VODOHOSPODÁŘSKÉ TECHNICKO-EKONOMICKÉ INFORMACE
(WATER MANAGEMENT TECHNICAL AND ECONOMIC INFORMATION)

VTEI / 2024 / 4

60 years ago in VTEI

In VTEI No. 5 from 1964, František Křivý from worsted laundry in Nejdek wrote about their semi-operational experience in wastewater treatment using metallic iron.

In the wastewater treatment plants from the dyehouses in our textile industry, clarification with iron(II) sulphate and lime is currently mainly used, followed by sedimentation and sludge thickening. In his way, however, the salinity of the water and the amount of sulphates will increase. In order to eliminate this disadvantage, treatment with metallic iron (filings, shavings) using the so-called Niers method and the company Pista method was introduced abroad. Both methods work on the same principle, they differ only in construction.

The method consists of intensive aeration of wastewater and its simultaneous mixing with iron filings. This creates a large amount of sludge in the form of iron hydroxides, or iron sulphides, on which impurities and dyes are sorbed. Sludge is removed by sedimentation.

Centroprojekt Gottwaldov was commissioned to verify this method in local conditions. In 1962, laboratory experiments were completed with the following results:

The consumption of iron is greater when clarifying with metallic iron than when clarifying with iron(II) sulphate. However, the sludge volume is smaller, i.e. the sludge has higher dry matter. The effectiveness on the indicators of organic pollution was practically the same as in the case of clarification with iron(II) sulphate. However, there was a decrease in salinity. At the end of 1962, semi-operational equipment was installed in the dyeing room of our plant in Chrastava. Raw wastewater was pumped from the sedimentation tank into a cylindrical iron reactor with a volume of 5.1 m^3 (diameter about 180 cm, height 360 cm) with a conical bottom. A stirrer rotated in the narrowed lower part of the reactor, which sucked in air through a hollow shaft. From there, water with sludge flowed into a conical sheet sedimentation tank and from there, without sludge, into the receiver.

From a chemical-technological point of view, the optimal amount of iron needed for the reaction in the reactor was tested, which was 15–20 g/l of iron, and the optimal flow rate, which was between 0.5–1.0 l/s. Under these conditions, COD reduction of more than 50 % and dye reduction of more than 90 % was achieved. COD of used wastewater from pulp dyeing with a combination of direct and sulphur dyes fluctuated in the range of about 80–500 mg O2/l. During operation, the stirrer and the bottom of the reactor tank were severely abraded in a relatively short period of time, which was caused by iron filings. In the next phase of testing at the end of 1963, mixing and aeration with a mechanical stirrer was replaced by an air-lift pump. The results of this phase of the research will be processed and opponents' opinion will be given in the first quarter of 1964. In the event of a favourable result, guidelines and documents will be written for the design and operational application of the given method of wastewater treatment in dyeing rooms.

From the TGM WRI archives

VTEI Editorial office

Content

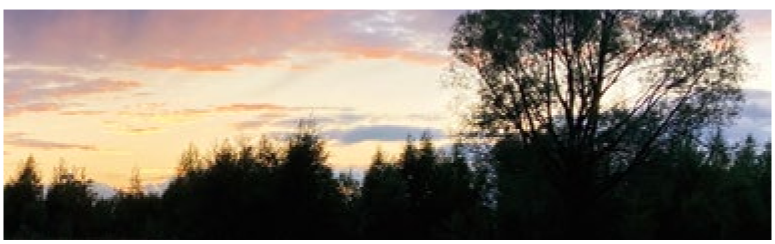


Photo: 123RF.com

Dear readers,

it seems like only yesterday that we wished you a wonderful Christmas – and today you are holding the August issue of our journal in your hands. Although this year is flying by, there have been several important events in our editorial office in the past few months.

As many of you may know, the VTEI journal has been published continuously since 1959. All printed issues have been digitized and are available for you on the VTEI website under the "Archives" tab. Also, after many months, we have managed to prepare everything necessary to register VTEI in the Scopus citation database, which will hopefully increase our journal's reputation. While waiting for the verdict on whether VTEI meets the conditions for admission to Scopus, we are also preparing the requirements for submitting an application to the Web of Science (WoS) citation database and the Directory of Open Access Journals (DOAJ).

And now back to the August issue – the first article is by David Honek and his colleagues from TGM WRI, in which the changes of the basic parameters of the surface waters of the Ústecká syncline in the Svitava basin is presented; an emphasis is placed on the changes not only of the amount of water in the Svitava, but also on its basic physical and chemical parameters with regard to the quality and future supply of drinking water. The paper compares historical datasets with the results of current monitoring.

The article of Luděk Bureš (CZU) and his collaborators also deals with surface waters. It is focused on one of the methods of estimating the parameters of catchment runoff conditions called Top-Kriging, which is successfully used in Austria or France. The extent to which this method is applicable in the conditions of the Czech Republic is described in the article "Interpolation of selected discharge rates in ungauged fourth-order catchments in the Otava basin".

Since its introduction in 2002, Water Footprint has become a popular tool for assessing water use by human society. A grey water footprint represents the hypothetical amount of water needed to dilute the pollution in the aquatic environment to an acceptable "no effect" limit. A study by Libor Ansorge and Lada Stejskalová (both TGM WRI) on the comparison of grey water footprint caused by "normal" pollution examines the occurrence of micropollutants in wastewater compared to commonly monitored substances, such as nutrients and organic pollution. The study analysed 24-hour samples taken from Indonesia's largest wastewater treatment plant, which uses a stabilization tank system. The paper also emphasizes the importance of monitoring micropollutants in wastewater as well as further ecotoxicity research.

The last expert article of the August issue provides a summary of the main points of the draft revision (revised wording) of Council Directive No. 91/271/EEC – the Urban Waste Water Treatment Directive; it sets out the rules for the removal, treatment, and discharge of urban wastewater with the aim of protecting the environment and human health. In the article, the author Daniela Mertová (MoE) provides information on both the tightening of existing requirements and the introduction of a considerable number of new obligations, which will need to be achieved within ambitious deadlines.

The informative article by Radovan Tyl and Petr Šercl from CHMI presents the update of watersheds for first to fourth order catchment areas, which took place in CHMI in 2018–2023. The basis of this update was not only the digital relief model of the fifth generation and the digital topographical model ZABAGED©, but also, for example, documents about the sewage network in Prague, current distribution networks of neighbouring countries, or the results of the "*Harmonization of main watercourses*" project.

The second informative article by colleague Kateřina Sovová from TGM WRI in Brno discusses the work trip of Czech female researchers to Canada. The visit included a program in Montreal and Winnipeg, specifically at McGill University and University of Manitoba, and its main goal was to develop cooperation with Canada in the field of water quality, wastewater monitoring and toxicity research.

In our August issue, we managed to interview Marek Výborný, the current Minister of Agriculture. In addition to looking at his professional beginnings and today's work as a minister, the interview also focuses on the activities of the Ministry of Agriculture in the field of combating drought, subsidy titles supporting measures to reduce the content of harmful substances in drinking water, and the amendment of the Urban Waste Water Treatment Directive.

Dear readers, our editors wish you not only pleasant and inspiring moments while reading this issue, but also a relaxing holiday period that is still ahead of you.

VTEI Editorial Office

Development in and status of surface waters in an important drinking water source area

DAVID HONEK, MILENA FOREJTNÍKOVÁ, ZDENĚK SEDLÁČEK, JITKA NOVOTNÁ

Keywords: surface water — contaminant — the Svitava river — the Ústecká syncline

ABSTRACT

The paper discusses changes in of the basic parameters of surface water within the important drinking water source area of hydrogeological unit 232 Ústecká syncline, in the Svitava river basin. Emphasis is placed on the changes in the amount of water in the Svitava river and the changes in the basic physical and chemical parameters of these waters. The possible effect on local groundwater, which is intensively used for drinking purposes, is discussed. The contribution compares historical data sets with the results of current monitoring within the project No. SS06010044 (PPŽ VI, TA CR). The current qualitative state of surface water points to caution in promoting direct infiltration into groundwater due to the risk of contamination.

INTRODUCTION

Monitoring surface water status is a long-term task that is often influenced by the contemporary mindset of society and its interests. Changes in the environment and the effects of human activity manifest themselves very well and often very quickly in surface waters, streams or reservoirs, which can be quickly documented, measured and analysed. At present times of significant environmental changes, there is often a discussion about the quantity and quality of water, where the interests and opinions of many groups collide and it is often problematic to reach a consensus. However, it is necessary to constantly monitor water status and strive for the best possible status in general, regardless of the specific use.

A much-discussed topic is "water retention in the landscape" [1]. Many professional workplaces and research projects have been dealing with this topic for many years, and the topic is part of national and international strategies to combat the negative impacts of climate change [2, 3]. There are many approaches and recommendations to help with water retention in the landscape, such as the *Catalogue of semi-natural measures for water retention in the landscape* [4]. However, in general we can say that the more stable and healthy the landscape is, the more water the landscape can retain on its own. From this point of view, agricultural and forest land and their management are increasingly monitored. The condition of these soils is unsatisfactory in many parts of the Czech landscape [5] and action is needed. In the case of surface water quality, it is important to address the intensive use of fertilizers (both artificial and natural), cultivated crops, and large livestock farms. An interesting issue is the amount and extent of meliorated land within the agricultural area in the Czech Republic [6], which is relatively little discussed, but which is important from the point of view of water quantity. It is logical that if we have extensive areas that are meliorated, a large amount of water drains away from the area at an accelerated rate, and there is also an accelerated movement of contaminants, which then spread in watercourses and are deposited in reservoirs. Not to mention the fact that in such a case, the application of measures to retain water in the landscape is almost not worth the effort.

From the point of view of long-term water status monitoring, the least complex is water amount measurement, or water level, which can then be converted to water volume, both in watercourses and in reservoirs. There are many monitoring points and they are mainly managed by CHMI [7], Povodí state enterprises, and other entities. The situation regarding the monitoring of water quality parameters is a bit more complicated; it is mainly due to the complexity of the measurements and the necessity of taking water samples, which must then be processed in a laboratory, and which greatly limits the possibilities of continuous measurement (such as is the case of water level). However, information on water quality is crucial if we want to evaluate the impact of human activity on industry, agriculture, waste management, transport, etc.

The selected research area of hydrogeological unit 4232 Ústecká syncline in the Svitava river basin is an example of a natural system that is an important source of high-quality groundwater for human consumption and, at the same time, the impact of human activity on these clearly definable resources can be assessed here: intensive agriculture, industrial activity (especially in the last century), the influence of settlements and transport. From a hydrogeological and hydrological point of view, the area is made up of a closed system, where all rainwater drains away through a main surface watercourse – the Svitava [8, 9]. From the point of view of hydrological balance, the runoff conditions here are strongly influenced by groundwater pumping, namely in the vicinity of the town of Svitava and especially in the Březová nad Svitavou water resource, from where the water is diverted by long-distance water supply to the city of Brno [10]. The high rate of groundwater pumping, together with the accelerated runoff from the area due to land reclamation and the influence of increasing weather extremes (heavy rains vs draught), cause a large decrease and fluctuation of water in the monitored area. This is most evident in the growing season, when there is the greatest pressure on water resources; for example, the river Svitava itself loses its water level even before it flows into the town of Svitava. Nowadays, there they often speak (in a sarcastic manner) about the "new spring of the Svitava at the Hradec nad Svitavou WWTP". During this period, the water quality in watercourses also drops significantly.

In addition to a change in management or a reduction in water consumption, other options are being sought to reverse this situation. In recent years, the possibility of restoring watercourses (which are largely in artificial stone-concrete channels) has been discussed in connection with this area. The most significant changes were made in the 1970s during the construction of the second Březová water supply system; a 6km stretch of the Svitava river was reinforced between the towns of Hradec nad Svitavou, Březová nad

Svitavou, and Banínský stream. These measures were taken due to the danger of water contamination at the Březová nad Svitavou headwater with highly polluted waters from intensive industrial production and municipal waters [11].

The recent dry period (2015–2018) also focussed attention on surface water and groundwater relations in the groundwater source area. Efforts to increase groundwater supplies by means of simplified and supported direct infiltration are hindered by insufficient knowledge about the local quality of these waters and related concerns about introducing unwanted contaminants into underground collectors used or protected for human consumption. In the long term, an increase in nitrates and pesticides in groundwater [12–14] has been monitored; its origin is assumed to be mainly from agricultural activity. Pesticides are also gradually appearing in the water supply network [15], which is very problematic.

In the area of interest, the groundwater status is relatively well monitored (both in terms of quality and quantity) for at least a hundred years in connection with the use of water in the Březová spring [10]. Surface waters are monitored rather sporadically, or systematically with a purpose to monitor the impact of the use of the headwater on the Svitava downstream. The observance of minimum flows is emphasized in the Svitava river below the headwater and further downstream during the flow through the industrial towns of Blansko, Adamov, and Brno in particular. The proposed monitoring (or rather screening) of surface water quality in the area of interest is intended to alleviate this lack of knowledge.

METHODOLOGY AND AREA DESCRIPTION

For the needs of the project and the fulfilment of its goals, eleven locations were selected for surface water sampling from the Svitava and its main tributaries (*Fig. 1*). The Svitava is the main stream of the hydrogeological unit 4232 Ústecká syncline in the Svitava river basin research area (hereinafter referred to as the HG unit). The HG unit mainly covers the Pardubice region and partially extends into the South Moravian region (the southern edge of the HG unit). The area ranges between 400 (southern part) and 650 metres above sea level (eastern and western edges). The total size of the HG unit is 358 km^2. It is oriented in a north-south direction and is an example of the eastern edge of the continuous occurrence of Cretaceous sediments in the Czech Republic. The HG unit composition is determined by the alternation of permeable hydrogeological aquifers (sandstones) and impermeable hydrogeological insulators (claystones) [8, 9], thanks to which important groundwater sources are formed in the area, used mainly for drinking purposes [10, 16, 17].

From the point of view of land use, the hydrogeological unit is mainly made up of agricultural land (about 40 %), which are found on flat land around watercourses in the upper to middle part. Forests (about 35 %) are also significant, mostly found on hills on the edge of the area and in the southern part, where the Svitava and its tributaries are deeply incised in the surrounding terrain. Permanent grasslands (about 13 %) and built-up areas (about 11 %) occupy a similar amount, while the built-up areas are clearly linked to watercourses (with the exception of the town of Svitava, the municipalities are very long and often interconnected). There are very few water bodies (about 0.3 %), located in the northern part of the area. More detailed information about use of the area and its development over the last 200 years can be found in [17].

There are also relatively large areas of drained agricultural land (*Fig. 1*). The main part is in northwest of the research area, between the towns of Opatov, Svitavy, and Hradec nad Svitavou. Some land reclamations are over 100 years old, but the majority were created in the second half of the 20th century [6]. According to a field survey, the reclamation facilities are still functional in many places.

The Svitava forms the mail stream of the area and, in the northern part of the HG unit, has extensive headwater, which is heavily waterlogged throughout the year. With the exception of the Lačnovský stream (confluence in Svitavy) and Chrastovský stream (confluence in Moravská Chrastová), all significant tributaries of the Svitava are right-hand. These include the Vendolský stream (confluence in Hradec nad Svitavou), Radiměřský stream (confluence at the end of Radiměř village), Banínský stream (confluence above the Březová nad Svitavou water resource) and Bělský stream (confluence in Brněnec village). At the confluence with the Svitava, ten collection points were established (*Tab. 1*) where surface water sampling has been taking place in monthly increments since June 2023. These sites are complemented by a collection point on the Svitava pond, above the town of Svitavy, which collects water from the entire headwater of the Svitava river.

Tab. 1. Description of surface water collection points

Collection point				
ID	**Name**	**Watercourse**	**Location**	**Coordinates**
RYB	Svitavský pond	Svitava	Svitavy, above the dam, right bank	49°45'53.964"N, 16°27'53.054"E
SV1	Hradec nad Svitavou	Svitava	Hradec n/S, after the bridge, CHMI gauging point	49°43'27.874"N, 16°28'56.571"E
VEP	Hradec nad Svitavou	Vendolský stream	Hradec n/S, after the bridge, under WWTP	49°43'24.485"N, 16°28'52.487"E
RAP	Radiměř	Radiměřský stream	Radiměř, before the bridge, above the mouth	49°41'1.782"N, 16°28'28.878"E
SV2	Radiměř	Svitava	Radiměř, after the bridge	49°41'7.631"N, 16°28'30.616"E
BAP	Banín	Banínský stream	after the bridge, above the mouth	49°40'22.168"N, 16°28'32.547"E
SV3	Banín	Svitava	before the bridge	49°40'23.969"N, 16°28'34.594"E
SV4	Dlouhá	Svitava	Dlouhá, after first-grade OPVZ	49°39'25.770"N, 16°30'27.434"E
BEP	Brněnec	Bělský stream	Brněnec, above the mouth	49°37'31.586"N, 16°31'26.142"E
SV5	Brněnec	Svitava	Brněnec, above the confluence	49°37'33.674"N, 16°31'28.266"E
SV6	Rozhraní	Svitava	Rozhraní, before the bridge, CHMI gauging point	49°36'1.499"N, 16°31'53.391"E

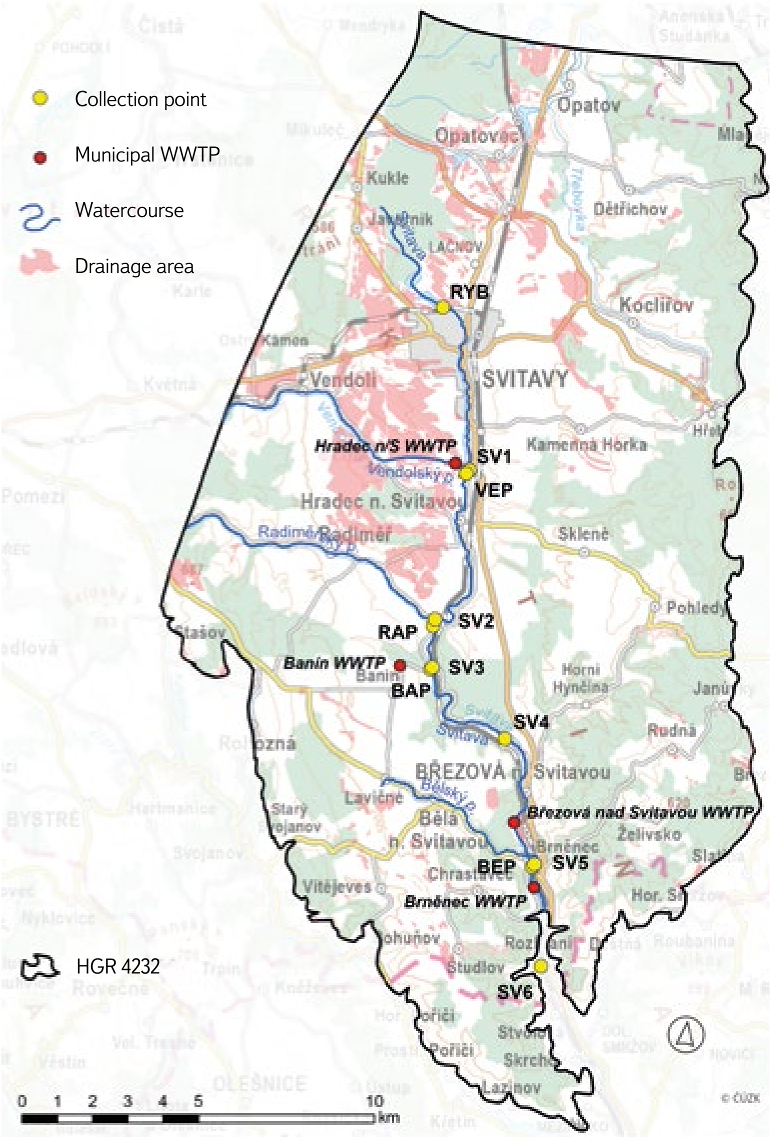

Fig. 1. Location of collection points within hydrogeological unit 4232 Ústecká syncline in the Svitava river basin (further information in *Tab. 1*)

The selection of locations took place in the field after consultations and with the participation of researchers working on the project. Subsequent sampling was carried out by a sampler with appropriate accreditation. Basic chemical analyses and microbiological analyses were carried out at the TGM WRI laboratory in Brno, and the results of the individual tests are part of the laboratory's standard work. In the following part of the text, we process and present only those indicators that are relevant to the project's goals.

