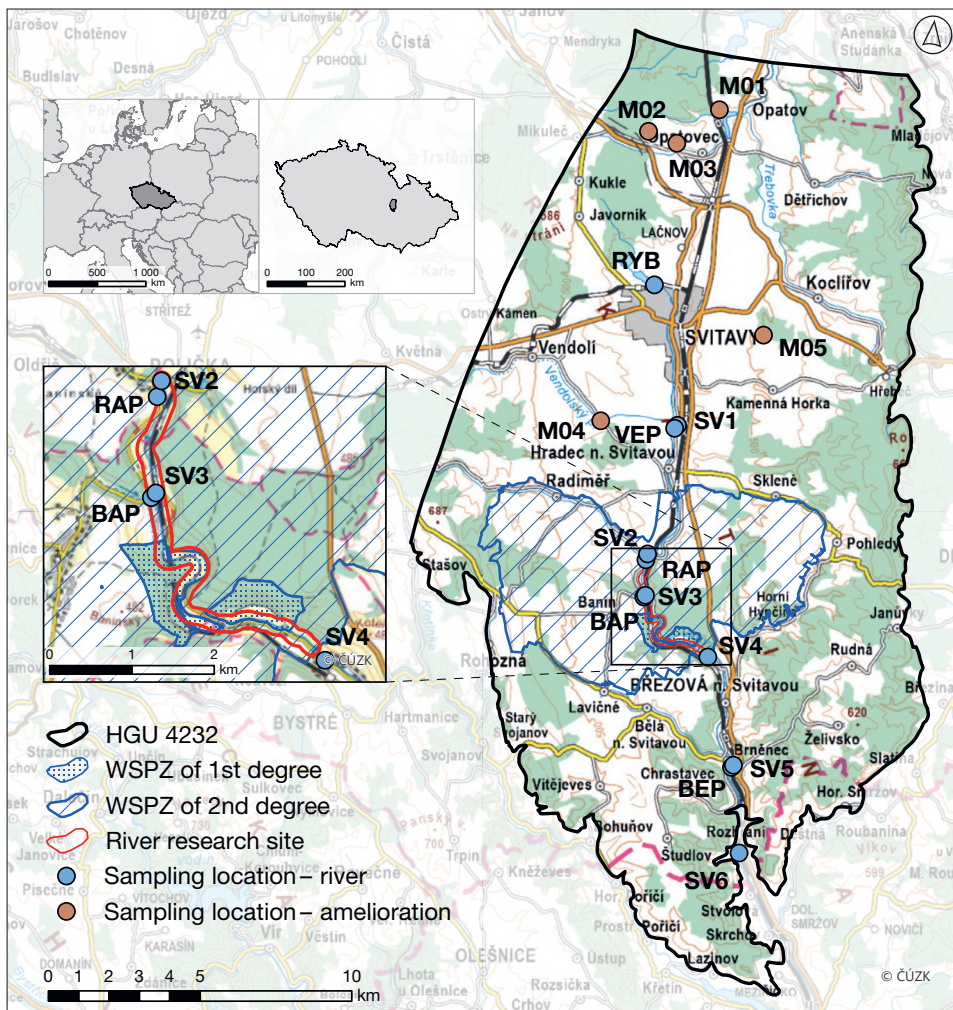


Fig. 1 – Research area and sampling locations

only function of this whole system is to prevent interaction between the surface water and groundwater within the so-called hyporheic zone which in a natural watercourse enables exchange of water between surface water and groundwater surface. This part of the Svitava River passes directly through the water source of groundwater for drinking purposes and therefore it is absolutely undesirable that any degradation of this water should occur.

From the point of view of water source protection, this section is critical for several reasons: (1) The section of the Svitava River passes through a highly urbanized area; (2) above the section there is a large wastewater treatment plant; and

(3) a large part of the Svitava river basin is intensively used for agriculture. In the past, the water in the Svitava River was of a very bad quality, especially due to the intense industrial activities and lack of a wastewater treatment plant in the town of Svitavy. The water quality has significantly improved since then. Nevertheless, concerns about contamination still persist. A sudden temporary deterioration of surface-water quality due to operational failures at the wastewater treatment plant or on major transport infrastructure running parallel to the river cannot be entirely excluded. While the progression of the failure-related pollution in surface water can be monitored and, to some extent, managed, once a contaminant enters the groundwater, its spread is difficult to manage and hard to predict, particularly in the case of deeply buried hydrogeological structures.

The water source in Březová nad Svitavou is formed by two groundwater pumping systems: the 1st and 2nd Březová water supply conduits, pumping water from two hydrogeological collectors, B and C, which are parts of the Hydrogeological unit 4232 Ústecká syncline in the Svitava river basin (HGU 4232; Fig. 1). The whole HGU area is 358 km² and is oriented in a north-south direction representing the eastern edge of the continuous occurrence of Cretaceous sediments in Czechia. The HGU area is formed by alternating permeable hydrogeological collectors (sandstone) and impermeable hydrogeological insulators (claystone; Herčík, Hermann, Valečka 1999; Novotná et al. 2023), which contributes to the formation of a significant source of groundwater used mainly for drinking purposes (Honek et al. 2021; Viščor 2013). The water is supplied via two routes to the city of Brno, about 60 km to the south. This water source is a strategic source for Brno and its agglomeration, comprising over 400,000 inhabitants. Its protection is therefore absolutely crucial.

3. Data and methods

The paper uses data taken from the Czech Hydrometeorological Institute (CHMI; see I.), previous projects handled by the T. G. Masaryk Water Research Institute (WRI; see II.) and measurements performed within the research project, SS06010044 “Defining and evaluating the areas decisive for subsidizing strategic groundwater resources with regard to their protection and stabilization” (Prostředí pro život VI, TA ČR; see III.):

- I. Average monthly flows of the Svitava River at the Hradec nad Svitavou and Rozhraní stations between 1985 and 2024: The Hradec nad Svitavou and Rozhraní stations are part of the CHMI measurement network and they record information on flows of the Svitava River on a daily basis. The location of the stations is identical to the offtake point, i.e. SV1 = Hradec nad Svitavou and SV6 = Rozhraní (Fig. 1).