RESULTS AND DISCUSSION

Change in runoff conditions and impact on water resources

In the following graphs in *Fig. 2*, the annual trends of average monthly flows are drawn for comparison, always with an interval of ten years. The grey background area represents the long-term monthly average for 1981–2023. In both profiles, the Svitava is characterized by an increased flow in the spring months, especially in March. This can be related to snowmelt, spring rains, and agricultural land without vegetation which enables greater surface runoff. This spring "peak" is also shown by almost all other curves in the graph for the years under review, but sometimes with a shift to the following spring months. The second, albeit lower peak in the long-term average is no longer visible in the following monitored years; the effect of long-term intensive precipitation often occurs at the beginning of July (e.g. 1997 in Moravia). In July, there is the most significant change compared to the long-term average. The other seasons (the end of summer and autumn) have always been the period of lowest flows, and the monitored years are almost all below this long-term average.

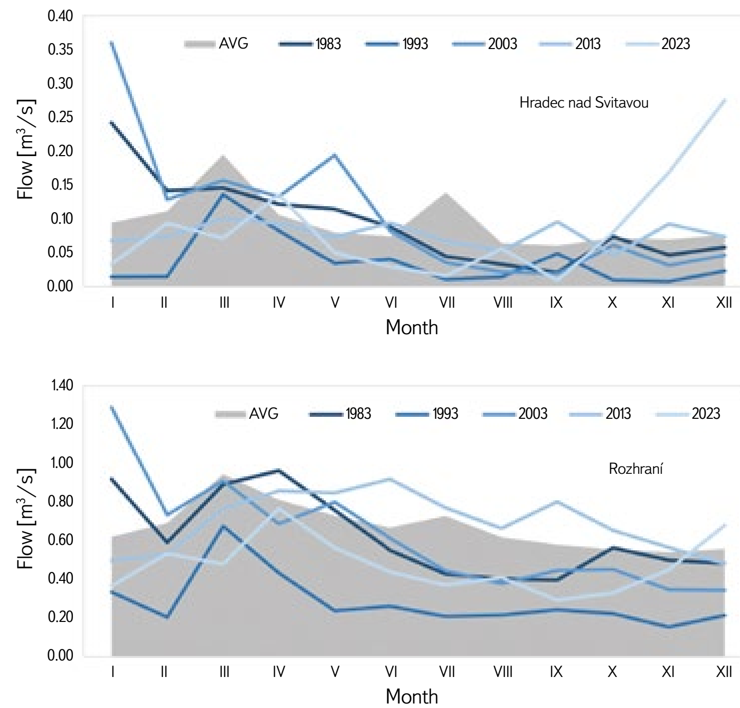

Fig. 2. Average monthly flow [m^3/s] of the Svitava river at the Hradec nad Svitavou station and the Rozhraní station (stations operated by CHMI), 1981–2023

In recent years, a big drop in the level of the Svitava and its tributaries can often be seen, which of course is most evident in dry periods. Evidence of a decrease in the water level of the upper reaches of the river are the changes of the flow at the Rozhraní water gauging station (*Fig. 3*), where data from 1931 are available. It is clear that until 1970 there was rather an increasing trend and the average annual flow during this period was 1.35 m^3/s. After 1981, there has been a big change in the flow, and in recent years it often falls below the average for this period, which is 0.69 m^3/s. This change is associated with a higher rate of groundwater pumping in the upper part of the basin, primarily for water supply purposes. The rapid decline in the 1970s is mainly associated with the construction of the second water supply system in Březová for the city of Brno. The changes in annual precipitation totals at the Stvolová station can also be seen in *Fig. 3*, where a slight decrease in recent years is visible, although this change is not significant. From this, it can be concluded that groundwater pumping has a much greater influence on the decrease in the Svitava flow.

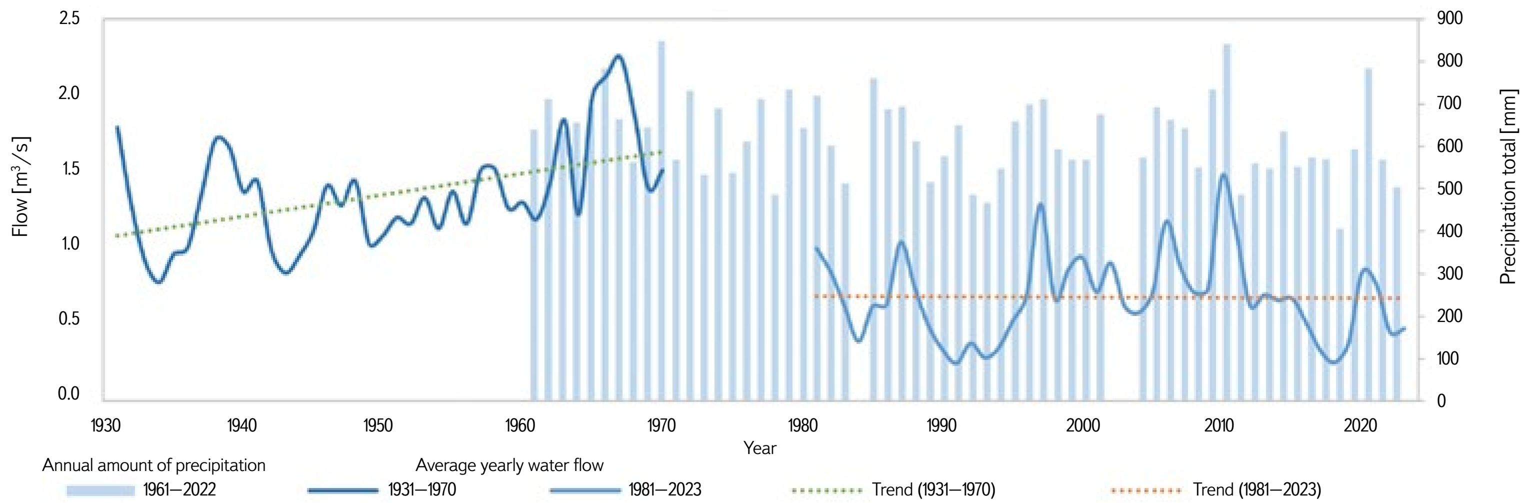

Fig. 3. Average yearly water flow [m^3/s] of the Svitava river at the Rozhraní station, and the annual amount of precipitation at the Stvolová station (stations operated by CHMI), 1931–2023

The above analysis indicates the issues that can be expected in the future. There are already groundwater limit levels [18] that must be maintained. If the actual level is close to the set limit, the use of resources will be restricted. If a dry period of several years occurs again, its effects may be more pronounced than now. As the graph in *Fig. 3* shows, the dry period of 2015–2018 was preceded by relatively rain-rich and aqueous years.

Changes in surface water quality

The development of water quantity and quality in the upper reaches of the Svitava is specific. Historically, the town of Svitavy had one of the first sewage networks in our country [19]. However, wastewater was discharged directly into the watercourse without treatment. Even after the wastewater treatment plant (WWTP) in Hradec nad Svitavou was put into operation, some parts of the town were connected to it very slowly [11]. No WWTP is capable of treating water economically to the level of an unaffected natural state. A certain dilution with water from the recipient is always taken into account, as well as the self-cleaning ability of the watercourse [20]. From the point of view of our topic, it should be mentioned that there are 50 settlements in the area of interest and only four WWTPs, according to the DIBAVOD database and other documents (and not all of them are in operation). This is due to the local situation; municipalities tend to be connected to a combined sewerage network, for example the Svitava sewerage network leading to the WWTP in Hradec nad Svitavou. This also corresponds to the data on "Discharges into surface waters" from the ISVS – VODA database (www.voda.gov.cz), where only five discharge sites are registered within the research area, while four are from local municipal WWTPs (*Fig. 1*) .

The following summary in *Tab. 2* shows average values from the data detected by monitoring for selected parameters. These average values of indicators provide a clear picture of the area of interest in terms of surface water quality. There are ten measured values (samplings), in the case of SV1 only six, and at SV2 nine samplings; in some cases, the flow of the Svitava itself was completely zero and it was not possible to take a sample.

From the point of view of microbiological indicators, the worst-rated place is VEP, the recipient of treated wastewater from the town of Svitavy. In the following places on the Svitava, it is noticeable that the values gradually decrease. None of the tributaries reach such high values. It can therefore be concluded that the Svitava (Hradec) WWTP affects the Svitava river in this direction along the entire monitored length. Only the last monitored profile SV6 deviates from this trend; there is a deterioration compared to the previous location (SV5). This can probably be attributed to municipal pollution from Brněnec, Moravská Chrastavá, and other parts of the municipalities, where the built-up areas approach the river and the disposal of wastewater has not yet been satisfactorily solved.

Similarly, it is possible to evaluate other indicators from the first part of *Tab. 2*; at BAP, the influence of water from the treatment plant on the Banínský stream (WWTP of Banín municipality) is more pronounced. This fact is also significant because Banínský stream directly connects to the Březová catchment area in its final section, and in recent years there have been efforts to restore the watercourse [21]. Somewhat surprising are the high NO_3 values at VEP and BAP. Nitrate loading is mostly attributed to agricultural pollution [11–14]. In the monitored case, however, it is also associated with increased values of ammonium ions and may thus indicate that the efficiency of nitrogen degradation at both WWTPs is not high. Other tributaries of the Svitava indicate a rather widespread and diffuse water load. However, these pollutants would manifest themselves more significantly in the water during sudden increased flows in the event of torrential rain, which could not be detected within the described monitoring.

RYB stands out from the entire set of collection points in many indicators. Since it is a sampling of pond water, other biological processes affect its quality. From the indicators in *Tab. 2*, it is possible to prove it, for example, by low concentrations of nitrates, even though intensively used arable land predominates in the catchment area above the pond. Reduction of nitrogen concentrations in stagnant water is caused by chemical oxidation-reduction processes and the use of nitrogen by green organisms. Phosphorus concentration, which enters the water mainly through runoff from fields, is the lowest in the pond among the monitored locations. Nevertheless, it is high enough to allow the massive development of cyanobacteria if other conditions are met. Monitoring and studying these natural events is interesting in itself. However, the site was included in the monitoring in order to obtain background natural values of water quality when entering the monitored system. However, due to almost zero outflow from the pond for most of the monitoring period, this was not achieved.

Some indicators from the second part of the table are favourable in the entire basin. These are, for example, cadmium and mercury, which were below the detection limit or randomly just above it in all samplings. Other heavy metals such as chromium, nickel, and lead are below the limits established for these substances in all samples [22].

Tab. 2. Average values of chosen parameters of surface water

Collection point	Fecal coliform bacteria	*Escherichia coli*	Enterococci	pH	Electric conductivity	BSK5	CHSK-Mn	Cl	SO_4	Ammonium ions	NO_3	NO_2	o-PO_4 total	NL 105	RL105
ID	[KTJ/100 ml]	[KTJ/100 ml]	[KTJ/100 ml]	-	[mS/m]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]
RYB	3,280.00	26.44	90.60	7.58	41.41	4.92	7.74	26.35	34.36	0.36	3.70	0.05	0.24	27.41	282.40
SV1	184,000.00	11,528.00	8,950.00	7.53	62.62	3.04	5.59	69.78	48.93	0.68	16.68	0.26	0.35	38.80	396.33
VEP	328,300.00	69,855.56	20,661.00	7.37	78.16	2.92	6.60	77.10	80.43	1.20	50.07	0.24	2.67	35.73	529.00
RAP	5,900.00	930.00	2,001.00	7.67	40.09	2.36	3.48	8.76	34.27	0.09	19.54	0.07	0.31	29.91	278.10
SV2	87,000.00	21,592.00	7,131.11	7.65	69.90	2.17	5.81	71.92	72.46	0.80	25.16	0.51	1.36	17.39	454.56
BAP	1,800.00	2,578.00	10,791.00	7.79	69.82	3.71	4.02	25.62	66.63	0.65	47.82	0.88	1.88	16.46	507.40
SV3	84,000.00	10,240.00	5,224.00	8.13	60.82	1.72	4.29	52.27	58.52	0.60	25.03	0.28	0.98	16.64	407.50
SV4	32,800.00	1,759.89	2,150.00	7.57	61.49	1.50	2.76	36.98	51.41	0.13	34.66	0.14	0.52	14.66	436.90
BEP	1,600.00	809.00	698.40	7.61	52.05	1.40	2.40	27.36	44.25	0.04	39.59	0.10	0.31	25.10	396.60
SV5	30,400.00	1,325.56	1,728.00	7.56	57.84	0.90	1.82	30.51	47.42	0.15	30.40	0.09	0.35	11.05	407.70
SV6	63,000.00	2,044.44	3,080.00	7.61	56.28	0.79	2.64	31.65	48.94	0.25	31.00	0.09	0.44	16.06	406.50

Collection point	Na	K	Ca	Mg	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
ID	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]
RYB	12.51	4.22	64.28	4.00	156.02	3.72	< 0.1	< 1	8.35	684.90	< 0.05	67.90	2.41	1.81	5.30
SV1	39.20	2.88	77.15	3.38	275.95	1.70	0.10	1.14	4.32	711.17	< 0.05	56.00	2.63	2.14	16.67
VEP	55.27	14.26	83.57	5.93	229.66	1.64	< 0.1	1.19	4.33	560.00	0.06	60.40	2.81	1.49	25.00
RAP	2.14	2.31	75.56	1.59	196.20	1.25	< 0.1	1.21	2.67	182.20	< 0.05	27.90	2.03	1.61	7.30
SV2	46.57	10.74	78.63	4.86	169.33	1.55	< 0.1	1.10	3.30	317.33	< 0.05	43.89	2.31	1.43	12.89
BAP	12.91	7.31	128.18	2.48	160.01	1.51	< 0.1	1.08	4.01	99.71	< 0.05	24.80	2.14	1.17	11.20
SV3	29.61	7.14	80.67	3.74	117.38	1.40	< 0.1	1.08	4.99	217.70	< 0.05	29.20	2.20	1.29	11.00
SV4	18.11	4.27	97.55	3.35	95.24	1.44	< 0.1	1.09	2.61	191.48	< 0.05	27.80	2.10	1.32	9.30
BEP	6.78	2.32	91.64	2.49	142.61	1.19	< 0.1	< 1	2.28	121.40	< 0.05	27.30	2.54	1.29	7.00
SV5	11.96	3.22	94.69	3.52	76.12	1.24	< 0.1	1.07	2.49	142.50	< 0.05	25.40	2.07	1.24	8.70
SV6	12.09	3.24	95.18	3.52	90.02	1.22	0.10	1.18	2.97	259.38	< 0.05	30.00	2.33	1.59	12.80

For some important indicators, the monitoring data were processed in more detail. *Figs. 4–9* show the results of the basic statistical analysis of selected parameters of surface water at individual sampling sites; the thin lines show the dispersion of values (MIN and MAX), the lower limit of the box shows the value of the first quartile, the upper limit of the box shows the value of the third quartile, and the interface between the light blue and the dark blue box shows the median value. All samplings were carried out during average or rather lower flows; the situation after torrential rainfall or during a longer period of increased status was not recorded. The variability of pollutant concentrations described below is thus most probably caused by the seasonality of agricultural work, or by fluctuations in the efficiency of treating processes at the WWTP.

Fig. 4 shows the statistical evaluation of detected values of electrical conductivity. The first RYB site represents a natural background in the basin above the town of Svitavy, unaffected by point pollution. This site also has the lowest concentration fluctuations. The conductivity of the Radiměřský stream, which also represents a separate small basin, unloaded by external influences, has a similar character. The collection point SV1, on the other hand, shows the highest MAX value and, at the same time, the largest deviation of this value from the median. This is a site below the town of Svitavy, where the smallest number of samples could be taken due to insufficient flow. The measured values rather document the sudden flow of wastewater or the displacement of contaminated sediments.