Table 1 – Description of sampling locations of surface water and amelioration on arable land in the research area

Sampling locations of surface water					
ID	Name	River	Description of location	Coordinates	Number of samples
RVB	Svitavský rybník	Svitava River	in front of pond dam, right river bank	49°45'53.964"N, 16°27'53.054"E	13
SV1	Hradec nad Svitavou	Svitava River	behind the bridge	49°43'27.874"N, 16°28'56.571"E	9
VEP	Hradec nad Svitavou	Vendolský Stream	behind the bridge, behind WWTP	49°43'24.485"N, 16°28'52.487"E	13
RAP	Radiměř	Radiměřský Stream	in front of the bridge	49°41'1.782"N, 16°28'28.878"E	13
SV2	Radiměř	Svitava River	behind the bridge	49°41'7.631"N, 16°28'30.616"E	12
BAP	Banín	Banínský Stream	behind the bridge	49°40'22.168"N, 16°28'32.547"E	11
SV3	Banín	Svitava River	in front of the bridge	49°40'23.969"N, 16°28'34.594"E	13
SV4	Dlouhá	Svitava River	behind the WSPZ of 1 st degree	49°39'25.770"N, 16°30'77.434"E	13
BEP	Brněnec	Bělský creek	behind the river confluence	49°37'31.586"N, 16°31'26.142"E	13
SV5	Brněnec	Svitava River	behind the river confluence	49°37'33.674"N, 16°31'28.266"E	13
SV6	Rozhraní	Svitava River	in front of the bridge	49°36'1.499"N, 16°31'53.391"E	13
Sampling locations of amelioration					
ID	Name	River	Description of location	Coordinates	Number of samples
M01	Opatovec	Černý Stream	in front of the pond	49°49'7.107"N, 16°29'8.598"E	1
M02	Opatovec	Mikulečský Stream	in front of the bridge	49°48'36.152"N, 16°27'16.434"E	10
M03	Opatovec	Mikulečský Stream	in front of the pond	49°48'25.123"N, 16°28'7.649"E	10
M04	Vendolí	Vendolský Stream	in front of the culvert	49°43'23.645"N, 16°26'50.131"E	3
M05	Kamenná Horka	nameless stream	in front of the pond	49°45'14.039"N, 16°31'0.819"E	8

- II. Results of macrozoobenthos monitoring: The saprobic index of macrozoobenthos was used between 1970 and 2010 for the evaluation of water quality in rivers in Czechia. The index indicates the relationship of the invertebrates living in bottom sediments to the indicators of organic pollution and to the extent of decomposition processes (Hegrab, Khalifa 2021). The index was monitored during five-year cycles within a special monitoring network (ČSN 1998; Zahrádková et al. 2015). In the paper, results from 1985, 1995 and 2005 are presented to compare the pollution development over time.
- III. Sampling in 16 selected locations within the HGU area (Fig. 1; Table 1): Surface-water sampling was carried out from June 2023 to June 2024; amelioration water sampling took place from April 2024 to March 2025. This dataset has not yet been publicly published in such a comprehensive form, and it is further discussed in more detail in this paper.

Additionally, map outputs were created on the basis of data sets provided by the Czech Office for Surveying, Mapping and Cadastre (COSMC) – Basic topographic map of CR 1: 10,000. GIS analyses and map outputs were processed in the ArcGIS Pro 3.4.2 software of the company ESRI™.

4. Results

Figure 2 shows the annual course of average monthly flow in the Svitava River in the stations of Hradec nad Svitavou and Rozhraní over a ten-year period (the grey base area shows the long-term monthly average for the period between 1985 and 2024). The Svitava River in both profiles is characterized by increased water flow in spring months, especially in March. This can be attributed to snow melt, spring rains and agricultural land without vegetation when surface runoff is easier. This spring peak is typical for almost all selected watercourses although sometimes it occurs later in the following spring months. Another significant peak appears in July, due to the more frequent occurrence of intense precipitation events (e.g. the 1997 floods in Moravia). It is particularly in this month that the most significant change compared to the long-term average can be seen. Other seasons of the year, the end of summer and autumn, have always been periods of the lowest flows and the years monitored have almost always been under the long-term average.

From the long-term perspective, the Svitava River flow has been decreasing, except for years with above-average rainfall. In warm months, the watercourse often completely dries up, which was observed at the Hradec nad Svitavou station. A slightly different situation can be noticed further downstream where the steadier flow in the river has been influenced by the runoff from the Hradec nad Svitavou WWTP (large municipal WWTP for the town of Svitavy) and also by