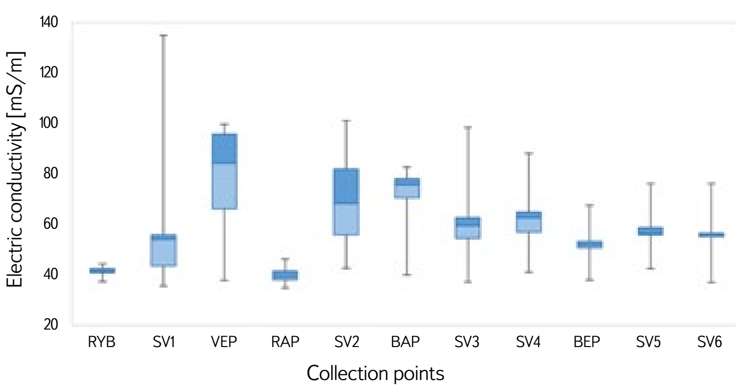

Fig. 4. Variance of values of electric conductivity [mS/m], June 2023 to March 2024

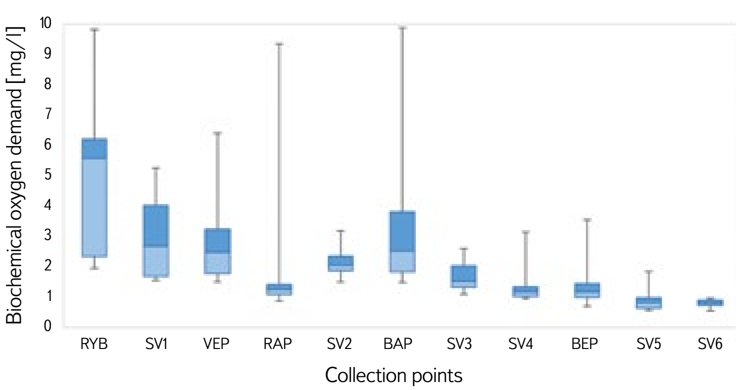

Fig. 5. Variance of concentration values of biochemical oxygen demand [mg/l], June 2023 to March 2024

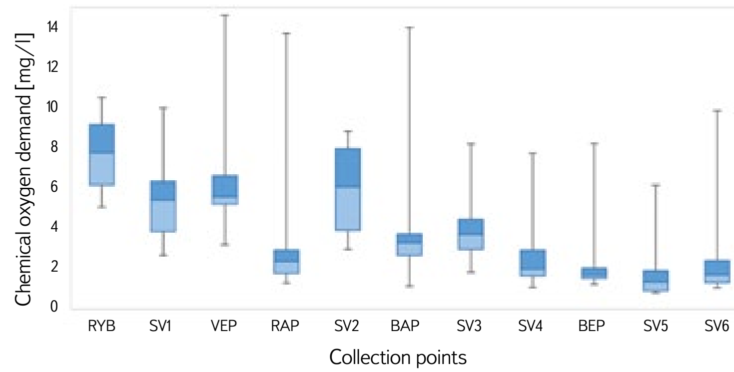

Fig. 6. Variance of concentration values of chemical oxygen demand [mg/l], June 2023 to March 2024

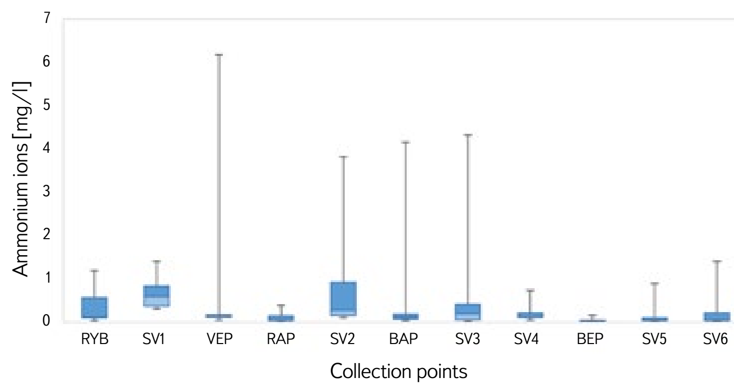

Fig. 7. Variance of concentration values of ammonium ions [mg/l], June 2023 to March 2024

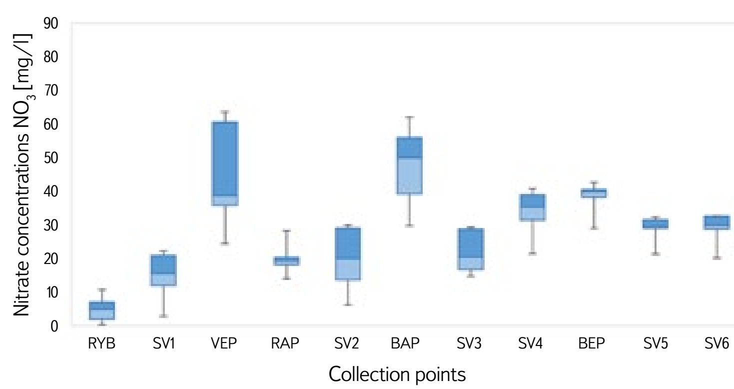

Fig. 8. Variance of concentration values of nitrates (NO_3) [mg/l], June 2023 to March 2024

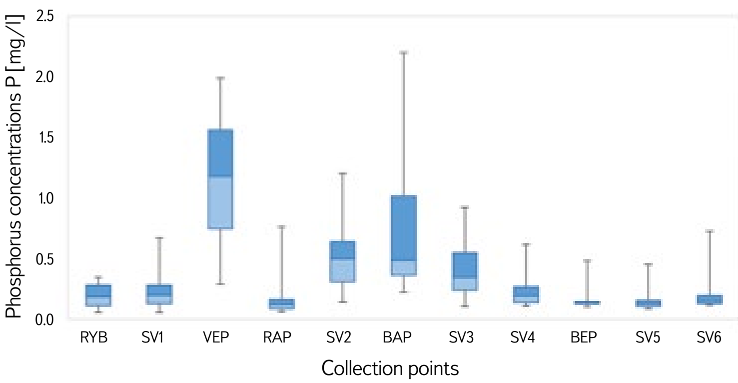

Fig. 9. Variance of concentration values of phosphorus (P) [mg/l], June 2023 to March 2024

The variance of phosphorus concentration values in the monitored streams clearly shows the influence of municipal pollution when wastewater passes through the treatment plant (see *Fig. 9*, VEP and BAP). The loaded stream waters affect the flow of the Svitava itself, where the phosphorus concentration gradually decreases downstream (SV2, SV3, SV4 and SV5). The decrease is caused by gradual dilution by unloaded water, and by the transition of phosphorus into river sediments. Phosphorus itself is not an immediate danger to the watercourse, but it again shows the greatest fluctuations and the highest peak values in the streams in places below the WWTP. This may indicate lapses in treatment efficiency in these devices and may also relate to other more serious quality indicators.

CONCLUSION

Groundwater in the Svitava part of the Ústecká syncline is one of the largest reservoirs of usable water in the Czech Republic. A comparison of historical and current data on flows in the Svitava shows a clear connection between the watercourse status and the amount of groundwater abstracted. If pressure on the amount of water abstracted for drinking purposes increases, stricter limits for the sustainability of this resource must be expected in the future.

Groundwater quality is directly related to surface activities and surface water quality. This must also be considered when designing restoration and other measures to retain water in the landscape. Although there is a certain time delay in the manifestations of the effect on groundwater, constant attention must be paid to the quality of surface and drainage waters. So far, relatively little data is available on surface water quality in the research area, especially in the case of extreme weather conditions. In the future, it would be advisable to carry out more detailed time monitoring to capture such events.

Comprehensive monitoring of surface water quality showed considerable seasonal variability. Although the measured values are not a sign of emergency state, it is recommended to continue similar monitoring, including in other places and with the extension to drainage waters of meliorated areas of agricultural land. Although the results of surface water monitoring show a significant improvement in quality compared to the conditions at the time of the construction of the second Březová water supply system, it is highly desirable to leave and repair the impervious treatment of the bed of the Svratka and Banínský streams in direct connection with the Březová headwater. This is not only protection against significant accidental pollution from industry or transport; it is becoming obvious that even minor shortfalls in the efficiency of some of the WWTPs will have a significant effect on the quality of water in the Svitava over a long stretch.

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Interpolation of selected discharge rates in ungauged fourth-order catchments in the Otava basin

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Keywords: discharge — fourth-order catchment — interpolation — Top-Kriging

ABSTRACT

Knowledge of catchment runoff values is the key to a wide range of engineering and scientific applications. However, direct measurements in the scope of all fourth-order catchments in the Czech Republic are not realistic. Standard methods for estimating these parameters are local regression models, rainfall-runoff models, or other interpolation techniques. Regression models provide reliable results, but the derivation of local regression equations is demanding on the amount of input and reference data. Rainfall-runoff models have their application in design activities at a local scale. Their application in the Czech Republic is not trivial and requires knowledge of precipitation distribution. Interpolation techniques provide a fast but often less reliable approach. Most of these interpolations are not primarily intended for hydrological applications; the exception is the Top-Kriging method. It is based on kriging methods used in geostatistics, which it extends in many directions in order to affect hydrological regularities, especially the concentration of runoff in the river network. This method has been successfully used in Austria or France to estimate discharge rates in ungauged branches of the river network. However, is this method also suitable for use within the Czech Republic? Our results show that the heterogeneity of the catchments, especially in the mountainous and foothill areas of Šumava, significantly reduces the Top-Kriging performance. Additional transformation of the results can improve its performance in the case of some discharge rates. However, compared to direct calculations, Top-Kriging lags behind.

INTRODUCTION

Knowledge of hydrological parameters, such as the long-term average outflows actual river discharge, is a key factor for flood risk management, landscape planning, and a number of scientific or engineering applications. Sufficient amount of surface water is a topic currently being addressed in connection with the changing climate, and its availability is essential for adapting to new environmental conditions.

The basic hydrological unit for which hydrological data is required is the fourth-order catchment. There are over 8,500 such catchments in the Czech Republic. For the vast majority of them, data on their water content is not available. The unavailability of these data is largely linked to the issue of data collection, especially to the limited number of limnigraphic stations. The largest hydrological monitoring network in the Czech Republic is operated by the Czech Hydrometeorological Institute (CHMI), which currently has around 550 stations. The increase in the number of stations is primarily limited by the financial complexity of their establishment and operation.

Another possibility to obtain the required hydrological data is various types of hydrological estimates, predictions, and analogies. Estimation of variables related to catchment runoff is usually based on regression methods between the variable and selected catchment characteristics. When estimating within large or highly heterogeneous catchments, it is usually divided into several areas. Regression parameters are determined for individual areas separately [1]. Another approach is estimation using rainfall-runoff models, which are usually demanding on the amount of input data, compilation time, and calculation time. However, they are used with success on a local scale and in design activities [2]. The last possibility is the use of spatial interpolations. It is a quick and relatively simple approach. However, the disadvantage is the lower quality of the estimate, often resulting from disregarding the hydrological topology in the relations between catchments and sub-catchments. Interpolation is controlled primarily by the Euclidean distance between the interpolated location and the location where the given variable is known [3, 4]. In the international field, the PUB (Prediction in Ungauged Basins) initiative deals with hydrological prediction in ungauged catchments, for example. The aim of the activities is to create a better scientific basis in the field of hydrological modelling, to reduce uncertainties in prediction, and to search for new approaches [5]. The most important institution that deals with hydrological predictions in the Czech Republic is the CHMI. It normally uses the method of regional regression models for its predictions of water distribution in a catchment [6].

A method falling between spatial interpolations and a conceptual model is the Top-Kriging (TOP) method. TOP is based on geostatistical methods originally developed for the needs of the mining industry [7]. By expanding and transforming them, a geostatistical interpolation method was created which enables the estimation of various hydrological parameters in ungauged catchments. TOP combines two main groups of processes: 1) creation of runoff within the catchment and 2) aggregation and routing of runoff within the river network. To this end, runoff generation is conceptualized as a spatially continuous process that exists at any point in the landscape. Runoff aggregation is then described as a cumulatively increasing value that increases with distance from the source. The basis of the method is the kriging interpolation method (also known as the Best Linear Unbiased Estimator), which is modified to respect the hierarchy within the hydrological network. The method uses a variogram to estimate hydrological variables. Thanks to this, it is also able to process non-stationary variables. The method considers local measurement uncertainties, which may vary in different locations, and thus is able to use even short measurement records. It also enables the estimation of uncertainty in the determination of the measured variable [8].

It is assumed that the performance of the method increases with the increasing density of the river network, the increasing size of the catchment areas, and depends on the number of gauged catchments [9]. Compared to the Ordinary Kriging method, it provides better results especially when describing nested catchments on neighbouring river branches [8]. However, it is typical for both methods that they overestimate the results in the lower sections of the watercourses (closer to the closing profile of the gauged catchments) and, simultaneously, underestimate the results in their more distant parts [10, 11]. The method achieves good results in the case of large homogeneous catchments [12]. However, the question remains how the algorithm will be able to describe the variability of runoff within smaller non-homogeneous catchments.

In addition to estimating runoff sizes, TOP has also been applied, for example, to calculate runoff curves [13], estimate water discharge velocity [14], determine the time series of runoff from a catchment [10], estimate the height of flood probability quantiles, and the suitability of a watercourse as an ecological habitat [15, 16].

The aim of this article is to evaluate the applicability of the TOP method for the estimation of runoff from fourth-order catchments in the Czech Republic.

MATERIALS AND METHODS

Pilot site

The pilot site is the Otava river basin. The Otava is formed by the confluence of the Vydra and Křemelná near Čeňkova Pila in Šumava; the basin covers an area of 3,788.0 km^2 and the length of the river is 113 km. In its upper part (above the town of Sušice, 91.7 river km) it is characterized by a steep river bed and high water content. This gives it the character of an upland watercourse. In this section, it flows mainly through wooded valleys; from Sušice towards the mouth, it mainly flows through cultural agricultural landscape. Its character changes to a meandering lowland watercourse with signs of sedimentation [17]. The upper parts of watercourses in the Otava basin show a low degree of anthropogenic transformation (e.g. in the source area of Vydra, Hamerský potok, Otava, Volyňka, and Spůlka). In contrast, the rate of anthropogenic transformation of the hydrographic network is increasing in the middle and lower sections. This increase is related to the increase in socio-economic use of valley floodplains [18]. The lower part of the river is permanently flooded; the length of this depends on the current height of the water level of Orlík hydraulic structure (HS). Under normal conditions, this is about the last 19 km (18.6 river km to Sulan weir). The highest point in the Otava basin is Luzný (1,373 m above sea level), the lowest point where the river reaches Orlík HS. The most important tributaries are the rivers Blanice, Volyňka, Lomnice, Ostružná, Křemelná, and Vydra. The location of the Otava basin within the Czech Republic is shown in *Fig. 1*.

Top-Kriging

TOP calculates a point variogram based on the measured data (discharge measured in the gauged catchments in m^3/s). It is used to describe the degree of spatial dependence on a spatial random variable (specific runoff) within the modelled territorial unit. However, this point variogram cannot be used directly to estimate runoff for individual catchments due to the different sizes of the sub-catchment areas. For this reason, different groups of theoretical

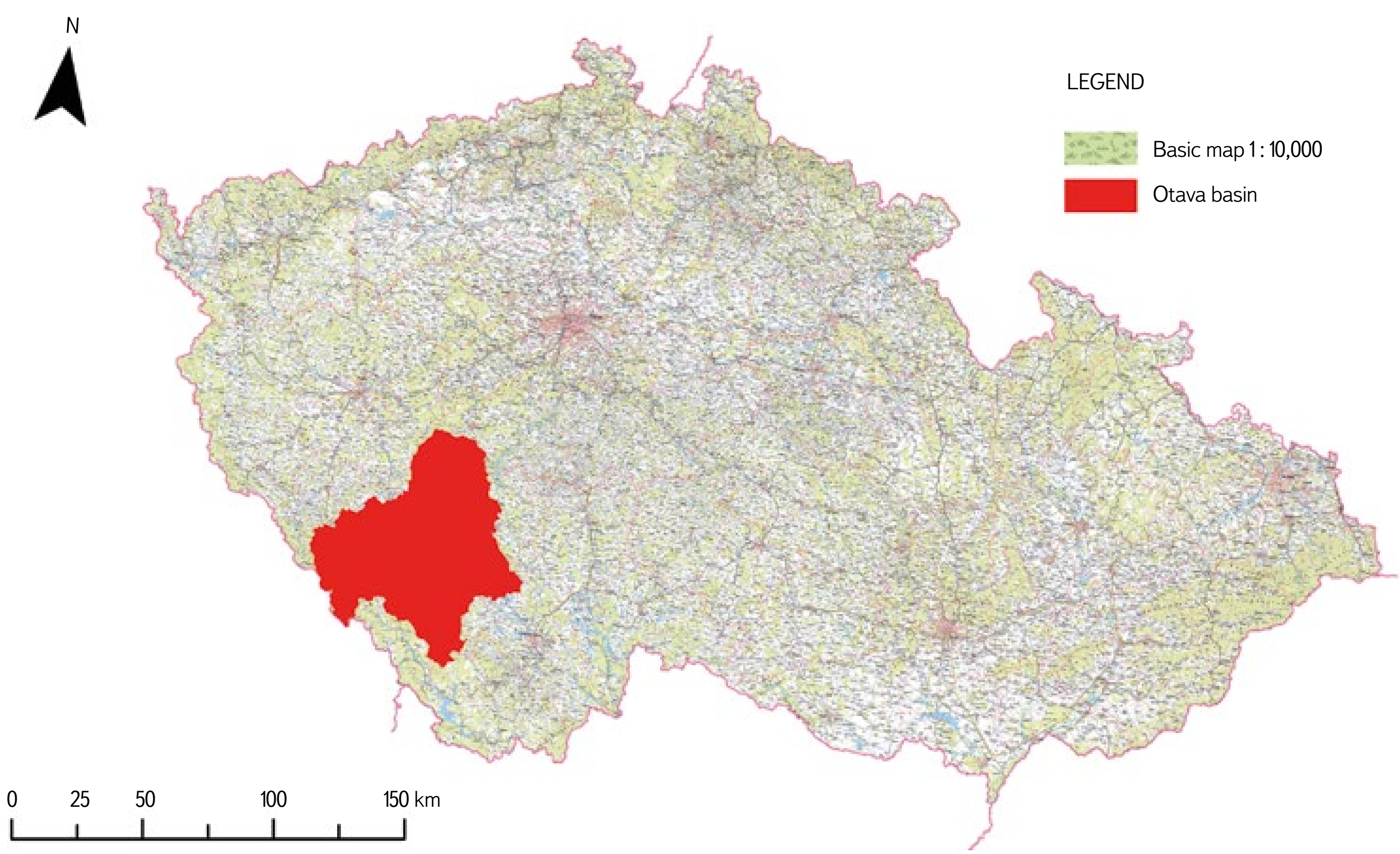

Fig. 1. Location of the Otava basin within the Czech Republic

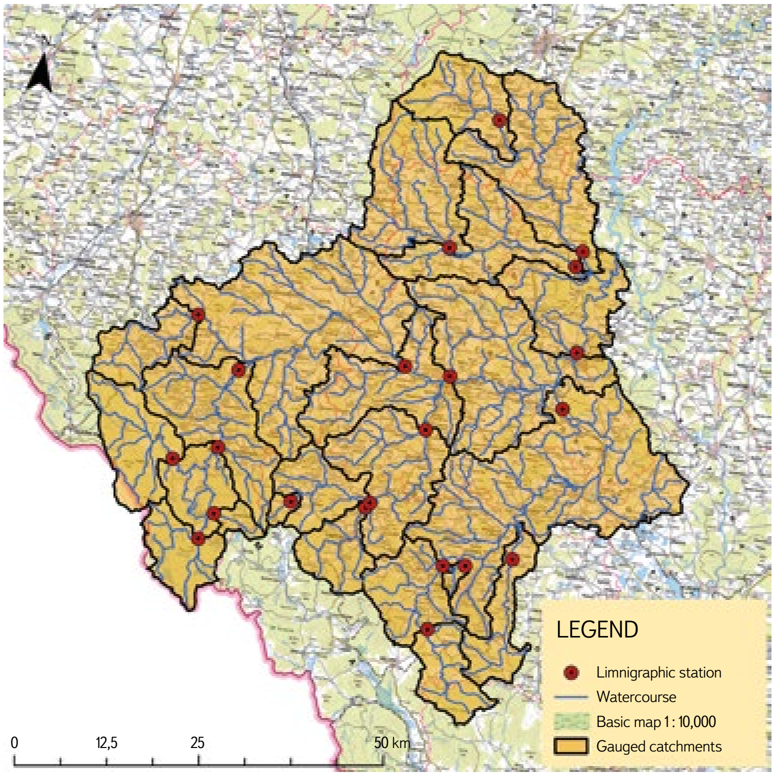

Fig. 2. Location of gauged catchments within the Otava basin

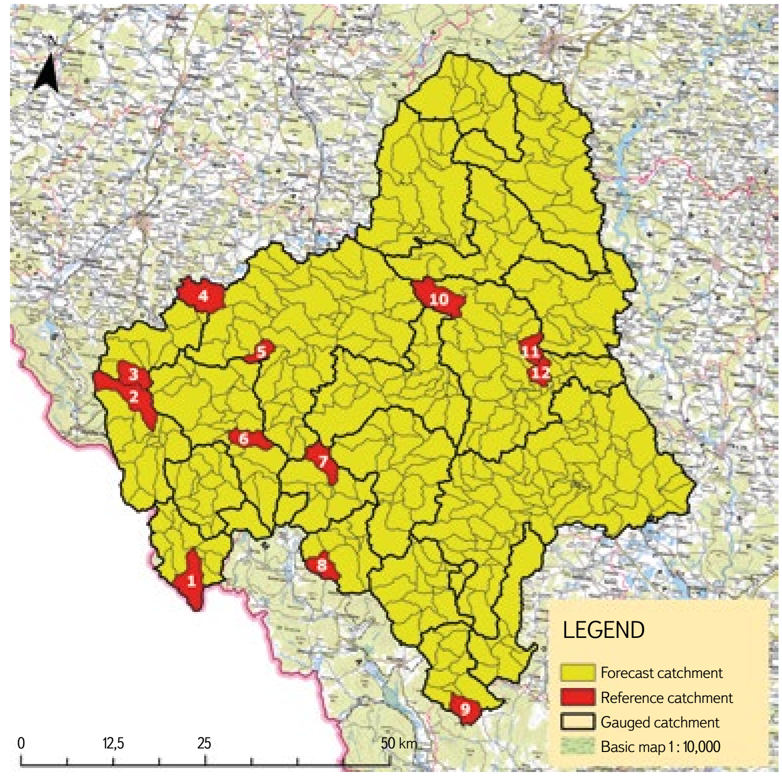

Fig. 3. Location of reference catchments within the Otava basin

variograms for individual size classes of sub-catchments are tested in TOP, for which the most suitable variogram model is then automatically selected. After the variograms for individual classes are determined, the prediction of the specific runoff for individual forecast catchments will occur [8].