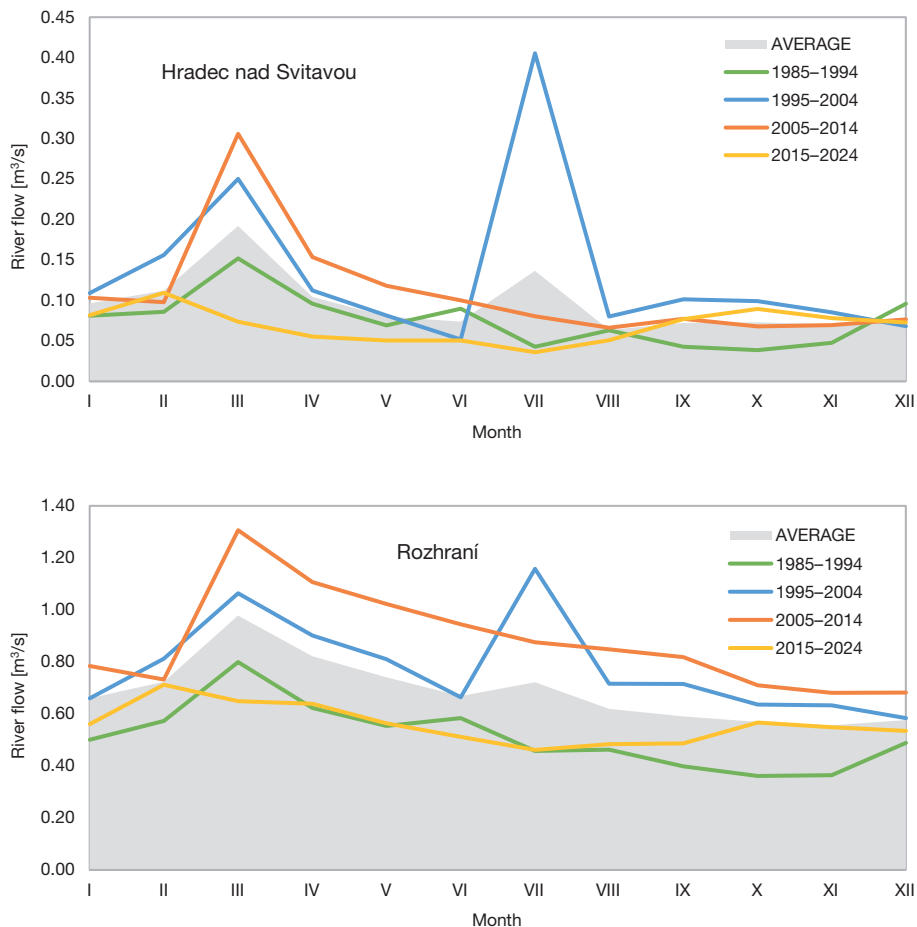


Fig. 2 – Long-term average monthly flow [m^3/s] of the Svitava River at the Hradec nad Svitavou and Rozhraní stations (stations operated by the CHMI) during the time period from 1985 to 2024

several smaller tributaries, thanks to which the watercourse at the Rozhraní station does not dry up completely.

Pollution in the Svitava River was caused in the past mainly by the concentration of the textile industry around the river and by the discharge of wastewater from all settlements in the vicinity of the river. The zoobenthos saprobility index evaluation results demonstrate a gradual improvement in the river water quality between 1985 and 2005 (Fig. 3). The original very bad quality was caused mainly by the wastewater from the town of Svitavy and intense agricultural activity in the spring area of the Svitava River. In this section the river does not contain enough water to water down the pollution, in contrast to the case further downstream. Intense pollution spread to the water source area in Březová nad Svitavou and for

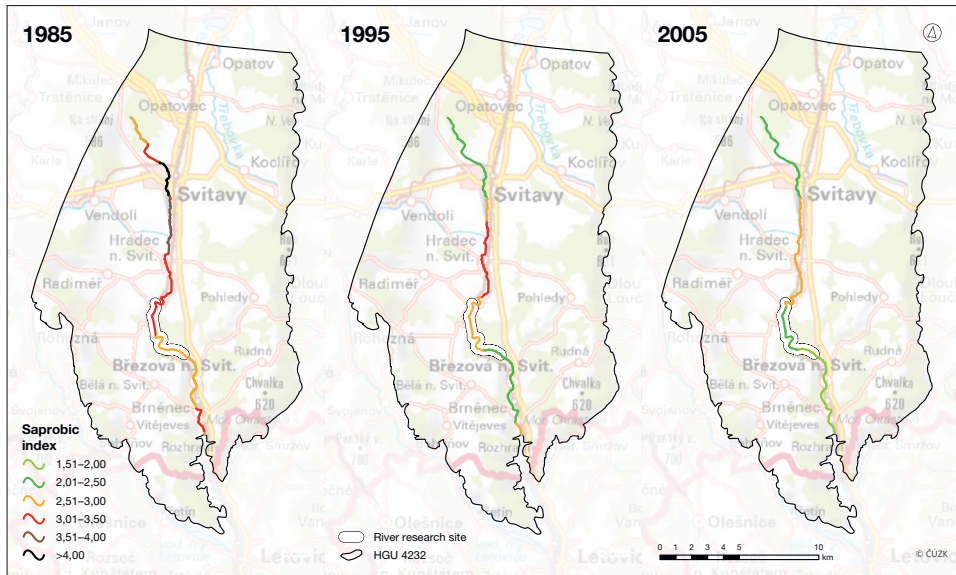


Fig. 3 – Development of the zoobenthos saprobicity index in the Svitava River (upper part of the river) from 1985 to 2005

this reason, the river bed was modified in the 1970s to prevent pollution infiltration into the groundwater.

The river water quality has been gradually improved (Fig. 3), mainly due to a decline in industrial activity and the diversion of most wastewater to the Hradec nad Svitavou municipal WWTP. Nevertheless, the area between the town of Svitavy and the research location (the beginning of the reinforced part of the river) remains in a worse condition due to the pollution washed away from settlements and roads. A potential risk is posed by the Hradec nad Svitavou WWTP itself where the treated water is discharged directly into the watercourse. A low flow in the Svitava River often prevents the substances in the treated water from being naturally diluted and eliminated.

Long-term situational monitoring is carried out in the territorial scope, which is not sufficient for the evaluation of the current state of the area of interest. Therefore, annual monitoring of surface water and outlet points of amelioration outfalls was selected between 2024–2025 in the network of locations according to the study requirements. Examination results are part of the standard agenda of the laboratory. In the following text, only those indicators that are relevant to the objectives of the study are presented. In Table 2 these selected indicators are processed as average values taken usually from 12 measurements. A lower number of measurements in some locations is due to low to zero flows at certain times of

the year. Table 1 therefore also includes the number of relevant sampling events from which the average values were calculated.

The visualization in Figure 4 was created to provide a better understanding of the location, type and severity of water pollution. Quality indicators are divided into five groups according to their characteristics:

- Oxygen regime: O₂, BOC5, CHOC-Mn
- Microbiology: Fecal coliform bacteria, *Escherichia coli*, Enterococci
- Salts: RL, RAS, CL, SO₄, Mg, Ca
- Nutrients: nitrate regime, o-PO₄ total, TOC
- Metals: Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Ps, Zn.