The inputs for TOP are the axes of the watercourses in the study area, the delineated gauged catchments, and the delineated forecast catchments. Gauged catchments are larger territorial units (catchments) within the overall described area (Otava basin), for which selected hydrological characteristics are known. The magnitude of the given characteristic is interpolated by the TOP method into the forecast catchments that fall into the gauged catchment (they are their sub-catchments).

Watercourse axes in the Otava basin

The current axes of watercourses for the entire Otava basin were taken from the DIBAVOD system (Digital water management database) in ESRI digital vector format (*.shp). Specifically, it was layer A03 – watercourse (rough sections) [19].

Forecast catchment

This is a catchment for which the TOP method is to be used to predict selected hydrological parameters (runoff). For the needs of this article, the fourth-order catchments were chosen as the forecast catchment, which was also taken from the DIBAVOD system. In this case, it was layer A08 – hydrological division – fourth-order catchment [19].

Gauged catchments

For the TOP needs, the catchments to the existing limnigraphic stations in the Otava basin were chosen as the gauged catchments. These catchments were created by grouping fourth-order catchments according to their affiliation to the given limnigraphic station. The fourth-order catchment in which this station was located became the closing catchment for the newly grouped catchment. If there were several limnigraphic stations on a watercourse (e.g. Otava), only the catchments located between the individual limnigraphic stations were assigned to the lower stations. The reason for determining the gauged catchments based on the distribution of limnigraphic stations was the availability of hydrological data for these stations. The distribution of gauged catchments within the Otava basin is shown in *Fig. 2*.

Hydrological data for the gauged catchments

Hydrological data for limnigraphic stations are freely available thanks to the "Reporting Profile Record Sheets", which can be found, for example, through the "Flood Forecasting Service" (HPPS). The HPPS is operated by the CHMI [20]. As part of this study, data were used from the Reporting Profile Record Sheets Nos. 112–120, 121a, 122–124, 126–131, and the Record Sheets of the operative profiles of Antýgl, Strakonice, and Nový Dvůr. In total, there were 22 limnigraphic stations from which discharge Q_1, Q_{10}, and Q_{100} were taken. Discharge Q_{355d} and Q_a were then added for the same stations, which are available through the ISVS portal – Records of the amount of surface water [21].

Map of mean precipitation totals

It is published by CHMI. The map is part of a group of maps describing climate characteristics in the Czech Republic. Specifically, it shows mean annual rainfall (mm) for 1991–2020. The map is issued in the form of a raster [22].

Map of long-term mean base runoff

It is published by the Czech Geological Survey. The map is available through the Web Map Service (WMS). It expresses the mean values of the long-term mean base runoff ($l/s/km^2$) for 1991–2020 [23].

Reference runoff data

Reference data for the needs of this study were purchased from CHMI in the form of basic hydrological data (according to ČSN 75 1400) for selected fourth-order catchments. According to the classification of basic hydrological data of surface waters, all reference data fell into class III. *M*-day discharge were derived for the reference period 1981–2010 and *N*-year discharge for the maximum available observation period. In total, data were purchased for 12 fourth-order catchments. A more detailed specification of the reference catchments is given in *Tab. 1* and their distribution within the Otava basin in *Fig. 3*.

Tab. 1. Specification of reference fourth-order catchments

Designation	HLGP_ID	UTOKH_ID	Catchment size [km²]	Watercourse	Q_{355d} [m³/s]	Q_a [m³/s]	Q_1 [m³/s]	Q_{10} [m³/s]	Q_{100} [m³/s]
1	108010010	1196500	19.37	Vydra	0.251	0.861	13.00	30.00	53.70
2	108010190	1198300	23.78	Křemelná	0.098	0.521	8.80	24.00	48.40
3	108010650	1202900	11.82	Ostružná	0.040	0.204	2.90	10.00	22.80
4	108010740	1203800	21.71	Kalný stream	0.044	0.140	3.20	11.00	30.70
5	108010790	1204300	7.02	Ostružná	0.387	1.580	17.00	46.00	109.00
6	108010470	1201100	11.00	Opolenecký stream	0.022	0.106	4.40	15.00	32.60
7	108020170	1212200	12.98	Mladíkovský stream	0.006	0.117	2.90	9.70	23.20
8	108020010	1210600	10.42	Volyňka	0.044	0.146	3.00	11.00	24.80
9	108030010	1218900	11.53	Blanice	0.020	0.137	4.30	16.00	37.30
10	108020680	1217300	21.37	Rojický stream	0.019	0.107	2.00	8.00	19.30
11	108020790	1218400	9.29	Dobevský stream	0.001	0.028	1.40	5.70	14.00
12	108020800	1218500	8.23	Brložský stream	0.070	0.472	8.00	28.00	72.60

All data used in this study are in the S-JTSK / Krovak East North coordinate system (EPSG 5514) and the Baltic height system after levelling (EPSG 5705).

METHODOLOGY

Several methods were chosen for runoff prediction. The basic method was the Top-Kriging (TOP) method. Other methods were the transformation of TOP results based on data on the mean annual precipitation total (TOP_Hs) and long-term mean base runoff (TOP_ZO). The other two methods used a direct runoff calculation, which was based on the values of the mean annual precipitation total (R_Hs) and the long-term mean base runoff (R_ZO). The prediction was made for a range of discharge rates (Q_{355d}, Q_a, Q_1, Q_{10} a Q_{100}). All calculations and subsequent evaluation of the results were processed in the R software environment [24].

Top-Kriging

Specific runoff (l/s/km²) were predicted for all fourth-order catchments in the Otava basin, which were subsequently converted (through the area of the given catchment) to runoff from the catchments (m³/s). To determine the prediction in the R environment, the rtop extension [25] was used, through which the TOP method is available. The required inputs were the gauged catchments, watercourse axes, and the catchments for which the prediction was to be determined (in our case, fourth-order catchment).

Transformation of Top-Kriging results

For the TOP values, their transformation was continued based on the value of the mean annual precipitation total (Hs) and the long-term mean base runoff in the given catchment (ZO). The purpose of the transformation was to redistribute the original values within the gauged catchment based on the selected weights (Hs, ZO). Mean values of Hs and ZO were determined for each gauged catchment and its forecast catchment (fourth-order catchment, which together form the given gauged catchment). If the Hs (ZO) value of the forecast catchment was higher than the value of a given gauged catchment, its TOP value was increased. Otherwise, it was decreased. The rate of increase (decrease) in redistribution values was controlled by the size ratio of Hs (ZO) between the gauged and forecast catchment.

Direct runoff calculation

A direct discharge calculation was also implemented within the gauged catchments. This calculation was based on a weighted average over the areas of forecast catchments, where Hs (R_Hs) or ZO (R_ZO) values were chosen as weights.

Assessment of prediction quality

Conformity assessment was performed for all monitored discharge rates and all reference catchments (12 catchments). Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were used as evaluation metrics.

$$MAE = \frac{1}{N}\sum_{i=1}^{N} | Q_{PRED} - Q_{Ref} | \qquad 1)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (Q_{PRED} - Q_{Ref})^2} \qquad 2)$$

where:

Q_{PRED} is the discharge value for fourth-order catchment (corresponding to the given reference catchment) determined by calculation methods (TOP, TOP_Hs, TOP_ZO, R_Hs, R_ZO)
Q_{Ref} discharge reference value for the given catchment
N number of reference catchment

RESULTS

The results show that the smallest mean errors were achieved by the R_ZO method for all evaluated discharge rates. The lowest error was for discharge rate Q_{355d} (0.063 m^3/s), the highest error was for discharge rate Q_{100} (17.778 m^3/s). The second best results were achieved by the R_Hs method. The TOP, TOP_Hs, and TOP_ZO methods produced mutually comparable, but worse results than the R_ZO and R_Hs methods. This was especially true for the results at low discharge rates (Q_{355d} and Q_a), where they reached several times higher error values. For discharge rate Q_{100}, the value of their errors was around 25.5 m^3/s. The least significant difference was in the Q_{10} discharge rate. A summary of the determined MAE values is given in *Tab. 2*.

Tab. 2. Summary of achieved MAE values (m^3/s)

	TOP	TOP_Hs	TOP_ZO	R_Hs	R_ZO
Q_{355d}	0.128	0.130	0.134	0.072	0.063
Q_a	0.492	0.493	0.500	0.197	0.155
Q_1	3.804	3.828	3.794	2.850	2.649
Q_{10}	10.600	10.578	9.904	8.495	8.303
Q_{100}	25.717	25.799	25.169	18.061	17.778

The best RMSE results were again achieved by the R_ZO method at discharge rate Q_{355d} (0.123 m^3/s). The TOP, TOP_Hs, and TOP_ZO methods produce the highest RMSE values at all discharge rates, with minimal differences between them. Their values are in most cases almost double compared to R_ZO. The individual values follow the trends of the error distribution depending on the predicted runoff similar to the MAE values. The RMSE values for the Q_{355d} and Q_a discharge rates are almost double the corresponding MAE values, which indicates the occurrence of significant error values for some catchments within the datasets of all methods. In contrast, the R_ZO and R_Hs methods show only small differences between RMSE and MAE for discharge rate Q_{100}. This indicates that the error sizes for individual catchments within the data set did not reach significant values. The summary of the determined RMSE values is given in *Tab. 3*.

Tab. 3. Summary of achieved RMSE values (m^3/s)

	TOP	TOP_Hs	TOP_ZO	R_Hs	R_ZO
Q_{355d}	0.238	0.238	0.242	0.140	0.123
Q_a	0.957	0.959	0.963	0.449	0.384
Q_1	5.197	5.230	5.254	3.307	3.132
Q_{10}	14.200	14.215	13.437	9.151	8.913
Q_{100}	33.857	33.969	33.109	19.746	19.060

Fig. 4 shows the variability of errors for individual prediction methods and studied discharge rates. It is clear that the variance of the absolute error at discharge rate Q_{355d} is significantly lower for the R_ZO and R_Hs methods than for TOP, TOP_Hs, and TOP_ZO. This trend can be observed for all forecast discharge rates. The distance of the position of the medians from the averages (especially for discharge Q_{355d} and Q_a) points again to the presence of significant values in the error files of the TOP, TOP_Hs, and TOP_ZO methods. In the case of discharge Q_{10} a Q_{100}, these significant errors were associated with the quality of prediction in catchments No. 7, 11 and 12.

DISCUSSION

TOP is also often compared with regional regression models. It turns out that when modelling low discharge rates, which are primarily controlled by subsurface processes, its results are comparable to regression models – while requiring a minimal amount of input data compared to regression models [3].

The goal of transforming the original TOP results using Hs and ZO was to improve the performance of the TOP method. The method itself does not work with additional inputs. It uses only the spatial dependence of the given variable defined by the variogram. The most appropriate approach would be to directly

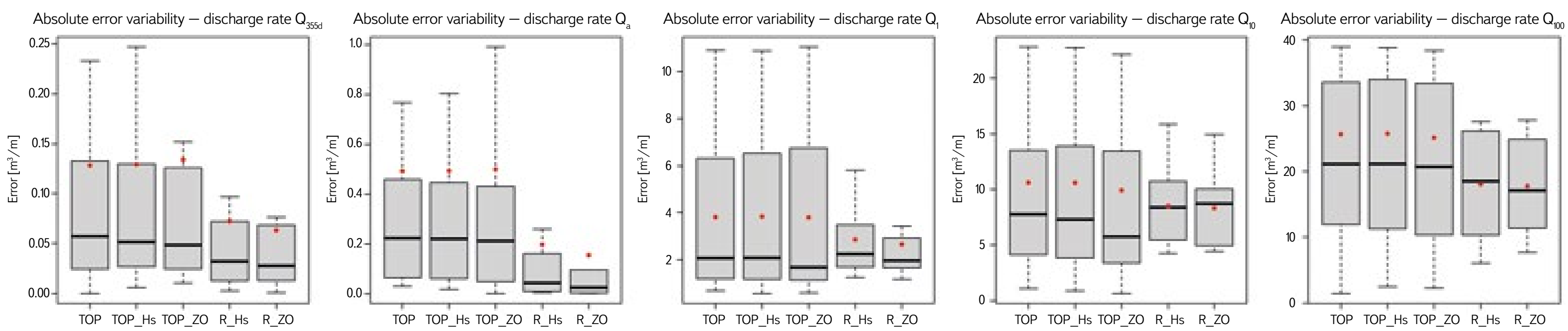

Fig. 4. Graphic representation of the variability of the errors achieved by the compared methods for individual evaluated discharge rates

implement Hs or ZO into the TOP algorithm. However, this exceeds the objectives of this study.

The transformation of the original TOP values always took place within the gauged catchments. This step ensured that the resulting discharge rate value was not altered after redistribution. The possibility of redistribution within the entire Otava basin was also investigated. This variant led to non-compliance with the discharge rates in the individual gauged catchments. The reason for conducting the redistribution separately was the effort to find out which of the variables (Hs, ZO) will have a greater influence on the results. The question remains whether the choice of a more appropriate transformation mechanism would not bring a more significant increase in performance than that described in this article.

The direct discharge rate calculation based on Hs or ZO was used for comparison (as a basic method) with the TOP method and its derivatives. However, it proved to provide better performance than TOP and its derivatives. The poor performance of TOP may be related to the high heterogeneity and small size of the forecast catchments, which TOP is unable to capture and describe [12].

The gauged catchments were drawn based on the grouping of fourth-order catchments. The fact is that some limnigraphic stations are not within the fourth-order catchments placed directly into their closing profiles. They therefore have a slightly larger area than the given limnigraphic station (or the area of the inter-catchment between two limnigraphic stations on the same watercourse). We assume that this aspect affects only the exact value of the discharge rate that is calculated, but not the methodological procedure of this calculation.

The reference data in this study were only available for a small part of the fourth-order catchment. The reason is the price of this data. The authors are aware that such a small reference set may affect the uncertainty of the results. Another source of uncertainty can be the reference data values themselves. These belong to class III basic hydrological data of surface waters. The relative value of the root mean square error for data from this class can take values from 20 (Q_a) to 40 (Q_{100}) % [26].

The selected range of investigated discharge rates aimed to show what results the TOP method will achieve in different discharge scenarios. As expected, larger absolute errors were achieved at high discharge rates.

This paper is part of TA CR project No. TK04030223 and as such follows its goals. One of them is to estimate the outflow of Q_a from the fourth-order catchments in the Czech Republic. For this purpose, it is necessary to use the available datasets covering the entire Czech Republic, process and evaluate them appropriately. This paper can therefore be seen as a pilot part of the entire project.

CONCLUSION

In this paper, an evaluation of the performance of the Top-Kriging method and its derivatives in determining runoff from ungauged fourth-order catchments in the Otava basin was performed. The study results show that the R_ZO method achieved the best performance in determining runoff from ungauged catchments, regardless of the size of the predicted discharge rate. It was followed by the R_Hs method. The TOP method shows in some cases the production of significant differences between predicted and reference data. These differences were detected especially in reference catchments No. 7, 11 and 12. The question remains as to what makes these catchments unique. This phenomenon appears regardless of the predicted runoff size and is further prescribed in the performance of the TOP_Hs and TOP_ZO models. The study also tried to improve the performance of the Top-Kriging method itself in post-processing. The behaviour of the original algorithm was shown to be stronger than the additional adjustment of the results, resulting from considering the distribution of the mean annual precipitation total or the long-term mean base runoff. This resulted in only a slight performance improvement for the TOP_Hs and TOP_ZO methods.

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Comparison of the Grey Water Footprint of conventional pollution and micropollutants: A case study of the Bandung WWTP (Indonesia)

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Keywords: grey water footprint — wastewater treatment plant — micropollutants — contaminants of emerging concern — CECs

ABSTRACT

Grey water footprint refers to the amount of water required to dilute pollutants released into the aquatic environment so that the water quality remains above agreed water quality standards. This study examines the grey water footprint of micropollutants, also referred to as contaminants of emerging concern (CECs), compared to commonly monitored water parameters (such as nutrients and organic pollution) in wastewater. 24-hour samples were analysed from Indonesia's largest WWTP, which uses a stabilization pond system for wastewater treatment. The grey water footprint was calculated for 12 micropollutants and six parameters of standard chemical monitoring. The highest value of the grey water footprint in the WWTP effluent was for BOD_5 (13.5 l/l). The highest value among the micropollutants in the WWTP effluent was for Fluoxetine (0.08 l/l). When using other published PNEC values, Fluoxetine reached higher grey water footprint values than BOD_5. The highest value of the grey water footprint in the WWTP influent was for Ibuprofen (210.4 l/l), but this substance was effectively removed in the WWTP.

INTRODUCTION

Since its introduction in 2002 [1], water footprint has become a popular tool for assessing water use by human society. In general terms, the water footprint of an assessed product system represents both direct and indirect consumption of water for creation of a product, service or process throughout its life cycle [2]. Water footprint consists of three components denoted by "colours". The blue water footprint represents the amount of water withdrawn from water sources and consumed during the life cycle of the product system under consideration. The green water footprint represents the amount of precipitation (e.g. in the form of soil water) consumed during the life cycle of the product system under consideration. It is usually significant in agro-systems and food products. And finally, there is the grey water footprint, which represents the amount of water needed to dilute the life-cycle pollution discharges from the product system under consideration.

Wastewater production is intrinsically linked to both human settlements and industrial production. To ensure environmental water quality standards, individual countries adopt legislation that regulates wastewater discharge. This legislation usually prescribes such limits that trigger the need to build WWTPs. In the past, the calculation of the grey water footprint of wastewater was the subject of a number of studies focused on, for example, the efficiency of WWTPs [3] or the comparison of different WWTP systems [4]. These studies usually focus on assessing "common" pollution as expressed by parameters of biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total phosphorus (TP), and total nitrogen (TN). Various studies then add other substances, such as nitrate nitrogen [5] and total oxygen [6].

In recent years, the issue of so-called micropollutants has begun to be discussed in the professional community [7]; these are substances usually of anthropogenic origin, which occur in the environment in very low concentrations and which we are only able to detect with the advent of new detection techniques such as LC-MS/MS. However, their behaviour in the environment has not yet been sufficiently investigated, and therefore there is a risk of adverse effects of these substances on the environment and ecosystems, even at very low concentrations. These substances are sometimes referred to as 'emergent' (in the sense of 'new') pollutants or substances/contaminants/pollutants of emerging concern (CECs). Typical representatives of these substances are pharmaceuticals, industrial and agricultural chemicals, personal care substances, etc. [8]. Several studies of the grey water footprint of pollution discharged from WWTPs have also been devoted to micropollutants. So far, these studies are relatively few as scientists have so far mainly focused on describing the occurrence and behaviour of these pollutants in the environment [9, 10].