Each group was evaluated for the given location according to the worst evaluated indicator. A four-color scale ranging from the best (blue) to the worst (red) quality was used to express the quality status. Each monitored location has a sign on the map with five sections colored according to the monitoring results. Figure 4 clearly shows that, taking into account all groups of indicators, the locations with the worst quality are the ones under the town of Svitavy (SV1) and under the Svitavy wastewater treatment plant on the Vendolský Stream (VEP). With the exception of the presence of metals, this unfavorable condition persists in other locations on the Svitava River above the intake area (SV2 and SV3). A reduced number of metals in the water of this section may be caused by their entrapment in the river bottom sediments, which are created here due to low flows and low hydraulic head.

The favorable nutrient status of all monitored drainage waters (M01–05) is surprising although a worse status was expected due to nitrate leakage from the arable land (Fig. 4). However, it appears that any excess nitrate in the flat upland part of the river basin is directly transferred to groundwater. Unfavorable evaluation of this nutrient group in other locations is mainly due to phosphorus leakage from municipal and possibly industrial pollution sources.

The best water quality was in the location M01 (Fig. 4). According to available resources, this is a drainage water outlet under a large swathe of arable land. The laboratory results, however, suggest that this is a groundwater spring that has been diverted by a drainage pipe further below to facilitate the cultivation of the entire agricultural land.

For some significant indicators the data have been processed in more detail – Figure 5 to Figure 10. All sampling was carried out at times of average or lower flows; no situation was captured after a heavy rainfall or during a prolonged period of elevated water levels. The variability of pollutant concentrations is thus most likely due to the seasonality of agricultural work or fluctuations in the efficiency of the treatment processes at the WWTP that discharges into the Svitava River. In the case of heavy rainfall, increased concentration of pollution from diffuse agricultural sources can be expected, together with erosion-driven

Table 2 – Average result values of chosen parameters of surface water

Sampling location	Fec. colif. bact.		Escherichia coli		Enterococci	pH	EL. conduct.	BOC5	CHOC-Mn		Cl	SO4	Amomn. ions
	KTJ/100 ml	KTJ/100 ml	KTJ/100 ml	KTJ/100 ml					mg/l	mg/l			
RYB	3,280.00	33.17	232.17	7.82	38.80	6.01	8.44	26.10	34.13	0.29			
SV1	184,000.00	10,205.00	7,077.78	7.55	57.82	3.20	5.41	57.60	47.50	0.59			
VEP	328,300.00	187,641.67	45,046.92	7.38	76.88	2.96	6.85	74.18	80.68	1.90			
RAP	5,900.00	1,289.23	2,472.31	7.69	40.58	2.19	3.51	8.73	33.72	0.10			
SV2	87,000.00	19,244.00	6,856.67	7.61	68.23	2.30	5.77	65.82	70.68	0.69			
BAP	1,800.00	2,380.00	9,928.18	7.76	70.07	3.55	3.87	25.12	67.15	0.65			
SV3	84,000.00	9,572.31	5,210.77	8.00	59.29	1.71	4.00	46.28	55.79	0.64			
SV4	32,800.00	2,353.25	2,143.08	7.54	60.68	1.39	2.67	34.19	50.63	0.24			
BEP	1,600.00	968.46	991.08	7.62	52.27	2.47	2.25	25.76	44.02	0.05			
SV5	30,400.00	2,110.83	2,044.62	7.58	57.14	0.99	1.84	28.92	46.72	0.15			
SV6	63,000.00	3,158.33	3,061.54	7.65	55.54	0.98	2.55	29.71	47.82	0.25			
M01	—	—	—	7.40	39.10	40.20	3.01	6.57	48.60	0.02			
M02	1.00	63.50	98.13	7.52	16.38	18.42	10.03	3.97	26.17	0.03			
M03	12.00	168.56	153.67	7.19	36.72	38.48	6.51	6.10	40.68	0.04			
M04	—	4,869.67	3,174.67	7.08	37.57	39.30	6.37	11.71	31.97	0.06			
M05	20.00	333.33	259.50	7.57	22.61	24.20	33.1	9.08	33.13	0.02			
Sampling location	NO ₃	NO ₂	o-PO4 total	NL105	RL105	Na	K	Ca	Mg	Al			
ID	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l			
RYB	5.50	0.06	0.23	28.05	267.15	12.46	4.22	59.10	3.78	174.94			
SV1	14.11	0.25	0.36	28.58	375.33	32.02	3.11	75.77	3.48	279.01			
VEP	46.90	0.47	2.47	33.87	518.31	53.12	13.82	83.95	5.91	270.68			
RAP	24.08	0.10	0.30	29.82	285.46	2.45	2.35	76.61	1.71	267.00			
SV2	25.65	0.51	1.33	15.82	442.17	42.84	10.21	79.03	4.88	245.01			
BAP	48.76	0.81	1.74	22.96	507.36	12.52	7.20	122.59	2.46	444.03			