Probably the first study to quantify the grey water footprint of micropollutants is a Spanish study of 12 WWTPs [11]. This study more or less defined the procedure to assess micropollutants through the grey water footprint. However, it also pointed to the possibility that micropollutants may have a higher grey water footprint than the commonly monitored pollution. This finding has not yet been confirmed by any other study, but neither has any other study shown that the finding is more of an exception. One of the reasons is the fact that in wastewater, common pollutants and micropollutants are usually not monitored simultaneously. As far as we know, the only other study comparing the grey water footprint of common pollutants and micropollutants is the study of the Dolní Kralovice WWTP in the Švihov reservoir basin [12], where, however, the grey water footprint of common pollutants significantly exceeded the values of the grey water footprint of micropollutants. The goal of our study is to expand the so far very sparse literature dealing with the comparison of the grey water footprint of common pollutants and micropollutants.

DATA AND METHODS

WWTP of interest

The Bandung central WWTP is located in Bojongsoang (*Fig. 1*) and has an effective capacity of 40,000 m^3 per day [13]. It is the largest WWTP in Indonesia. Treated wastewater is discharged into the Citarum River, the largest river in West Java province and also one of the most polluted rivers in Southeast Asia [14]. The treatment process at the WWTP is two-stage. The first stage consists of physical/mechanical processes involving screens, sieves, and primary sedimentation. The second stage uses a system of stabilization tanks consisting of anaerobic, oxidation, and sedimentation tanks, in which biological wastewater treatment processes take place. Anaerobic and oxidation tanks are designed to reduce the biochemical oxygen demand (BOD_5), while secondary settling tanks are mainly used for tertiary treatment [15]. A diagram of Bandung WWTP is shown in *Fig. 2*.

Data published in an article on sample collection and processing at Bandung WWTP [16] were used for this study. The 24-hour composite samples analysed in the study were collected hourly using vertical samplers in Van Dorn bottles between 7:00 a.m. on 18th June 2019 and 6:00 a.m. on 19th June 2019. For the grey water footprint study, water quality data were used at the WWTP influent and at the WWTP effluent.

Grey water footprint calculation

The grey water footprint of a unit volume of wastewater is calculated for each pollutant using *Equation 1*:

$$GWF_i = \frac{\frac{L_i}{c_{max,}i - c_{nat,i}}}{Q} = \frac{\frac{c_i \times Q}{c_{max,}i - c_{nat,i}}}{Q} = \frac{c_i}{c_{max,}i - c_{nat,i}} \quad [l/l] \qquad (1)$$

For micropollutants, the equation is modified in accordance with the procedure described by Martínez-Alcalá [11]:

$$GWF_i = \frac{\frac{L_i}{c_{max,}i - c_{nat,i}}}{Q} = \frac{\frac{c_i \times Q}{PNEC_i - 0}}{Q} = \frac{c_i}{PNECi} \quad [l/l] \qquad (2)$$

where:

GWF_i	is	the grey water footprint of substance *i*
L_i		amount of discharged pollution *i*
$c_{max,i}$		the maximum allowed concentration of substance *i* in the aquatic environment (environmental standard)
$c_{nat,i}$		natural background concentration of substance *i* in the aquatic environment; for anthropogenic substances = 0
c_i		concentration of substance *i* in wastewater
Q		flow rate of discharged wastewater; considering the objectives of the study, a value of Q = 1 was considered
$PNEC_i$		concentration of substance *i* below which no adverse effect of exposure in the ecosystem is expected

The predicted no-effect concentration values were taken from the NORMAN database [17]. The values for c_{max} and c_{nat} used for the calculation according to *Equation 1* and the PNEC values for the calculation according to *Equation 2* are given in *Tab. 1*.

Tab. 1. Values of c_{max}, c_{nat} and PNEC used in analysis

ID	Parameter	Units	PNEC
TMP	Trimethoprim	µg/l	120
SMZ	Sulfamethazine	µg/l	30
ACT	Acetaminophen	µg/l	46
IBU	Ibuprofen	µg/l	0.011
TCS	Triclosan	µg/l	0.11
CBZ	Carbamazepine	µg/l	2
FLX	Fluoxetine	µg/l	0.1
BTA	Benzotriazole	µg/l	19
BPA	Bisphenol A	µg/l	0.24
CAF	Caffeine	µg/l	1.2
DEET	N,N-diethyl-m-toluamide	µg/l	88
TCEP	Tris(2-chloroethyl) phosphate	µg/l	6
TSS	Total suspended solids	mg/l	10
BOD	Biological Oxygen Demand	mg/l	2
COD	Chemical Oxygen Demand	mg/l	10
TOC	Total Organic Carbon	mg/l	3
TN	Total Nitrogen	mg/l	3
TP	Total Phosporus	mg/l	0.1
$N\text{-}NH_3$	Nitrite Nitrogen	mg/l	2.5

Fig. 1. Bandung WWTP

The grey water footprint of the WWTP is determined by the substance with the highest value:

$$GWF = max\ [GWF_1, GWF_2 \dots GWF_n] \qquad [l/l] \qquad (3)$$

where:

GWF	is	the grey water footprint of the WWTP
GWF_i		grey water footprint of the substance *i* at the WWTP

RESULTS AND DISCUSSION

Tab. 2 shows the summary results. The BOD_5 parameter has the highest value of the grey water footprint of common pollutants at the influent to the WWTP and the effluent from the WWTP, for which the GWF value decreased from 45 l/l to 13.5 l/l (influent → effluent). Thus, the findings of previous studies [5, 11], that the grey water footprint on the effluent from the WWTP is usually determined by total phosphorus, were not confirmed. It is probable that this phenomenon is typical for WWTPs based on a stabilization tank system, whereas previous studies have investigated mechanical-biological WWTPs with activation. BOD_5 has the overall highest value of the grey water footprint in the effluent of all monitored substances (*Fig. 3*).

Of the monitored micropollutants, the antidepressant Fluoxetine (0.08 l/l) had the highest value in the effluent. The overall value of its grey water footprint is mainly due to the low PNEC value of 100 ng/l. In recent literature, significantly stricter values can also be found, e.g. 0.0291 ng/l [18] from 2022, or 3 ng/l [19] and 10.8 ng/l [20] from 2019. For the PNEC of 0.0291 ng/l, the grey water footprint value of Fluoxetine would reach 274.9 l/l, which is 20 times higher than the grey water footprint value of common pollutants. It can be confirmed that the value of the grey water footprint is extremely sensitive to the choice/selection of the PNEC value, or c_{max}. The finding of Martínez-Alcalá [11] that micropollutants can be a determinant of the overall grey water footprint of pollution discharged from WWTPs cannot yet be unequivocally confirmed. Only further research into the toxicity of micropollutants will show whether these substances, despite their minimal concentrations in wastewater, are decisive

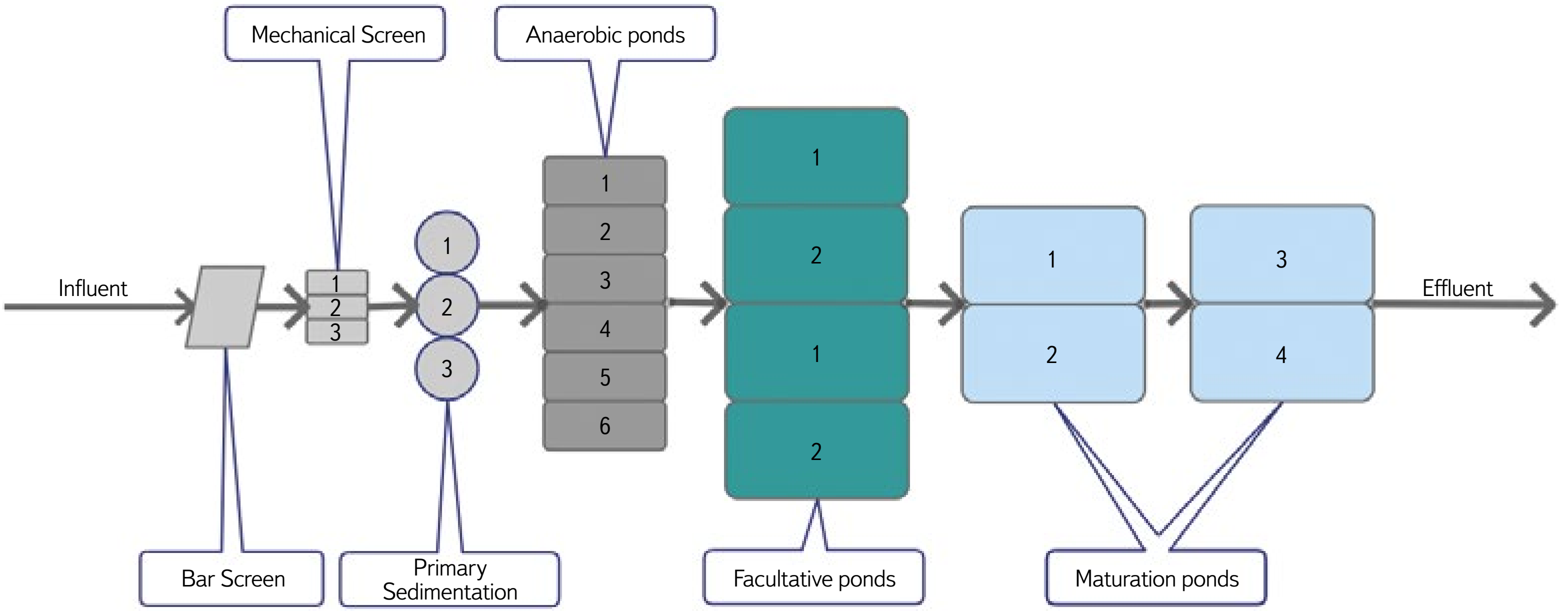

Fig. 2. Diagram of Bandung WWTP

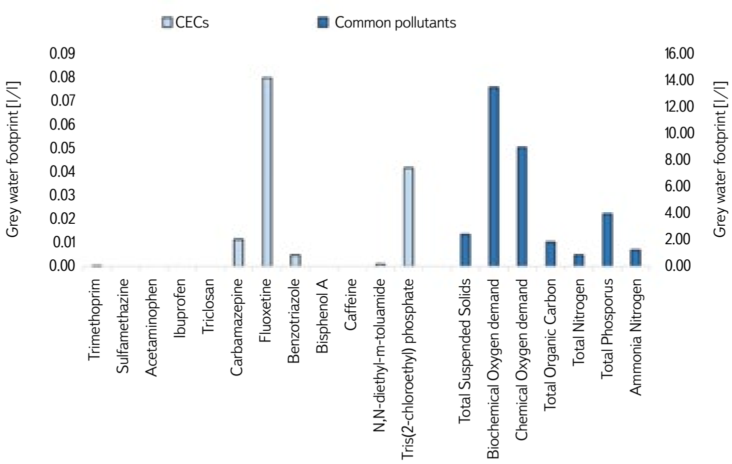

Fig. 3. Grey water footprint – Bandung WWTP effluent

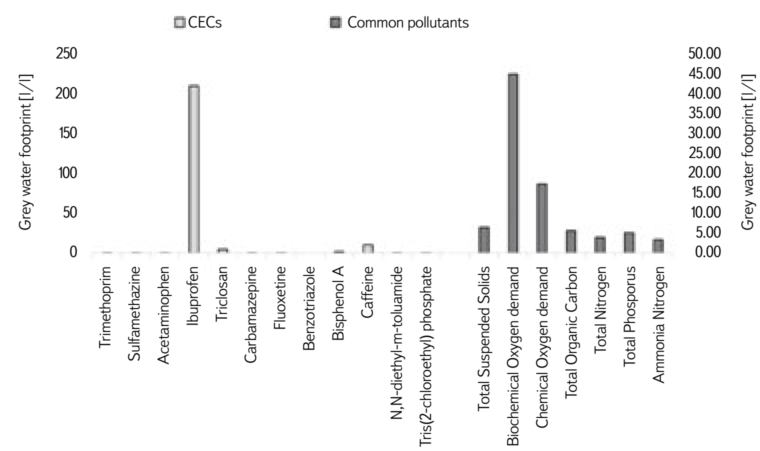

Fig. 4. Grey water footprint – Bandung WWTP influent

for the water footprint. Using the PNECs published in the NORMAN database instead of using other values can be recommended for three main reasons:

1. These are values discussed by experts associated with NORMAN.
2. Values are periodically revised/updated.
3. Values are available for most of the known micropollutants.

A slightly different situation occurs with untreated wastewater at the influent to the WWTP (*Fig. 4*). Ibuprofen has the absolute highest grey water footprint (210.5 l/l), which is due to the high concentration of this substance at the influent to the WWTP and especially the extremely low PNEC value of 11 ng/l. However, similarly low PNEC values are also reported by other authors [19, 21]. Other authors also confirm high concentrations of Ibuprofen in municipal wastewater [22]. Ibuprofen is usually very well degraded by the stabilization tank system, so this substance was not detected in the WWTP effluent. Other studies also confirm the effective removal of Ibuprofen at the WWTP [23]. The total reduction of the grey water footprint at the WWTP thus reached 93.59 %. Such a reduction value has not yet been recorded in any study dealing with grey water footprint reduction at WWTPs.

Tab. 3 shows a comparison of the grey water footprint of micropollutants from different studies. It shows that the studies to date differ greatly in the range of monitored micropollutants and in the values of their grey water footprint. There could be a number of reasons for this. This may be due to a) the different PNEC value used to calculate grey water footprint, b) the high variability of the presence of micropollutants in wastewater, and c) the different analytical methods used to determine micropollutants in wastewater. This can be demonstrated by two studies from European WWTPs [24, 25], where one set of samples was analysed by two different methods and different results are available for three substances that were analysed by both methods.

Several limitations of the study should be considered when interpreting the results. First, it is a study based on one-day samples, which may not show the temporal variability of the wastewater composition. Second, it should be taken into account that this is a study of a WWTP using a system of stabilization tanks, which is not widespread in, for example, central European conditions due to high requirements for area and lower treatment efficiency. Third, a WWTP in Indonesia is included in the study, where there are different climatic conditions

Tab. 2. Concentrations and Grey Water Footprint of conventional pollution and micropollutants

ID	Parameter	Concentration			GWF [l/l]	
		Unit	**Influent**	**Effluent**	**Influent**	**Effluent**
TMP	Trimethoprim	ng/l	182	31	0.00	0.00
SMZ	Sulfamethazine	ng/l	25		0.00	
ACT	Acetaminophen	ng/l	9,111		0.20	
IBU	Ibuprofen	ng/l	2,315		210.45	
TCS	Triclosan	ng/l	470		4.27	
CBZ	Carbamazepine	ng/l	12	23	0.01	0.01
FLX	Fluoxetine	ng/l	10	8	0.10	0.08
BTA	Benzotriazole	ng/l		92		0.00
BPA	Bisphenol A	ng/l	378		1.58	
CAF	Caffeine	ng/l	12,220		10.18	
DEET	N,N-diethyl-m-toluamide	ng/l	4,968	82	0.06	0.00
TCEP	Tris(2-chloroethyl) phosphate	ng/l	101	251	0.02	0.04
TSS	Celkové nerozpuštěné látky / Total suspended solids	mg/l	64	24	6.40	2.40
BOD	Biochemická spotřeba kyslíku / Biochemical Oxygen Demand	mg/l	90	27	45.00	13.50
COD	Chemická spotřeba kyslíku / Chemical Oxygen Demand	mg/l	173	90	17.30	9.00
TOC	Celkový organický uhlík / Total Organic Carbon	mg/l	16.8	5.5	5.60	1.83
TN	Celkový dusík / Total Nitrogen	mg/l	11.5	2.6	3.83	0.87
TP	Celkový fosfor / Total Phosporus	mg/l	0.5	0.4	5.00	4.00
$N\text{-}NH_3$	Amoniakální dusík / Ammonia Nitrogen	mg/l	8.4	3.1	3.36	1.24

Tab. 3. Comparison of values presented in studies of GWF of micropollutants at WWTPs

ID	Parameter	Unit	This study		[11]		[12]		[27]#		[28]	
			Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
TMP	Trimethoprim	l/l	0.00	0.00	*	*	–	–	0.00#	0.00#	*	*
SMZ	Sulfamethazine	l/l	0.00	–	*	*	–	–	*	*	*	*
ACT	Acetaminophen	l/l	0.20	–	*	*	*	*	*	*	*	*
IBU	Ibuprofen	l/l	210.45	–	*	*	*	*	0.00#	0.02–0.62#	*	342.36–501.99
TCS	Triclosan	l/l	4.27	–	*	*	*	*	0.06#	–	*	*
CBZ	Carbamazepine	l/l	0.01	0.01	0.47–22.08	1.21–11.75	*	*	0.42–3.62	0.56–6.86	*	0.04–2.31
FLX	Fluoxetine	l/l	0.10	0.08	*	*	*	*	0.06#	0.04#	*	*
BTA	Benzotriazole	l/l		0.00	*	*	*	*	0.00–0.12#	0.01–0.07#	*	*
BPA	Bisphenol A	l/l	1.58	–	*	*	*	*	0.02–0.34#	0.03–0.49#	*	0.01–0.23
CAF	Caffeine	l/l	10.18	–	*	*	*	*	0.82–3.29#	0.01–0.82#	*	1.29–496.62
DEET	N,N-diethyl-m-toluamide	l/l	0.06	0.00	*	*	*	*	0.00#	0.00#	*	*
TCEP	Tris(2-chloroethyl) phosphate	l/l	0.02	0.04	*	*	*	*	0.02–0.08#	0.01–0.08#	*	*

* Compound not included
- Data not available (typically the values were under the limit of analytical method)
Data not involved in the published article, but available on request

that affect the biological processes of wastewater treatment. Last but not least, it should be noted that a number of micropollutants, such as pharmaceuticals, are biologically active substances that have the ability to affect non-target organisms. Wastewater contains a varied mixture of these substances, in which individual micropollutants can mutually react and metabolize. However, the grey water footprint principle is based on the idea of assessing individual pollutants, and for micropollutants it would be more appropriate to consider mixtures [24, 26].

CONCLUSION

The conducted study complements the so far very sparse literature comparing the grey water footprint of standard monitored chemical parameters with micropollutants discharged from WWTPs. The study confirmed that the choice of PNEC value is crucial for whether micropollutants can be a determinant of the value of the total grey water footprint of discharged municipal pollution. Using the PNEC values available in the NORMAN database, the grey water footprint value of treated wastewater was determined by common pollutants. Conversely, in untreated wastewater, micropollutants would be dominant. Using the PNEC values that have been published in recent years, micropollutants would already be a determining pollutant even in the effluent from the WWTP. Further research on the ecotoxicity of micropollutants is thus essential for the assessment of grey water footprint in practice.

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Conflict of interest

The authors declare no conflict of interest.

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Recast of the Urban Wastewater Treatment Directive brings new challenges not only in the water management sector

DANIELA MERTOVÁ

Keywords: wastewater treatment — wastewater — European Commission — EU Directive

ABSTRACT

This article presents the main elements of the recast of Council Directive 91/271/EEC concerning urban wastewater treatment, which lays down rules for the collection, treatment, and discharge of urban wastewater in order to protect the environment and human health. In addition to strengthening existing requirements, the text of the new Directive, as provisionally agreed, introduces a significant number of new obligations to be achieved within ambitious deadlines.