SV3	26.81	0.25	0.86	15.34	401.77	25.16	6.31	83.76	3.64	213.38
SV4	35.90	0.13	0.47	14.25	435.23	15.50	3.86	98.62	3.27	313.73
BEP	40.28	0.11	0.31	25.90	401.00	6.23	2.32	92.89	2.51	225.09
SV5	31.08	0.09	0.34	13.71	407.38	10.82	3.10	95.62	3.43	391.03
SV6	31.28	0.09	0.43	19.78	401.77	11.08	3.13	95.94	3.45	394.94
M01	11.20	<0.03	<0.03	<2	271.00	4.43	<1	64.30	4.25	-
M02	7.70	0.05	0.09	6.18	133.44	3.64	2.05	24.88	2.19	323.29
M03	17.31	0.05	0.09	3.80	295.22	4.90	1.83	69.14	5.84	307.95
M04	6.27	<0.03	0.23	18.00	270.00	3.25	1.95	66.70	3.32	1,019.50
M05	39.02	0.13	0.13	16.84	183.14	3.15	1.82	29.41	3.38	81.10
Sampling location	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
ID	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
RVB	4.39	<0.1	<1	14.77	624.00	<0.05	65.36	4.05	2.11	8.00
SV1	2.46	0.10	1.33	4.20	581.22	<0.05	56.00	3.25	2.53	28.33
VEP	1.83	<0.1	3.34	5.79	558.54	0.06	63.75	2.77	1.98	27.10
RAP	1.37	<0.1	1.85	3.56	225.67	<0.05	46.33	2.14	2.22	28.00
SV2	1.74	<0.1	1.42	3.38	323.67	<0.05	48.63	2.46	1.84	19.20
BAP	1.94	<0.1	1.34	6.55	328.00	<0.05	30.17	3.35	2.39	18.67
SV3	1.62	<0.1	1.27	3.50	235.83	<0.05	43.00	3.01	2.20	35.00
SV4	1.80	<0.1	1.40	2.99	255.81	<0.05	39.50	2.49	2.47	26.50
BEP	1.38	<0.1	<1	4.49	162.00	<0.05	38.25	7.41	1.87	15.00
SV5	1.80	<0.1	1.19	4.10	173.90	<0.05	33.50	2.67	2.07	23.50
SV6	1.33	0.13	2.33	5.00	324.67	<0.05	45.00	3.66	3.52	31.00
M01	-	-	-	-	34.00	<0.05	<20	-	-	<5
M02	2.30	0.17	1.56	2.72	331.78	<0.05	48.80	4.22	1.03	<5
M03	1.97	0.12	1.53	3.81	245.89	<0.05	47.20	3.17	<1	<5
M04	2.23	<0.1	1.20	3.29	1355.00	<0.05	49.00	5.55	3.90	<5
M05	1.77	<0.1	1.47	2.00	377.67	<0.05	38.00	2.07	<1	<5

"-" marker means that the value could not be determined due to a small number of samples or was not determined at all

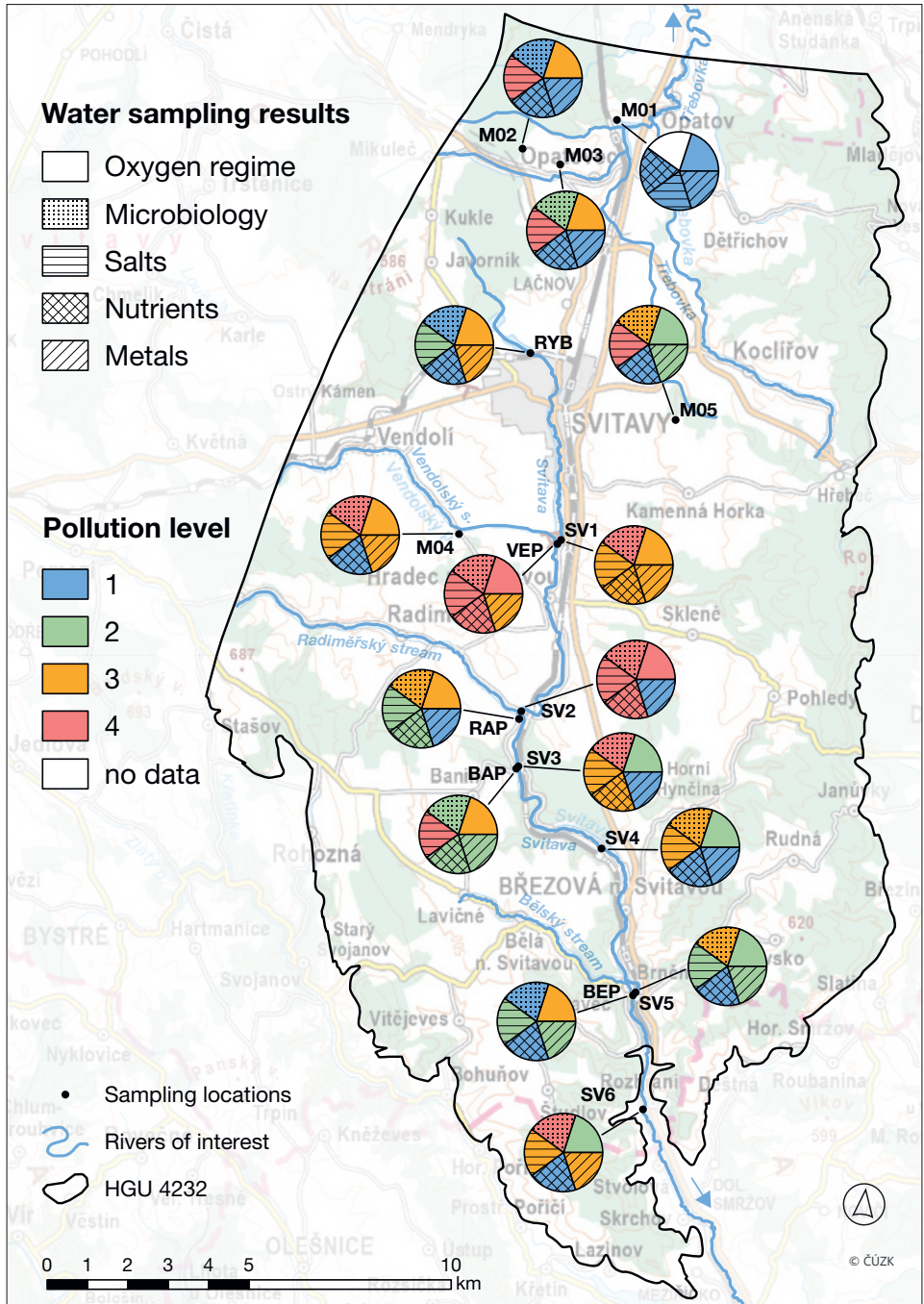


Fig. 4 - Water sampling results throughout the HGU 4232 research area.

Figures 5-10 show the results of the basic statistical analysis of the selected parameters in each sampling location, with the thin lines showing the variance of values (MIN and MAX), the lower box boundary the 1st quartile value, the upper box boundary the 3rd quartile value, and the interface between the light and dark blue boxes the median value.