INTRODUCTION

On 26th October 2022, during the Czech Presidency of the Council of the EU, the European Commission published a proposal for a revised wording of Council Directive No. 91/271/EEC of 21st May 1991 on urban wastewater treatment (together with an impact assessment of the proposal) [1]. The legislative process [2] in the EU Council for the Environment was complicated due to the need to take into account the different positions of individual Member States and was concluded after more than a year with the adoption of a 'general approach' on 16th October 2023. Simultaneously, the proposal was discussed in the European Parliament, which adopted a total of 252 amendments to the original proposal of the European Commission. Only two political trilogues were needed to reach an agreement between the EU Council, the European Parliament, and the European Commission. There was a fairly broad consensus on the proposal and it was only necessary to address some problematic areas of the proposal. The first trialogue took place on 21st November 2023, and the second, final one on 29th January 2024.

The political agreement reached in this way was provisionally approved by the Member States at the level of the EU Committee of Permanent Representatives (so-called Coreper) on 1st March 2024, and subsequently approved by the Committee on the Environment, Public Health and Food Safety of the European Parliament on 11th March 2024. On 10th April 2024, the agreement was also approved by the plenary session of the European Parliament [3]. The text must subsequently undergo a legal-linguistic revision, during which the content will not change and only certain language adjustments will be made. The final text will then be submitted to the new European Parliament for formal approval. After that, the new Directive will be adopted by the Council of the EU, subsequently signed by the representatives of the Council of the EU and the European Parliament and published in the Official Journal of the EU during the autumn of 2024, thereby formally entering into force. Member States will then have to start transposition into national legislation within 30 months of entry into force.

It is an extensive revision of the current wording of the Directive, which has not been amended since its publication in 1991. The revision of the Directive aims to fulfil the partial goal of the Zero Pollution Action Plan [4], which, among other things, defines the need to better integrate the sector of urban wastewater treatment and the circular economy. It also sets rules for the collection, treatment, and discharge of urban wastewater in particular, with the aim of protecting the environment and human health in accordance with the approach based on the "One Health" principle, which aims at a sustainable balance and optimization of human health, animal health, and ecosystems. In addition, the implementation of the Directive should contribute to:

- gradual reduction of greenhouse gas emissions to a sustainable level,
- support of energy self-sufficiency and energy production from renewable sources,
- transition to the circular economy,
- improvement of the governance and transparency of the sector,
- regular supervision of certain parameters of public health,
- access to sanitary facilities.

Last but not least, it also introduces the "polluter pays" principle in the field of water management. This principle imposes on subjects, or polluters, the obligation to participate financially in environmental protection.

In addition to the tightening of existing requirements, the Directive also introduces a significant number of new obligations, which will need to be achieved within ambitious deadlines.

Extending the scope of the Directive

The key change is the extension of the material scope of the Directive to all agglomerations producing pollution corresponding to the amount of 1,000 population equivalent (PE) and more in the case of a requirement to ensure centralized wastewater collection and treatment. The current limit is set at 2,000 PE. Within the framework of the current Directive, the Czech Republic registers a total of 648 agglomerations with a load of approximately 9.3 million PE. The revision of the Directive will mean an increase in the number of agglomerations falling within its scope by about another 750, which will represent an increase in the covered pollution by another 1 million PE. The deadline for compliance with this change (i.e., ensuring that all agglomerations from 1,000 EO are equipped with sewage systems and have all sources of sewage connected to a sewage system) is set for the end of 2035. For some Member States, there is the possibility to use an extension of this deadline due to the specific local conditions.

In agglomerations where it will not be possible to build a sewage system for technical or economic reasons, or where it would not bring any benefit to the environment or human health, the possibility of using individual wastewater treatment systems will be maintained. However, stricter requirements will be placed on these systems, not only from the point of view of wastewater treatment. Minimum requirements will be defined for the construction, operation, and maintenance of these systems, as well as for their regular inspections. In addition, individual systems should be entered in a new register.

In the case of the so-called secondary treatment of municipal wastewater, it will be necessary to fulfil the already existing concentration requirements, especially in the case of indicators of biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD; alternatively, it can be replaced by the total organic carbon indicator; the decision rests with the Member State). An optional limit is also set for the concentration of total content of undissolved substances. In addition to concentration limits, values for the minimum percentage of loss are also determined for individual indicators.

Tab. 1. Requirements for discharges from municipal wastewater treatment plants (secondary treatment)

Indicator	Concentration	Minimum percentage of loss
BOD_5	25 mg/l O_2	70–90
COD	125 mg/l O_2	75
Total organic C	37 mg/l	75
Undissolved substances	35 mg/l	90

Tightening of emission standards

Another key factor will be the tightening of emission standards for total nitrogen and total phosphorus, which are mandatorily collected as part of the so-called tertiary wastewater treatment. This requirement is relevant for all agglomerations exceeding the threshold of 10,000 PE. The requirements for collection of the mentioned indicators are not determined according to the size of the agglomeration, as was the case until now, but directly according to the size of the load on the individual wastewater treatment plant (WWTP). The new requirements for tertiary treatment should be gradually fulfilled by the end of 2045, when all affected agglomerations should meet the newly established standards. Large WWTPs (i.e., those with a load of more than 150,000 PE) must, in addition to the concentration values, meet the value of the minimum percentage of loss in relation to the load on the influent. *Tab. 2* reflects the requirements of the existing and revised Directive on discharges from urban WWTPs. The term "areas at risk of eutrophication" is newly introduced here instead of the previously used term "sensitive areas". This change will not have an impact on the Czech Republic as it follows from the wording of the draft Directive that the whole country will have to be defined as an area at risk of eutrophication; at present, the whole of the Czech Republic is defined as a sensitive area.

Introduction of the quaternary stage of treatment

Furthermore, the Directive introduces a completely new obligation of the so-called quaternary stage of treatment. The stated requirement applies to large WWTPs over 10,000 PE and its goal is to ensure a reduction in the amount of micropollutants, in particular medicines and personal care products (or their residues) and microplastics in treated municipal wastewater. The requirement for the efficiency of specific micropollutant collection, especially pharmaceuticals, is set to a minimum reduction of 80 % and refers to a defined range of substances whose reduction will have to be monitored. At the end of 2045, all agglomerations above 10,000 PE should fulfil the obligations arising from quaternary treatment.

As this degree of treatment requires significant financial costs (investment and operational), this mechanism is to be helped by the newly introduced system of so-called "extended producer responsibility" (in accordance with the "polluter pays" principle), which is intended to apply to selected industries, namely the pharmaceutical and cosmetic industry. Manufacturers will have to contribute at least 80 % of the total costs to the scheme, leaving flexibility to Member States to share the remaining costs. Furthermore, it will be within the responsibility of the individual Member States to set up the system for the introduction and organization of this mechanism, including its monitoring. The obligation will not apply to manufacturers who place on the EU market the number of substances contained in products which do not exceed 1 tonne per year, or in cases where the substances in the products they place on the market are rapidly biodegradable in wastewater, or they are not present in wastewater at the end of their useful life. Member States should introduce obligations arising

Tab. 2. Requirements for discharges from municipal wastewater treatment plants (tertiary treatment)

Indicator	Concentration	Concentration (revision)	Minimum percentage of loss (existing)	Minimum percentage of loss (revision)
Total phosphorus	2 mg/l (10,000–100,000 EO)	0.7 mg/l (10,000–150,000 EO)	80	87.5 (10,000–150,000 EO)
	1 mg/l (> 100,000 EO)	0.5 mg/l (> 150,000 EO)	80	90 (> 150,000 EO)
Total nitrogen	15 mg/l (10,000–100,000 EO)	10 mg/l (10,000–150,000 EO)	70–80	80
	10 mg/l (10,000–100,000 EO)	8 mg/l (> 150,000 EO)	70–80	80

from extended producer responsibility within three years of the entry into force of the Directive, i.e. probably in 2027.

Energy neutrality of wastewater treatment plants

The revised wording of the Directive also introduces obligations related to the energy neutrality of urban WWTPs; this requirement will apply to treatment plants with a produced load of more than 10,000 PE. The requirement to meet this goal should be gradually achieved by 2045. The Directive further imposes the obligation to carry out energy audits, which will include identification of the potential for cost-effective measures to reduce energy consumption and increase the use and production of energy from renewable sources, with a particular focus on the identification and use of the potential for biogas production or the recovery and use of waste heat while simultaneously reducing greenhouse gas emissions. For WWTPs, it is possible to produce energy from renewable sources directly on the site or outside it, and partially purchase energy from external non-fossil sources. The maximum allowed rate of energy purchased from external sources is set at 35 % and only applies to the final goal under certain conditions.

Other obligations resulting from the revised text

Another obligation will be to monitor and significantly reduce precipitation runoff from urbanized areas, or pollution caused by rainwater relief (storm water overflow). Each Member State will have to prepare integrated urban wastewater management plans for agglomerations exceeding a load of 100,000 PE by 2033. The obligation to prepare these plans will also be necessary for agglomerations in the 10,000–100,000 PE category, where rainwater overflow poses a risk to the environment and human health or represent more than 2 % of the annual load of discharged wastewater in the dry season, or when overflow will prevent the fulfilment of the relevant EU water policy directives, by 2039. Plans should prioritize green and blue infrastructure solutions. They must be reviewed at least once every six years and updated if necessary.

Member States will also have to monitor a number of new parameters at WWTPs, for example the amount and composition of sludge, produced greenhouse gases, the share of reused treated wastewater, produced and consumed energy, pollutants, and the presence of microplastics. Monitoring and identification of public health parameters (e.g. influenza virus, poliovirus, SARS-CoV-2 virus and its variants, newly emerging pathogens) in urban wastewater will be voluntary, at least at the inflow to the WWTP, with the exception of declaring the status threat to public health (i.e. pandemic). In all agglomerations above the threshold of 100,000 PE, Member States will also have to regularly monitor the indicators of so-called antimicrobial resistance in the influent and outflow from urban WWTPs.

It will be necessary to handle the sludge in accordance with the waste management hierarchy. Disposal methods must maximize prevention, preparation for reuse, recycling, and other resource utilization, as well as minimize adverse effects on the environment and human health. A minimum rate of reuse and recycling of phosphorus from sludge will be determined, taking into account available technologies.

Consideration will also need to be given to the possibility of reusing treated wastewater from all municipal WWTPs, where appropriate. This option is primarily targeted at water-scarce areas for all uses. In addition, a review provision was added to analyze the added value of mandatory national water reuse plans.

The new Directive also introduces recommendatory provisions on access to sanitary facilities for all, free of charge or for a low fee. This requirement applies to agglomerations exceeding the threshold of 5,000 PE, for both public buildings (mainly administrative) and private spaces accessible to the public. In the case of agglomerations over 10,000 PE, it is expedient to set up facilities in public spaces. The deadline imposed by the Directive for the fulfilment of this requirement is 2029.

In a number of the mentioned obligations, the Member States have the possibility to deviate from the deadlines specified above or their fulfilment, but always under conditions precisely defined by the Directive. Many provisions will be further specified through individual implementing acts of the European Commission.

Tab. 3. Implementation deadlines by individual areas and final goals

Obligation	Agglomeration	Deadline for fulfillment
Scope	Over 1,000 PE	2035
Secondary treatment	Over 1,000 PE	2035
Tertiary treatment	10,000–150,000 PE	2045
	Over 150,000 PE	2039
Quaternary treatment	10,000–150,000 PE	2045
	Over 150,000 PE	2045
Extended producer responsibility		2027
Integrated management plans	10,000–100,000 PE	2039
	Over 100,000 PE	2033
Energy neutrality	Over 10,000 PE	2045
Energy audits	10,000–100,000 PE	2032
	Over 100,000 PE	2028
Risk assessment and management		2027
Access to sanitation facilities	Over 5,000 PE	2029
Reporting activity		2030

CONCLUSION

The objectives of the revised Directive can be seen as a significant opportunity to determine more effective protection of the environment, especially aquatic and water-related ecosystems, or as one of the ways to permanently improve the status of water bodies. At the same time, it is necessary to mention that a large part of the draft is quite ambitious and the fulfilment of some new requirements will require high financial costs. The cost estimate provided by the European Commission in the impact study appears to be greatly underestimated and we can assume a significant impact on the state budget. The new version of the Directive is expected to be officially adopted and signed at the end of 2024 (autumn/winter) and then published in the Official Journal of the EU, thus formally entering into force. The Czech Republic will then have to start implementing it into national legislation within a period of 30 months.

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Meeting of the Ministers of Agriculture of the Visegrad Four countries in Znojmo in September 2023 (Photo: MoA archive)

Interview with Mgr. Mark Výborný, Minister of Agriculture

Mr Výborný is participating in preparations for the construction of new reservoirs in the Czech Republic and is planning to build new pumped storage waterpower stations. According to the Minister, the priority in the field of water management is mainly the development of water supply and sewerage infrastructure, including drinking water treatment plants and wastewater treatment plants, technological measures to retain water in the landscape, construction and restoration of small water reservoirs and ponds, development of water supply systems, and also the modernization of existing irrigation systems. Mgr. Marek Výborný told VTEI about his first year as Minister of Agriculture and the objective he would like to achieve in this position.

Minister, last June the President of the Czech Republic appointed you Minister of Agriculture. What vision and plans did you come to the Ministry of Agriculture with?

One of the fundamental topics was the new EU Common Agricultural Policy, for which we had to evaluate the first year of its operation. It was clear to me that we would come across things that would have to be adjusted; and that the changes we will come to must be for the benefit of Czech farmers and the Czech landscape. After all, the support of organic farming, which I also focus on, is for its benefit as well; it is also agriculture which makes it possible to carefully manage the precious soil in the countryside. If we want to pass it on to future generations in good condition, we must start here and now before it is too late. The same applies to conditions for farmers and food producers; they must have the most favourable working conditions. We have to be competitive with other countries. Some steps cannot be taken from day to day, month to month or year to year, but we must be able to prepare; if only because the preparation of another new Common Agricultural Policy began this year and we, as the Czech Republic, want to be among the leaders of the debates.

In an interview shortly after your appointment, you said that a minister does not have to be an expert in a given issue. You said then that the key for a minister is to have a strong political mandate and to be able to communicate. Have you changed your opinion after a year of being a minister?

Even before joining the Ministry, I emphasized that I wanted to focus on changing the communication style. Nothing has changed since then; on the contrary, I think the ability to communicate well has become even more important. I am still convinced that the Minister and the entire Ministry must communicate very actively not only with the professional but also with the lay and agricultural public. I am a person who can listen to others and is ready to help in dealing with problems. I am aware of the fact that it is not always possible to find a solution that satisfies everyone. It is always about finding a compromise, agreeing, explaining – in short, working together for the benefit of this important field.

Water management is divided between several ministries, especially between the Ministries of Environment and Agriculture. How problematic do you perceive the division of these competences between several ministries, e.g. in the field of flood protection?

Allow me to correct the statement that water management is divided. It is a matter of sharing competences, which in itself suggests that it is not about creating different attitudes on different topics, but about cooperation in finding the most appropriate solution to any problem related to water management. Competencies are shared by the Ministries of Agriculture, Environment, Transport, and Defence. In the case of the question about protection against floods, the situation is completely obvious – within the framework of shared competences, flood prevention is under the responsibility of the Ministry of the Environment while, for example, anti-flood measures are implemented by watercourse managers, the Povodí state enterprises, and Forests of the Czech Republic. The current European approach to watercourse modification, hydraulic structure construction, and water management is based on an effort to limit the negative effects of technological measures and modifications (both current and historical) of water bodies on water ecosystems and their quality; the goal is to improve the condition. That is why, for example, when discussing proposals for new hydraulic structures, especially reservoirs, there is a communication between the Ministries to find ways to limit negative impacts on the environment during the construction of technological measures, including the possibility of using the situation in the affected locations to support landscape and water ecosystems. Until recently, the situation of shared competences in the Czech Republic was criticized with reference to, for example, Austria, where a single ministry concentrated the top state administration for agriculture, forestry, water management, and the environment under one roof. Currently, there are also two Ministries in Austria, namely the Federal Ministry for Agriculture, Forestry, Regions and Water Management, and the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. It is evident that the issue of water management affects both Ministries, and even if the economic and environmental protection responsibilities are more clearly separated, they cannot work without close cooperation.

In 2023, the Ministry of Agriculture allocated over 20 billion crowns to combat drought. Can you tell our readers what specific measures these funds are intended for?

The "allocation" of funds resulted from the implementation of the Concept of Protection against the Effects of Drought for the Czech Republic 2023–2027, which contains 35 adaptation measures to limit the effects of drought and water shortages. The Ministries of Agriculture, Environment, Industry and Trade, Interior (represented by the Fire and Rescue Service), and Regional Development are responsible for the measures. It is a continuation of the Concept adopted in 2017, which the government decided on based on the evaluation of activities between 2017 and 2022. The adaptation measures are generally long-term, time-consuming to implement, and it is necessary to keep implementing them. This involves, for example, the construction of reservoirs for water supply, limiting the extent of erosion, and strengthening the content of organic matter in the soil. In no case can they be described as a "fight" against drought; they are measures to reduce the consequences of climate change, which manifests itself in rising air temperatures, which primarily affects water resources and water management. Unfortunately, global targets for reducing greenhouse gas emissions, which are the cause of global warming, cannot be met in such a way that by 2050 they reach the level from the beginning of the industrial age, i.e. 1850–1900. It is already obvious that it will not be possible to ensure that the increase in air temperature does not exceed the maximum by plus 1.5 degrees Celsius. An increase in temperatures above the mentioned limit – I will just mention that it is expected to be at least 2.5 to 3 degrees Celsius after 2050 – will increase water evaporation and will result in more significant impacts, in particular on water ratios, agriculture, landscape ecosystems and their biodiversity. Therefore, the importance of adaptation measures to limit these impacts is increasing, and the fulfilment of the measures contained in the Concept is becoming a priority of the aforementioned Ministries.

Priorities in the field of water management are mainly the development of water supply and sewerage infrastructure, including drinking water treatment plants and wastewater treatment plants, technological measures to retain water in the landscape, to accumulate water in the landscape through the construction or renovation of small reservoirs and ponds, development of water supply systems, preparation and construction of conduits to reservoirs, as well as modernization of irrigation systems. Over four billion crowns of support went to these measures. Examples of implemented measures are the connection and strengthening of water supply systems (seven pilot projects were completed with the support of 1.7 billion crowns), the implementation of 128 kilometres of water pipes, and 59 wastewater treatment plants. The preparation of reservoirs, such as at Vlachovice, Kryry, Senomaty, Šanov, and the conduits from the Ohře is underway; land is being bought. The implementation of agro-environmental measures is significant, for which approximately 4.5 billion crowns were allocated; for example for grassing over arable land and areas of concentrated runoff, for the treatment of grasslands, even for the protection of the northern lapwing, as well as for compensation in areas with special ecosystem protection. Land improvement projects are significant, allowing a comprehensive approach to improving the landscape structure and, in addition, through so-called joint measures they strengthen the retention of water runoff from agricultural land and contribute to the reduction of erosion. Last year, they were financially supported to the amount of 2.2 billion crowns.

One of the measures to combat drought is the construction of reservoirs. A long-standing evergreen is Nové Heřminovy hydraulic structure. What stage is this project at now?