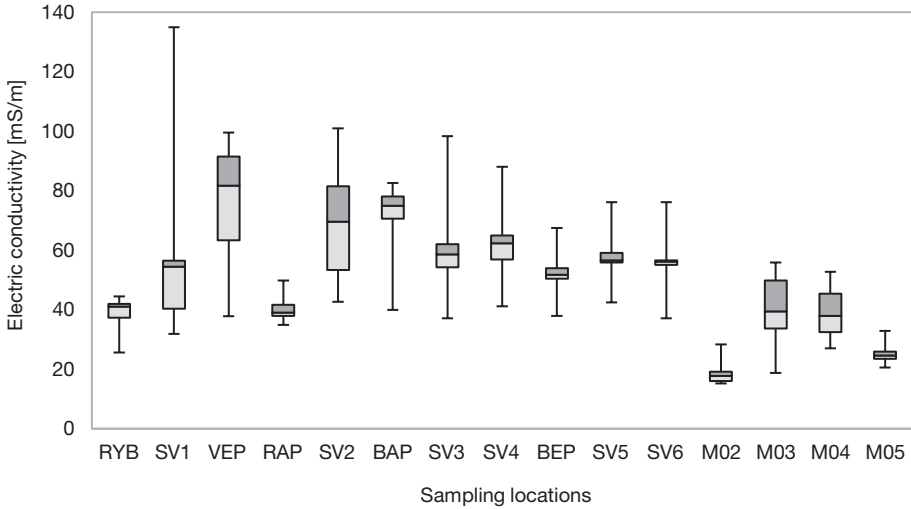


Fig. 5 – Variance of values of electric conductivity [mS/m] during the time period from June 2023 to March 2025

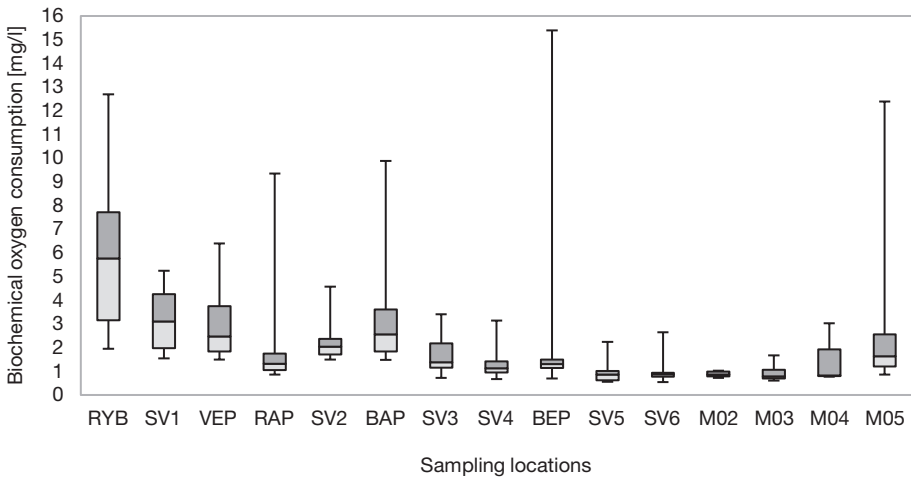


Fig. 6 – Variance of values of biochemical oxygen consumption [mg/l] during the time period from June 2023 to March 2025

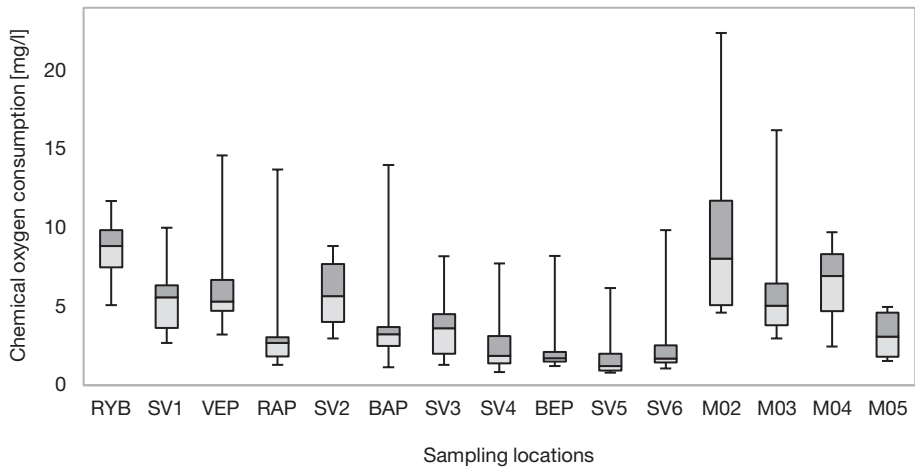


Fig. 7 – Variance of values of chemical oxygen consumption [mg/l] during the time period from June 2023 to March 2025

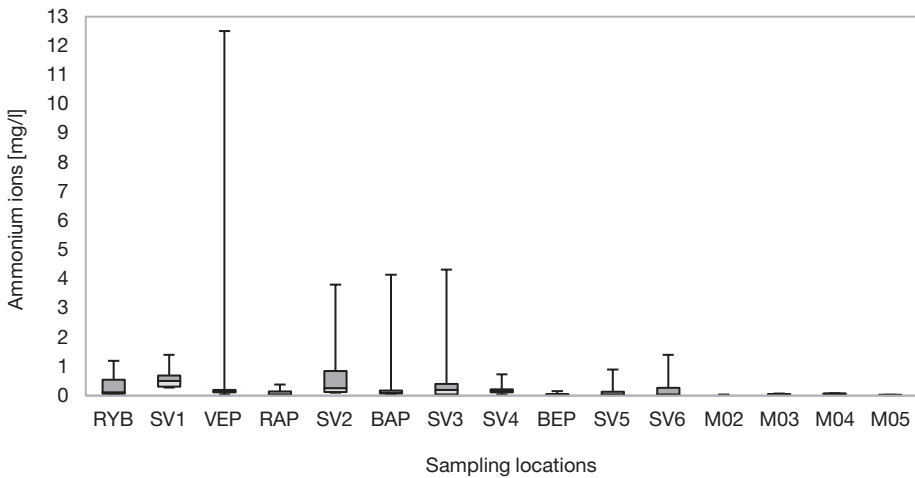


Fig. 8 – Variance of values of ammonium ions [mg/l] during the time period from June 2023 to March 2025

wash-off of topsoil; whereas for pollutants originating from municipal and industrial point sources, the pollution will more likely be diluted, resulting in reduced concentration in surface water. In particular, the left-bank part of the Svitava river basin, upstream of Březová, is highly susceptible to erosion. Based on previous experience, the majority of concentrated flow paths and their surrounding areas have already been grassed over or equipped with additional erosion-control measures.