Let me react to the word "evergreen". We can agree that the design of Nové Heřminovy reservoir is without a doubt a major intervention in any valley and river continuum and in the life of municipalities, especially Nové Heřminovy, which is affected by the construction in its lower open part. Therefore, since the catastrophic flood in 1997, an optimal solution for the protection of the inhabitants living in the Opava river valley from Nové Heřminovy through the villages of Zátor, Brantice, and Holasovice, and the towns of Krnov and Opava has been sought for about ten years. In the end, a compromise solution was agreed upon; the reservoir will be smaller, and to achieve the expected flood protection effects, adjustments will be made in the basin above the dam site as well as in the riverbed and valley floodplain below the dam. This approach includes the government resolution from 2008, which started the preparation of measures against floods in the upper Opava. In addition to the key element of the Nové Heřminovy reservoir, other measures are being carried out in the catchment, namely the construction of small reservoirs and polders, the modification of the Opava riverbed, the establishment of gauging stations to monitor precipitation and flow, as well as complex land improvements. This shows that the preparation is complex and time-consuming. So, the question is whether it is "evergreen" or the current progress of the preparation of a large-scale hydraulic structure for effective protection against floods, which starts in the village of Nové Heřminovy, ends below the town of Krnov, and concerns the border stream with Poland.

However, I can state with pleasure that a zoning decision has been issued for the Nové Heřminovy hydraulic structure, as well as a zoning decision for the realignment of road I/45 along the future flooding of the structure, which is a necessary prerequisite for implementation of the dam. It is also important that relationships with the municipality and communication with its current managers have been restored and are at a very good level.

The Nové Heřminovy reservoir is a complex measure. On the one hand, it will protect over 15,900 inhabitants and roughly 1,900 buildings, which are now in the floodplain of the 100-year flood, and on the other hand, the reservoir will raise the flow in the river and improve the water management balance of the river Opava between the towns of Krnov and Opava, which lies in the so-called precipitation shadow of the Jeseníky Mountains. Another positive fact is that as an investor, the Povodí Odry state enterprise proposes for this hydraulic structure, among other things, a number of modern and unique compensatory measures, such as a bypass channel around the reservoir, which will replace the interruption of the Opava riverbed flow caused by the structure, a solution for an alternative method of sewage flow with areas for their storage above the flooding, and their flooding below the dam. Furthermore, a migration passage through the dam, but also through the Opava valley, is proposed for otters and other animals. Part of the concrete gravity dam is filled with soil for aesthetic reasons and for better integration into the landscape and the Opava valley. The flooding of the hydraulic structure will bring mitigation of extreme climatic effects during hot weather, and the end of the flooding deals with natural development with the gradual creation of habitats.

I can say that a number of planned anti-flood measures in the upper Opava basin have already been completed. These are gauging stations, small reservoirs, and modifications of the Opava riverbed. Preparation of the Nové Heřminovy hydraulic structure continues and I assume that its construction will begin in 2028 with permanent operation starting by 2033 at the latest.

Within the Czech Republic, several dozen locations have been identified as potentially suitable for the construction of new reservoirs. Are there locations you want to focus primarily on?

The General of Areas Protected for Surface Water Accumulation, which was updated in 2020, currently contains 86 sites. Reservoirs are now being prepared from this General in Nové Heřminovy, which I mentioned, as well as in Vlachovice in Zlín district and Kryry in Rakovník district. The plan for Kryry reservoir is expanded to include the construction of the smaller Senomaty and Šanov reservoirs and, in particular, it is supplemented by the construction of a water conduit from Ohře, taken under Nechranice reservoir. This newly built water management system will ensure sufficient and sustainable water resources for the future, even in the event of continued adverse climate change developments. The possible further use of locations from the General will result from the evaluation of the security of existing water abstraction from reservoirs, which is carried out in all Povodí state enterprises. The obtained data will also be assessed from the point of view of the availability of water supply abstractions from groundwater and, in the event of an insufficiency after 2050, it will be possible to proceed with the search for the most suitable solution. It does not always have to be a new reservoir, but the connection of water supply and water management systems. It is obvious that the water resources threatened by the unfavourable development of the water management balance are mainly in the Dyje basin, where 12 sites are protected. The list of protected sites undoubtedly fulfils its purpose, and the choice of sites for implementation will always be based on a careful evaluation of the availability of water resources in relation to the development of the impact of climate change for the situation in individual sub-basins.

In March of this year, very interesting information regarding the selection of suitable locations for the construction of pumped-storage power stations was published on the Ministry of Agriculture website. What will be the next steps? And do you already have a specific schedule?

Yes, at the turn of February and March, the Ministry of the Environment together with our Ministry presented locations where it would be possible to build new pumped-storage hydroelectric power stations (PSH). These are sites where construction does not significantly conflict with nature and landscape protection. The indisputable advantage of PSH is that they can supply electricity to the network almost immediately in case of an acute need, strengthen the stability of the transmission system, and are therefore one of the sources of "green" energy. It is another step on the path to energy independence and security for the Czech Republic, as evidenced by the already existing pumped-storage hydroelectric power stations, such as at Štěchovice dam, Mohelno, and especially Dlouhé stráně in Moravia.


Press conference after the inauguration of Minister Marek Výborný on 29 June 2023 (Photo: MoA archive)

The list of six potential PSH sites was based on the original study of the Ministry of Industry and Trade from 2010, supplemented by the Ministry of the Environment and assessed by Povodí state enterprises. Among the six sites selected for the possible development of new pumped-storage hydroelectric power stations, which are Orlík, Slapy, Pastviny, Libochovany, Vinice, and Slezská Harta, there are two in which the Povodí state enterprises could be a potential investor. For the remaining four, the investors may be different, especially ČEZ, which operates the existing hydroelectric power stations. With their installed capacity of 1,222 megawatts, the potential of these six sites will double the current capacity of pumped-storage hydroelectric power stations in our country.

This year, the Ministry of Agriculture amended the conditions for a subsidy to reduce the content of harmful substances in drinking water, or the conditions for the use of pesticides in protective zones of water resources on arable land. Please tell us about the benefits of this amendment.

The issue of reservoir pollution has long been followed by both experts and the lay public. It is a sensitive topic because the quality of the water we drink is a public interest for all of us, since the quality of drinking water has a direct effect on human health. Given that the Czech countryside is very intensively farmed, which entails, among other things, frequent applications of plant protection products (PPP), i.e., vernacularly speaking, spraying against pests, it is necessary to make a direct connection between the applied PPP substances and the subsequent residues of these substances detected in reservoirs. These are primarily pesticides and their metabolites. As it is in the interest of society to improve the quality of drinking water for the inhabitants of the Czech Republic, it is necessary to motivate economic entities in the catchment area of reservoirs to limit the application of PPP only to the necessary extent, ideally so that agricultural activities are carried out completely without the application of PPP.

The Ministry of Agriculture has prepared a pilot project to reduce the application of PPP in the Švihov protection zone for vulnerable water resources on the Želivka River, which supplies around 1.5 million inhabitants in Prague and Central Bohemia. This pilot project was implemented between 2019 and 2023, with interim results showing a positive trend in the reduction of applied PPP, and it was decided to expand it to other reservoirs at Římov, Vrchlice, and Opatovice. Římov reservoir serves as a source of drinking water for approximately 350,000 inhabitants in South Bohemia, Vrchlice reservoir supplies drinking water to about 60,000 inhabitants in Kutná Hora and Čáslav districts, and Opatovice reservoir to around 42,000 inhabitants in Vyškov district. The purpose of the project is to limit the application of PPP on agricultural land in the protection zones of these reservoirs, where intensive agricultural management leads to an increased occurrence of pesticides and their metabolites. An essential part of the project is the "*Methodology for the management in the protection zones for vulnerable water resources*" (OPVZ) of the affected reservoirs. This document regulates, within the framework of plant production, the possibility of applying only PPP which, in the Register of Plant Protection Products, are not excluded from use in OPVZ II and sanitary protection zones (PHO) of level II of surface water resources, while the maximum limit per hectare of the applied area is strictly set for permitted PPP. Compliance of the management in accordance with the methodology will be checked by the Central Institute for Supervising and Testing in Agriculture through on-site inspections of all involved entities. In compliance with the farming conditions fully in accordance with the Methodology, the involved entities will be entitled to financial compensation as damages for the limited production of commodities, which the farmers will implement as a result of the limited possibility of applying PPP. In the event of any violation of management, i.e. violation of the Methodology, compensation will be reduced by 100 per cent. Although this is a very strict approach, it is essential for our Ministry that the rules are followed 100 per cent for the duration of the pilot project, because only then will we be able to evaluate the impacts of this project in a relatively short period of time. In order to be able to measure and evaluate the given goals, the relevant Povodí managers will monitor both surface and drainage waters in a targeted manner. Continuous monitoring of water quality in the reservoirs in various sections will be a matter of course. I wish and believe that this measure will significantly contribute to improving the quality of drinking water, and therefore the health of the population, which is undoubtedly in the interest of all of us.

The amendment to the Urban Wastewater Treatment Directive (UWWTD) is a current topic in water management. What will the adoption of this amendment mean for Czech water management?

The amendment to the Directive will have a very significant impact on Czech water management. Its implementation will, among other things, reduce the pollution of both surface water and groundwater, which are a source of drinking water, thanks to the tightening of limits for the discharge of wastewater and the introduction of the collection of new substances such as micropollutants, i.e. mainly products of the pharmaceutical and cosmetic industries. Another contribution will be the obligation for municipalities with more than 1,000 inhabitants to have their sewers ending at an appropriate wastewater treatment plant. Until now, this limit was 2,000 inhabitants, so this obligation will now apply to about another 750 municipalities with approximately one million inhabitants.

Simultaneously, the amendment brings opportunities for the introduction of new technologies and innovations in this area, but also in the area of renewable energy sources in connection with the energy neutrality of wastewater treatment plants and sewers.

We must also take into account the fact that all these measures, which as a result will lead to the mitigation of the impact on the environment and human health, will cost a considerable amount of money and will have to be reflected in the future sewage charge.

The amendment to the UWWTD Directive introduces the so-called producer responsibility, where producers should bear part of the costs of breaking down substances contained in their products at wastewater treatment plants. What are your plans and ideas about fulfilling this obligation?

We do not yet have specific ideas about the introduction because the detailed conditions for the introduction of the so-called extended producer responsibility (EPR) are not known. The European Commission should present recommendations and guidelines for implementation in individual Member States before final approval of the Directive, which we expect this autumn. One of the possible guidelines could be the introduction of EPR within the framework of waste management, where manufacturers have responsibility for their products, including their packaging, from the production process through their distribution and sale to the final ecological disposal. For the time being, the responsibility of manufacturers will only concern the pharmaceutical and cosmetic industry, and this system will need to be set up in cooperation with other Ministries – the Ministry of Health, the Ministry of Industry and Trade, and the Ministry of the Environment, in order to ensure the necessary financial resources for fulfilling the EPR with no subsequent restriction on the availability of certain medicines.

You have completed a year in the "chair" of the Minister of Agriculture. Is there anything you would do differently? And what specifically would you like to achieve at your position?

It is confirmed to me again and again that the problem needs to be dealt with constructively and without delay at the negotiating table. We have been dealing with the flood zone decree for almost a year now, which I consider a drawback. I think that in this case we should have been more forceful from the beginning and demanded clear and unchanging opinions from the Ministry of the Environment. The problem now falls on local governments, which I am very sorry for.

And what would I like to achieve? We must certainly focus on the issue of completing the construction of sewers (or domestic sewage treatment plants), the issue of drought and water accumulation in the landscape must be addressed, which is also related to sufficient financial resources for large water management structures, such as the Nová Heřminovy, Kryry or Vlachovice hydraulic structures. I definitely want to continue the debate with the Povodí state enterprises, so that we can direct effective measures on watercourses not only to conventional "concrete" solutions, but also to the semi-natural restoration of streams.

Minister, thank you for the time you have devoted to our interview.

Ing. Josef Nistler

Mgr. Marek Výborný

Mgr. Marek Výborný was born on 10th July 1976 in Chrudim. He studied theology at St. Cyril and Methodius Faculty of Theology, and history at the Faculty of Arts of the Palacký University in Olomouc. Initially, he worked as a teacher of history, social sciences, and Latin at the Pardubice Secondary School, and between 2012 and 2018 he was its headmaster. He has been a member of KDU-ČSL since 2005 and was its chairman in 2019–2020. He has been a member of the Chamber of Deputies of the Parliament of the Czech Republic since 21st October 2017 and was appointed Minister of Agriculture on 29th June 2023. He is also a member of the Scout organization, the Czech Christian Academy, and the secretary of the Vlastislav Heřmanův Městec choir.

New watersheds for first to fourth order catchment areas

RADOVAN TYL, PETR ŠERCL

Keywords: watershed — DMR 5G — catchment area — state geodatabase ZABAGED©

INTRODUCTION

Watershed or catchment area are used as basic input data for a whole range of water management-oriented activities, whether it is rainfall-runoff modelling, calculation of the water management balance, preparation of flood plans, or the use of watersheds as one of the data sources for spatial analysis. A catchment area, defined by its watershed, is also a necessary basis for deriving standard and non-standard hydrological data according to the standard *ČSN 75 1400 Hydrological data of surface waters* [1] and, at the same time, is the basic spatial unit used in hydrological practice.

The definition of a catchment is enshrined in Act No. 254/2001 Coll. (hereinafter referred to as the Water Act) [2], where a catchment is an area from which all surface runoff flows into the sea through a network of watercourses and possibly lakes. A sub-catchment is an area from which all surface runoff flows through a network of watercourses and lakes to a certain point in the watercourse, which is usually a lake or a river confluence. According to decree 252/2013 Coll. [3], hydrological catchments are registered in the form of a polygon based on data from their numerical identifier and the size of the area and are determined on the basis of the hydrological structure of water channels. This identification is the responsibility of the Czech Hydrometeorological Institute (CHMI). From the above it is clear that, in order to accurately determine the watershed of sub-catchments, it is necessary to have the most accurate topographical data available, i.e. the river network with confluences, a defined hydrological structure (the stream order of the mouths of watercourses), as well as the most accurate information about the altitudes of the given area for the correct management of the watershed. In the Czech Republic, CHMI is also responsible for the spatial delineation and numerical registration of watersheds.

Watersheds of primary catchment areas have a long history starting in the second half of the 20th century, when the first hydrological delineation of watercourses was published, in L. Horský et al. *Hydrologické poměry ČSSR* (Hydrological conditions of Czechoslovakia) [4]. With the refinement of the necessary documents, it was also necessary to update the watersheds of the primary catchment areas over the years so that the spatial resolution corresponds to the standards commonly used in state administration. At the same time, from about 1997, there was a transition from paper printed maps, such as the already mentioned *Hydrological conditions of Czechoslovakia* and the *Basic water management map on a scale of 1 : 50,000* (https://www.dibavod.cz/63/puvodni-tistena-zakladni-vodohospodarska -mapa-1:50-000.html), to digitizing watersheds, which subsequently made it possible to perform the first spatial analyses for the needs of hydrological computer modelling. Digitization of watersheds to a scale of 1 : 25,000 took place from around 2001, followed by refinement of the data set of substations to a scale of 1 : 10,000 from 2008.

In the last few years, watersheds of fourth-order catchment areas have been updated in response to the completed fifth generation digital relief model at a spatial resolution of 2 × 2 m [5] and the ZABAGED© stream dataset refined using aerial laser scanning [6].

New documents

One of the main impulses for updating watersheds of fourth-order catchments was the completion of the digital relief model of the fifth generation (DMR 5G) in the Czech Office for Surveying, Mapping and Cadastre (ČUZK). The terrain is processed in a spatial resolution of 2 × 2 m and was published on 30th June 2016 [5]. In CHMI, digital models of the relief serve as one of the key sources for the derivation of hydrological data in ungauged profiles based on the physical-geographical characteristics of the basin. Thus, the updating of watersheds was included in the institutional support project of the Long-term Concept for the Development of a Research Organization (DKRVO).

Other necessary documents are information on the structural and geometric arrangement of watercourses. The geometry of the watercourses was taken from ZABAGED© data. The structure of main watercourses, i.e. the definition of the main watercourse in a given fourth-order catchment polygon, was taken from two data sources, namely from the axial model of the river network, the so-called Central Register of Water Channels (CEVL) [7], which is managed by the Povodí state-owned enterprises together with the Forests of the Czech Republic (LČR) and the State Land Office (SPÚ), and also from the DIBAVOD sectional watercourse model, which, as the only model, contains the hydrological identifier of the order of watercourses and which was already used when updating watersheds on a scale of 1 : 10,000 [8]. Differences in the watercourse structure according to CEVL and DIBAVOD, or ZABAGED© are designed, commented on, and approved within the project "*Harmonization of main watercourses ISVS Voda*" [9]. The approved changes are subsequently incorporated into the ZABAGED© watercourse dataset in roughly six-monthly cycles.

Simultaneously, a number of additional datasets and layers were used when updating the watersheds. One of them is a complete group of ZABAGED© management data, where there are, for example, water bodies, culverts, or the "Nodal point of the river network" point layer, which has information about junctions, confluences, springs, and pseudo-nodes of watercourses. ČUZK map compositions were used with orthophoto images and the *Basic map of the Czech Republic at a scale of 1 : 10,000* provided via the GIS web services of the ČUZK server [10]. The digital surface model of the first generation (DMP1G) [11] was also used as a basis.

An important piece of information was the attribute distinction of ZABAGED© flows, i.e. whether they are underground or surface watercourse.

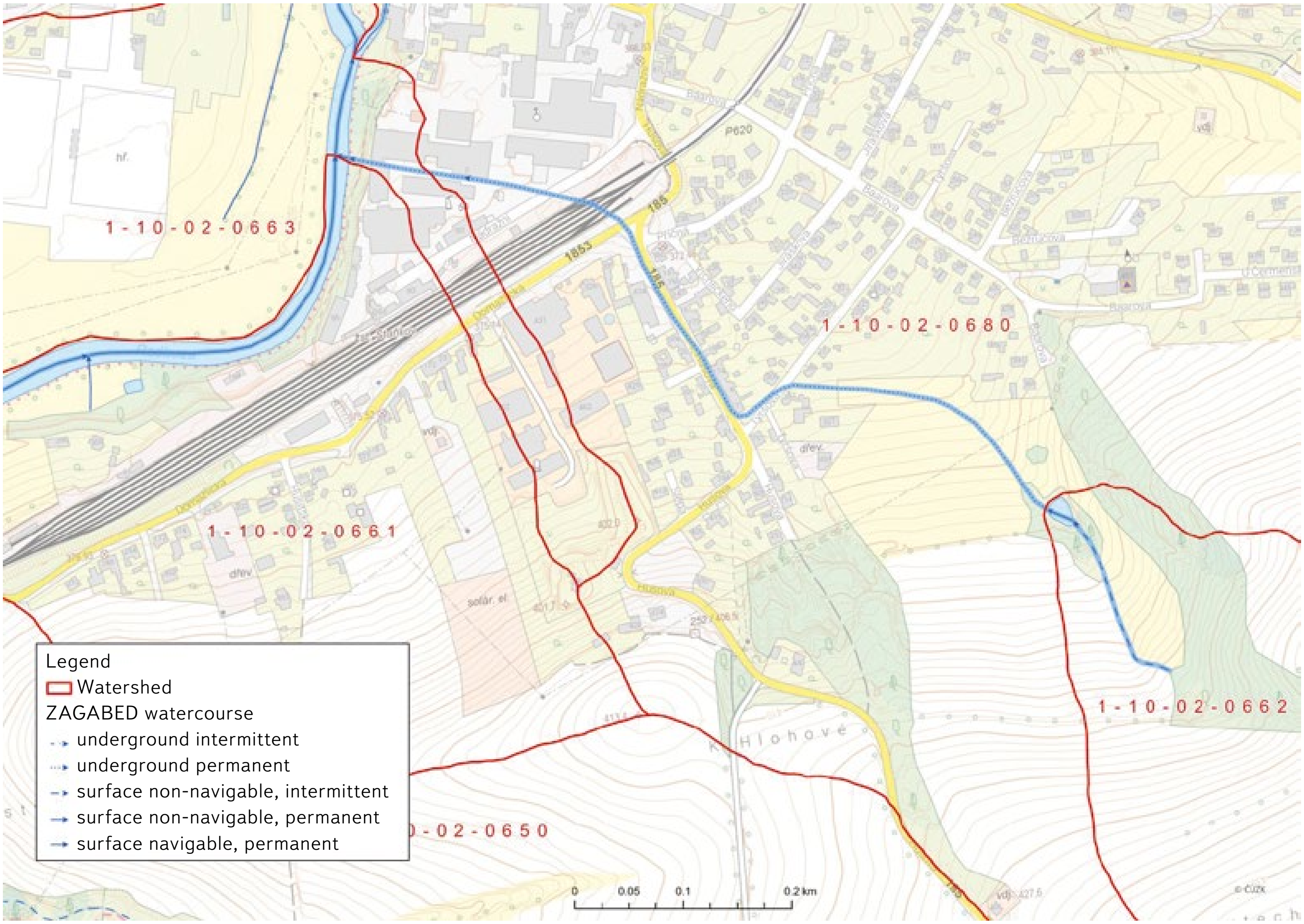

Fig. 1. Example where the drainage divide respected an underground section of a watercourse (dotted blue line)

The watersheds were systematically modified with regard to underground sections, where part of the main watercourse at a confluence can flow underground and where part of the area above the underground part of the watercourse belongs to another, neighbouring basin. The update resulted in six categories of interaction between the underground section and the watershed line:

- watercourse section in a municipality,
- watercourse section outside a municipality,
- watercourse separated crossing,
- short watercourse section in a dam body, bank,
- karst area,
- other.

Most of the cases are the urban parts of a municipality, where there was no need to modify the watersheds because the underground section of the watercourse follows the thalweg of the potential surface section. A more complex case, where the watershed is routed in accordance with the underground section of a watercourse, is illustrated in *Fig. 1*.

Use of the rainfall-runoff model for storm sewers in Prague

One of the impulses for updating the watersheds in the capital city of Prague, taking into account the storm sewer network, was the request of City of Prague to create a rainfall-runoff prediction model of Prague on small watercourses, and also the request of some customers to use the obtained data on the capacities of the sewage system when issuing hydrological data (*N*-year and *M*-day flows).

Pražská vodohospodářská společnost, a. s. (PVS) has its own hydraulic rainfall-runoff model built over the structure of the sewage network of Prague and the wider surroundings, where the basic input spatial units are polygons corresponding to the basic sections of the sewage network (*Fig. 2*). These polygons are derived separately for rainwater and unified sewerage in places where the sewerage networks are separate. There were therefore designated areas for draining rainwater into the sewers, especially where separate sewers exist, mainly in the peripheral parts of Prague. In the centre of Prague, rainwater is drained by a unified sewerage network into the main sewers, of which there are seven in total, and then to the Central Wastewater Treatment Plant (CWWTP) in Prague-Troja. In *Fig. 2*, the water from catchments 1-12-02-0034-0-00-00 and 1-12-02-0035-0-00-00 is diverted to the CWWTP, the other catchments belong to the Rokytka and Hostavický streams.

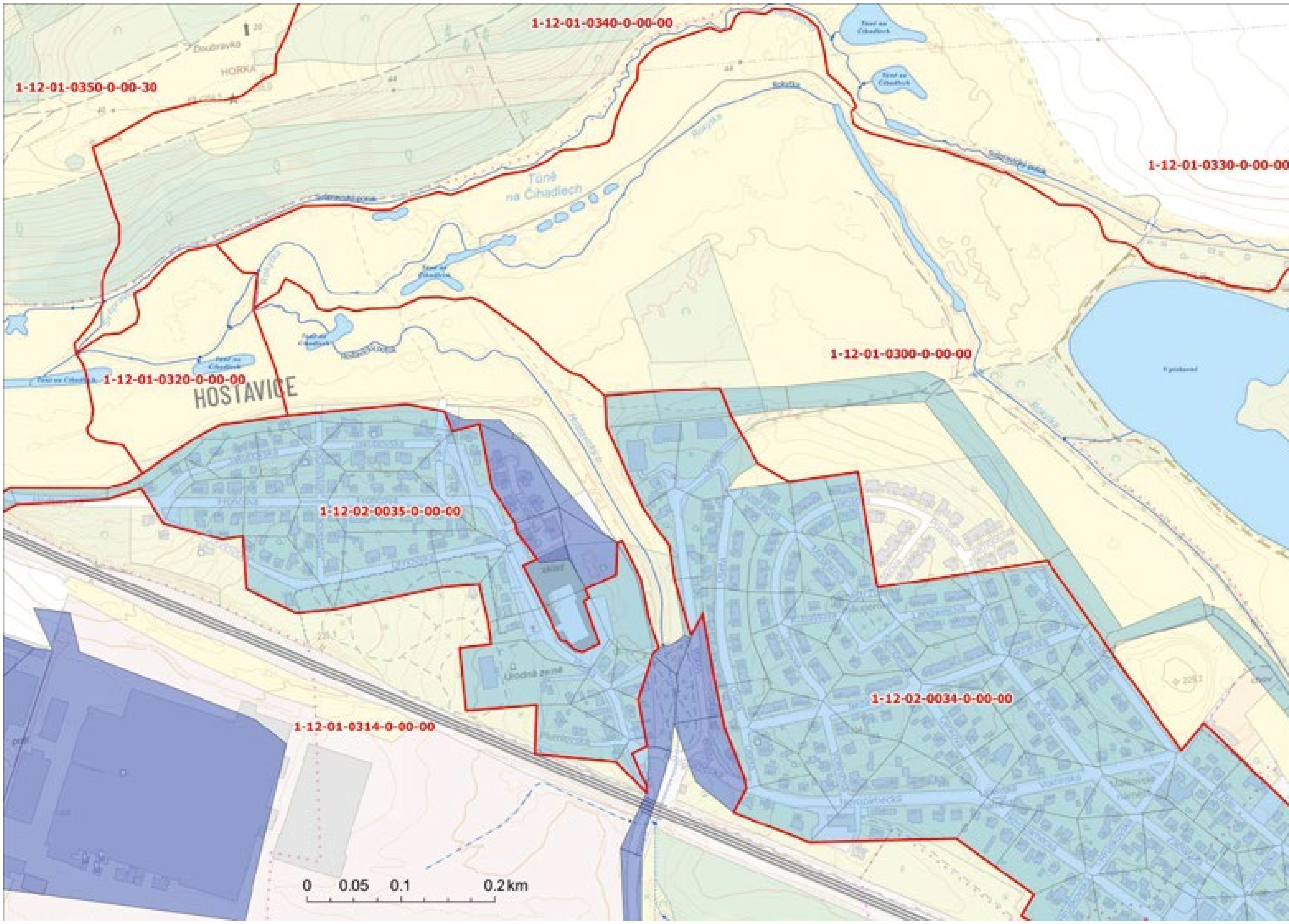

Fig. 2. Example of respecting the sewer drainage in the Prague-Hostavice and Dolni Počernice location in the derivation of the 4th order watersheds;the drainage divides follow the area from which the outflow is streamed to the rainwater sewerage

Foreign watersheds

The watersheds of primary catchment areas do not end at the state borders of the Czech Republic; they extend into neighbouring states. Part of the area is drained from abroad to the Czech Republic (e.g. the upper section of the Ohře, Lužnice, Dyje, and Olše), or only a small part of the foreign catchment lies within the Czech Republic (this concerns all border catchments with Poland, Germany, Austria, and Slovakia). In 2023, it was possible to obtain watershed data from all surrounding countries, but with different levels of details and degree of being up to date (*Fig. 3*). As part of the update of the watersheds, it was therefore necessary to check and correct the connection of our watersheds in cooperation with a selected foreign partner, which was done with as much consideration as possible to preserve the alignment of the provided foreign watershed and at the same time so that the watershed in the Czech Republic corresponds as much as possible to DMR 5G. The closing profiles of catchments flowing from the Czech Republic across national borders were also unified.

Publication of new watersheds

The update took place in the most detailed data set of fourth-order watersheds; other orders and sub- catchments are subsequently generated from this data set based on attributes (number of hydrological sequence/ČHP, sub-catchment flag). Fourth-order catchment attributes also contain information about the structural model of watersheds, i.e. information on the source and following catchments, the size of the area of the given catchment, the total area of the catchment from the source, the name of the main stream in the catchment, and more.

The updating of watersheds based on the most current and most detailed data has resulted in a more precise alignment of the dividing line between two catchments, especially in lowland and flat areas, compared to watersheds at a scale of 1 : 10,000. Changes in the catchment area are most evident in small catchments and sub inter-catchments, with the increasing total area, the differences between the old and new area are smaller or negligible (unless there have been structural changes linked to structural changes of watercourses). Separately, no-runoff areas of the lignite mines of Ore Mountain foothills were delineated with quantitative determination of water transfers to the surrounding natural recipients, which results in a change in the size of the area of the Ohře basin, or Labe. A more

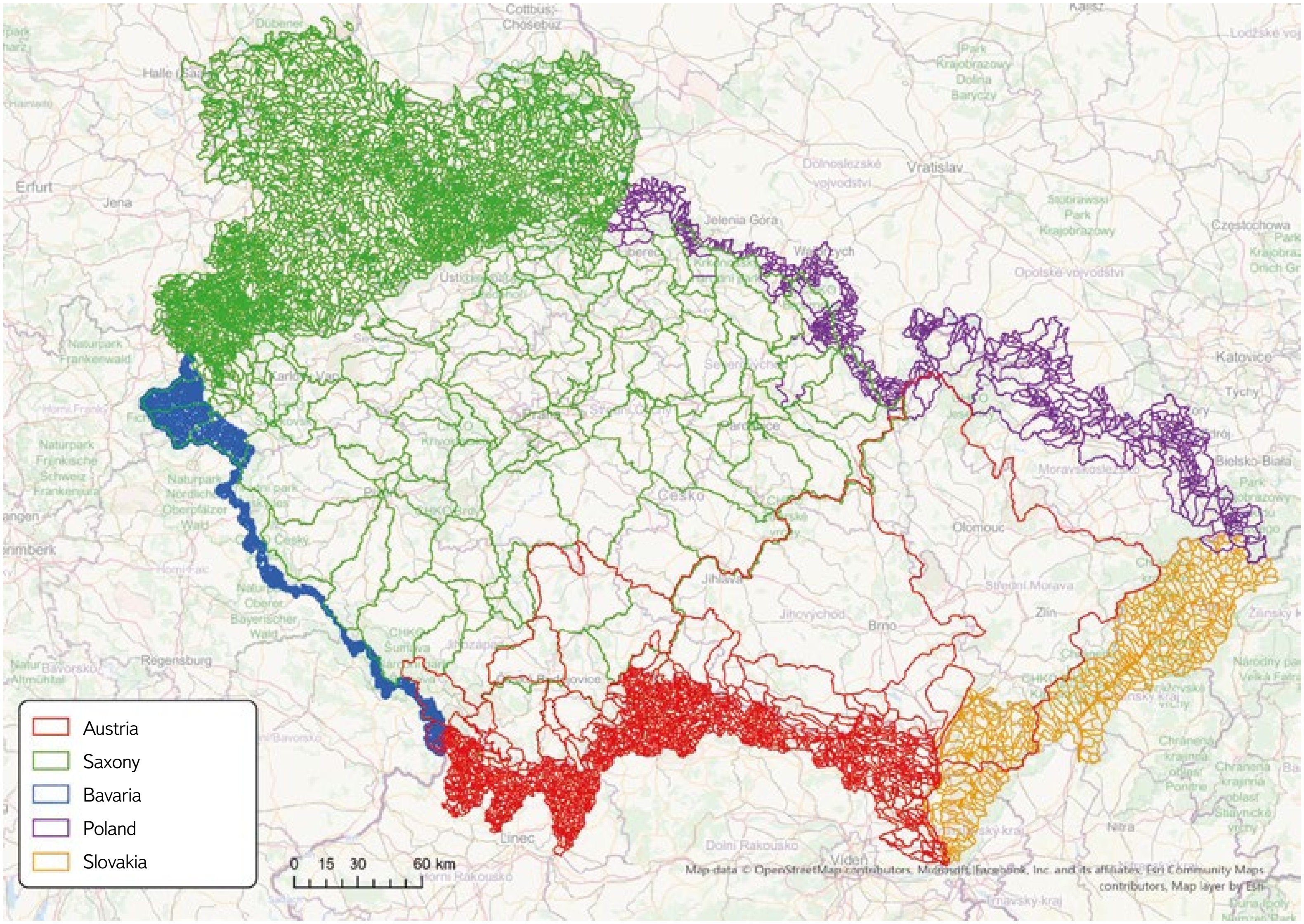

Fig. 3. Map of provided foreign drainage divides

detailed layer of watercourses leads in some cases to the further division of catchments and the creation of new ČHP.

The watersheds separating primary catchment areas reflect the situation under normal, average runoff. During floods, the drained area can vary (even quite significantly). The new watersheds are available to the public from 1st July 2024 at the following address: https://open-data-chmi.hub.arcgis.com/.

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Photo: 123RF.com

Fig. 1. Montreal

Developing cooperation with Canada in the field of water quality

Between 10th and 16th June 2024, Mgr. Kateřina Sovová, Ph.D., TGM WRI, and Ing. Pavla Fojtíková, Ph.D., the University of South Bohemia, visited Canada to liaise over water quality issues, wastewater monitoring, and toxicity research. This event was implemented with the support of the Ministry of Foreign Affairs. Its main goal was to deepen cooperation in the field of UN Sustainable Development Goal 6 (SDG 6).

Canada is engaged in extensive water research in all its key aspects. It places major emphasis on sustainability, also from the point of view of water management and monitoring contamination, as well as on the support of Indigenous peoples, whose communities often face limited access to clean and potable water. This is also why SDG 6, focused on the availability of water and sanitation facilities and their sustainable management, is among its priorities [2].

The visit, coordinated by the Czech consulate offices in Ottawa and Toronto, included a programme in Montreal and Winnipeg, specifically at McGill University and the University of Manitoba.

In Montreal, a visit and meeting took place at the Brace Water Centre at McGill University. McGill University is one of Canada's top-ranked and most comprehensive, research-intensive universities. The Brace Water Centre brings together staff from several faculties working in the field of water resources management, both in Canada and internationally. The visit also included a tour of the laboratories of the Department of Civil Engineering and a meeting with professors Frigon, Gaskin, and Loeb as well as students who presented their research activities in the areas of wastewater surveillance, antimicrobial resistance, eliminating As from drinking water, recovering P from sludge, photocatalytic remediation, and microbial indicators [3].

Lectures of both our researchers on the topics of water quality, wastewater, and toxicity made it possible to share information about key Czech institutions active in the field of water environment research and research projects, as well as to offer opportunities for further cooperation. A lecture by Mgr. Kateřina Sovová, Ph.D. focused on monitoring the occurrence of infectious agents through wastewater analysis (including SARS-CoV-2 monitoring) and the occurrence of antimicrobial resistance in the aquatic environment. Ing. Pavla Fojtíková, Ph.D. reported on research in the field of toxicity and degradation of pharmaceuticals [1–3].

In Winnipeg, a visit to the University of Manitoba took place. It is a leading research institution in areas such as the aquatic environment and agriculture. This university is an SDG 6 hub in North America. As part of the visit, there was an expert lecture by Czech researchers and a round table with experts focused on SDG 6 research (Dr. Sparling, Dr. Uyaguari Diaz, Dr. Klymiuk, Dr. Perry, Dr. Palmer, Dr. Bay, Dr. Becker, Dr. Farenhorst, Dr. Kumar) as well as a visit to the laboratories in the Richardson Centre for Food Technology and Research, Price Faculty of Engineering, and the Faculty of Science. At the Faculty, research was presented regarding the determination of pesticides and other substances in food products, testing of technologies for wastewater treatment and removing P and N from sludge, the issue of efflux pumps in acinetobacters, water quality, determination of selected pathogens, resistance genes, microbial communities

Fig. 2. Visit to McGill University

Fig. 3. Lecture at McGill University

Fig. 4. Acquaintance with students' work

Fig. 5. Tour of laboratories at McGill University

Fig. 6. McGill University

and resistome in different types of water, also in relation to the Indigenous people of Canada. The Czech delegation also visited a wastewater treatment plant in Winnipeg, where the University of Manitoba is conducting research focused mainly on the quality of discharged wastewater [2, 4].

During the visit to Canada, possible opportunities for cooperation were also discussed, including the mobility of students and researchers and possible joint research projects. Canada's participation in the Horizon Europe programme [2] offers a significant opportunity.

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Fig. 7. University of Manitoba

Fig. 8. Round table at the University of Manitoba

Fig. 9. Tour of microbiology laboratories at the University of Manitoba

Fig. 10. Tour of the laboratories of the Richardson Centre for Food Technology and Research

Fig. 11. Winnipeg

Fig. 12. Visit to a WWTP in Winnipeg (NEWPCC)

Fig. 13. Niagara Falls

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VIDNAVA WETLANDS

Vidnava wetlands protected nature reserve, created on the clayey sediments of the Vidnávka river, forms the lowest point of Jeseník district with its 222 m above sea level. It can be found north of the partially disappeared village of Vidnava (Weidenau) near the state border with Poland. The whole area of Javorník district, together with Osoblaha municipality located further east, is a landscape affected by a gradual decrease in the number of inhabitants, which often led to the complete disappearance of municipalities. In the immediate vicinity of Vidnava, there is, for example, the completely abandoned settlement of Johanka and Horní Heřmanice castle. Despite the ever-present melancholic mood of this landscape, we can find many beautiful and valuable places from the point of view of natural and national history. In the Vidnava wetlands, there are a large number of interesting and protected animal and plant species. Among the rare species of aquatic plants are common bogbean (*Menyanthes trifoliata*), water violet (*Hottonia palustris*), bog arum (*Calla palustris*), and round-leaved sundew (*Drosera rotundifolia*). Of the rare species of animals, we can observe barn owl (*Tyto alba*), lesser-spotted eagle (*Clanga pomarina*), common crane (*Grus grus*), and a yellow-bellied toad (*Bombina variegata*). Many native fish species survive here, such as common carp (*Cyprinus carpio*), crucian carp (*Carassius carassius*), northern pike (*Esox lucius*), common perch (*Perca fluviatilis*), and common bream (*Abramis brama*). This varied species composition once again points to the importance of aquatic and semi-aquatic habitats in the landscape in terms of biodiversity and ecological stability. Sitting under the canopy of trees on the bank during a summer day, we will gradually feel the peace and calm of this landscape and the genius loci of Jeseník and Javorník districts.

Text and photo provided by doc. RNDr. Jan Unucka, Ph.D.

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