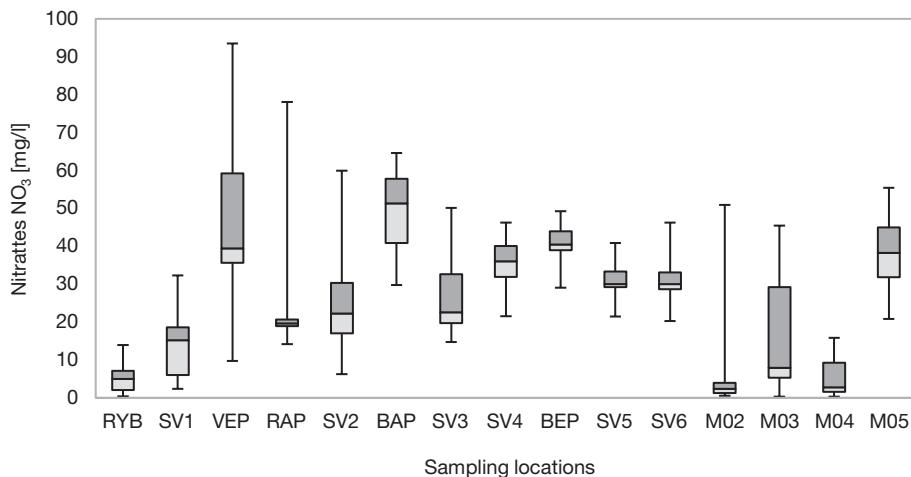


Fig. 9 – Variance of values of nitrates (NO₃) [mg/l] during the time period from June 2023 to March 2025

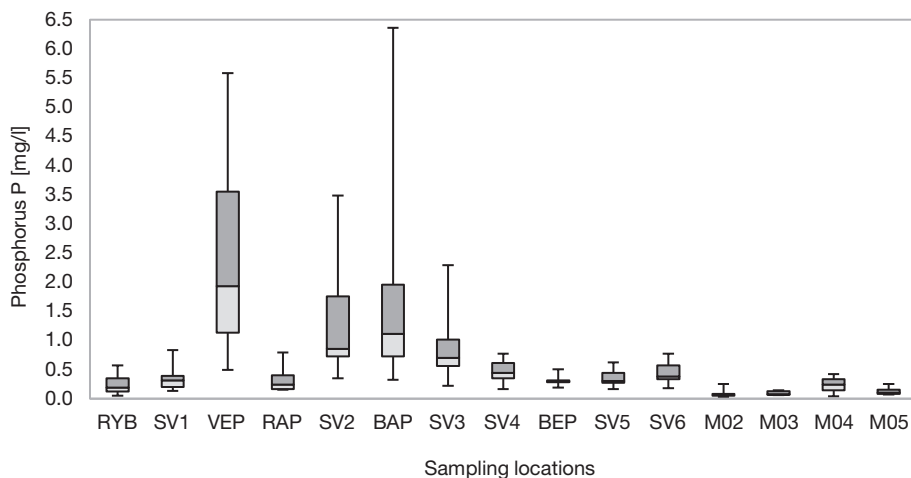


Fig. 10 – Variance of values of phosphorus (P) [mg/l] during the time period from June 2023 to March 2025

5. Discussion

The positive benefits of watercourse revitalization are, generally speaking, indisputable and have been confirmed many times in the context of stabilizing aquatic ecosystems (Shackelford et al. 2013; Durčák et al. 2017), supporting water retention in the landscape and mitigating the impacts of climate change (Edwards et al. 2012; Beran 2022) and serving as part of anti-flood measures (Rozman,

Hrkal 2020). In 2000, Directive 2000/60/EC of the European Parliament and of the Council (EU 2000) – Water Framework Directive – was adopted, which enabled national legislation and related practical measures to be adopted by EU countries for the overall improvement of the aquatic environment. The Directive was focused mainly on surface waters; groundwaters are mentioned only marginally in the context of relevant topics.

Biologists played an important role in the creation of the Directive (EU 2000) and therefore priority was given to addressing the problems of aquatic communities and water-dependent animals and plants. The Directive assumed that by 2027 all waters would be in their natural state and if this was not so, everything possible would be done to maximize the ecological potential. During the implementation of the Directive, important reasons, relevant for maintaining the existing status of the watercourse with its required structures, have been highlighted, such as flood protection measures, accumulation of surface water for drinking purposes or modification of the watercourse leveling for the use of hydraulic power. These reasons do not yet include a case where it is appropriate to maintain a watercourse section unrevitalized in order to protect another water body, such as groundwater. The Directive (EU 2000) and other regulations aim at returning rivers to their natural states. Revitalizations are proposed even in places where the technical adaptations have been going on for more than 100 years and during that time qualitative relationships have already been established in the hydraulic environment and throughout the whole landscape (Kurth, Weber, Schirmer 2015; Richter 2023). In such cases, revitalization measures need to be carefully considered to avoid other damage (Bridhikitti et al. 2021; Hörchner et al. 2024).

Proposals for the revitalization of the Svitava River and its tributaries have been discussed and smaller local studies have also been carried out (e.g. IEVA 2022). However, some studies' results indicate that a full-scale revitalization in the immediate vicinity of a water source is unlikely to be possible here due to its assumed impact on the quality of groundwater. The results presented here also evidence this assumption as they point to the pollution of the Svitava River caused by the local waters and runoff from the surrounding watercourses. Great variability in results (see Attachments S2 to S6) indicates the risk of sudden high to emergency pollution levels. In the case of the Banínský Stream, a right-side tributary of the Svitava River, its alluvial plain has already been revitalized (PMO 2024). The results of the collected water analysis, carried out by the water source operator, demonstrate a subsequent deterioration of microbiological indicators in the collected water although a direct link to the revitalization has yet to be assessed.

Maintaining the impermeability of the river bottom while revitalizing other elements, which will not conflict with this requirement, could be a compromise solution of revitalization in these complex cases. Figure 11 is an example of

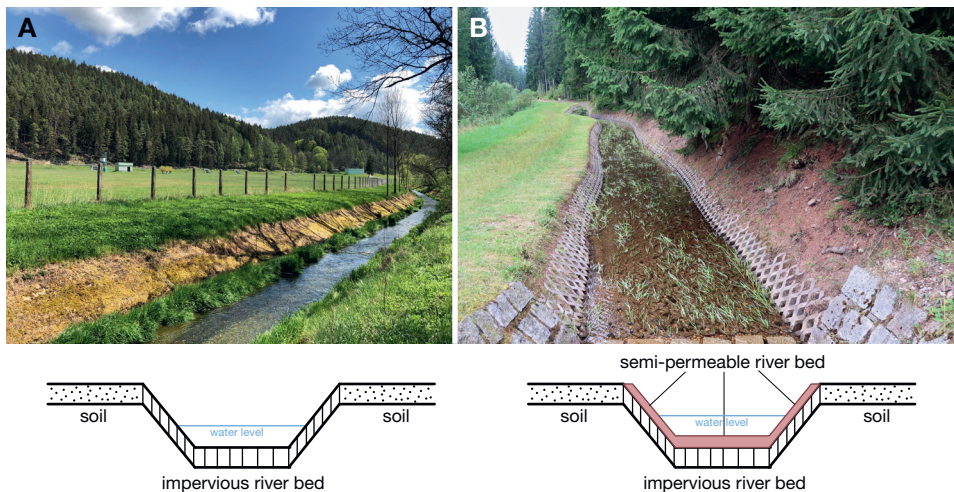


Fig. 11 – (A) River Svitava in Březová nad Svitavou (CZE; Photo by D. Honek, 12. 9. 2018); (B) the Hanggraben near Wildenthal (GER; Photo by M. Dzuráková, 20. 8. 2024). The impervious river bed is made (from the base) of a layer of clay, an impermeable foil, and a stone-concrete layer.

a possible modification of the water trough where the impermeable layer in the existing composition of the cross section (Figure 11A) is covered by concrete lattice which trap sediments and enable hydraulic ecosystem development. The proposed possible suitable solution was inspired by the revitalization in Hanggraben near Wildenthal in Germany (Figure 11B), where this kind of modification of a part of an artificial channel helped transfer water to a water tank. Based on the enhancement of riverine and ecosystem processes, no increase in maintenance demands is anticipated for the watercourse modified in this manner. Natural fluctuations in flow will lead to the trapping of an adequate amount of sediments and its revitalization; whereas the transport capacity of higher flows will remove excess sediments. Under significantly low to zero flows, moist sediment will provide conditions suitable for the survival of organisms that would not survive in a paved, smooth, and dried-out trough. This technical solution could also enable the transfer of problematic wastewater, e.g. water from a wastewater treatment plant or occasional accidental contamination, through the drinking water intake area.

If such a modified revitalization of the Svitava River is partially designed and implemented, it is advisable to use the variant with the impermeable bottom also upstream up to the confluence of the Vendolský Stream, the recipient of the treated municipal wastewater from the town of Svitavy, given the unstable water quality. In connection with landscape modifications in the watercourse surroundings, it would be possible to create a functional ecosystem, providing valuable services both to nature and human society (Gumiero, Boz 2017; Magliozzi et al. 2019).

6. Conclusion

This paper investigates the benefits and risks of the revitalization of the Svitava River and its tributaries in respect to it being an important underground source of drinking water. It presents general, theoretical as well as practical approaches to revitalization of watercourses under different conditions, including various authors' ideas and experience. However, during the research no example has been found which would correspond to the specific situation in the monitored location HGU 4232 Ústecká syncline in the Svitava river basin. The example of HGU serves as a basis for discussion over negative anthropogenic consequences connected with intense agriculture, industry and settlements and their impact on groundwater quality via interactions with surface water.

Quality indicators of surface and drainage waters have been analyzed over the course of two years to monitor the current state. The data obtained and subsequent discussion have confirmed that under the given conditions, a full-scope revitalization is not suitable because it could pose a risk to the watercourse quality. It seems to be indispensable to maintain technical measures for the impermeability of the river bed in selected parts of watercourses affected by pollution. In spite of that, it does not mean the revitalization should be completely given up. The paper discusses revitalization options which enable all other benefits except for the contact between the surface water and groundwater, which is entirely unacceptable in locations of this type. The modified revitalization will bring benefits to life in watercourses and their immediate surroundings and will enhance the overall character of the landscape. Economic evaluation, i.e. financial demands of the proposed solution, was not part of the research project. However, given that the Svitava River trough will need to be repaired in that section in the near future due to its current unsatisfactory condition, the situation represents a comparison of two different solution variants. No significant difference in investment costs is anticipated, as would be the case if a zero variant (leaving it in the current state without any intervention) was compared with any type of new modification. If this solution is accepted, further discussion with biologists, landscape ecologists etc. will be required to consider what elements and their parameters should be chosen.

In artificial troughs, aquatic vegetation appears spontaneously due to the wear and tear of the trough reinforcement. Nevertheless, the proposed modification of the watercourse revitalization could support the development of the aquatic ecosystem to a much greater extent, even when the original purpose of the trough reinforcement is maintained. The solution itself is relatively easy and able to be applied and adapted for similar locations. The technical solution is based on a real implementation, albeit with a different objective. This offers an opportunity to continue and develop this technical solution and to link it to other measures in the landscape, particularly in the unpolluted parts of the river basin, to maintain and enhance groundwater production.

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ORCID

DAVID HONEK

<https://orcid.org/0000-0001-6957-051X>

MILENA FOREJTŇÍKOVÁ

<https://orcid.org/0009-0004-9228-3155>

ZDENĚK SEDLÁČEK

<https://orcid.org/0009-0001-4780-4191>