SBORNÍK TAGUNGSBAND

Magdeburský seminář o ochraně vod 2023
Magdeburger Gewässerschutzseminar 2023
11.–12. 10. 2023

Extrémní hydrologické jevy a jejich dopady v povodí Labe

Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Seminář se koná pod záštitou ministra zemědělství a hejtmana Karlovarského kraje.
Das Seminar findet unter der Schirmherrschaft des Ministers für Landwirtschaft der Tschechischen Republik und des Hauptmanns des Bezirks Karlsbad statt.

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EXTRÉMNÍ HYDROLOGICKÉ JEVY A JEJICH DOPADY V POVODÍ LABE

EXTREME HYDROLOGISCHE EREIGNISSE UND DEREN FOLGEN IM EINZUGSGEBIET DER ELBE

Organizátoři děkují všem spolupořadatelům a partnerům konference.

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Odborné příspěvky / Fachbeitrage

Omezení následků hydrologických extrémů / Minimierung der Folgen hydrologischer Extremereignisse

Vyhodnocení extrémních povodní / Auswertung historischer Extremfluten

Dopady změny klimatu na vodní zdroje a ekosystémy / Auswirkungen des Klimawandels auf Wasserresourcen

Posterova sděleni / Posterprasentationen

Odborné příspěvky Fachbeiträge

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Experiences with the preparation of necessary measures to solve drought in the Czech Republic

Josef Reidinger

Initial conditions for the preparation of active drought management

- Long-term drought on the territory of the Czech Republic, which already in 2015 ranked among the most historically significant drought episodes on our territory, escalated even more in the following years
- coordination of activities of individual ministries within the inter-ministerial working group WATER-DROUGHT since 2014
- "Preparation of the implementation of measures to mitigate the negative impacts of drought and water scarcity" (approved by Government Resolution No. 620 on 29 July 2015)
- "Concept of drought protection for the territory of the Czech Republic" (approved by Government Resolution No. 528 of 24 July 2017) and, following the submission of the "Report on the implementation of the Concept of drought protection for the territory of the Czech Republic for the period 2017-2022", adopted a modified version of the "Concept of drought protection for the territory of the Czech Republic for the period 2023-2027" (approved by Government Resolution No. 354 of 17 May 2023)
- "Climate Change Adaptation Strategy for the Czech Republic" (update approved by Government Resolution No. 785 of 13 October 2021 and the National Action Plan for Adaptation to Climate Change (approved simultaneously with the Adaptation Strategy in 2021)
- Act No. 544/2020 Coll. amending Act No. 254/2001 Coll., on Water and on Amendments to Certain Acts (Water Act), as amended, and other related acts - for operational solutions, a new title of the Act "Drought and Water Scarcity Management"

Longer-term measures linked to water resources

- Significant investment and more permanent measures in the national river basin management plans (under the Water Framework Directive 2000/60/EC), currently approved for six-year periods (2022-2027), where drought is mainly addressed in the chapters
  - IV.5 Objectives to reduce the adverse impacts of hydrological drought
  - V.1.17 Summary of measures to reduce the adverse effects of drought

Operational (short-term) measures linked to water resources

- Drought and water scarcity management plans for areas where a water scarcity situation is declared (to be completed at the regional level by 31 January 2023, at the national level by 31 January 2024 at the latest)
  - selection of significant water users in the region and the water resources used by them
  - Establishing a sufficient time interval for the progressive adoption of the necessary measures to delay the risk of complete source disconnection
  - analysis of historical drought episodes and verification of the limits set
  - identification of the impact of limits outside the region
  - introduction of the concept of "user" (authorised water use, direct abstraction from a water source) and "customer" (indirect abstraction via public water supply) - respecting the same approach to limiting abstractions
  - measures for the necessary period of time:
    - general surface water uses shall be regulated, restricted or prohibited
    - permitted water uses shall be modified, restricted or prohibited
    - the use of tap water for public consumption shall be restricted
    - the owner of the water structure is ordered to carry out extraordinary manipulation on the structure beyond the approved manipulation rules
    - order the owner of a technical installation used for abstraction from a back-up water source to put it into operation, if technically possible, so that the back-up water source can be used

        - the ecological flow or the minimum groundwater level laid down in the water management permit shall be adjusted or set
        - order the owner of the necessary water management facility to put it into operation and make it available to address the water shortage, if technically feasible; or
        - order emergency monitoring of water quantity and quality
    - Priorities of water resource security (in descending order)
        - ensuring the functionality of critical infrastructure as per the regulations governing emergency management and other operations providing essential services
        - supply of drinking water to the population
        - livestock, fish and aquatic animal production, as agricultural production, and the ecological function of water
        - economic uses not falling under (a) to (c) and other uses linked to local employment
        - other uses
    - analysis of the possibilities for progressive reduction of abstractions and their impact on water resources
    - consultation with major water users
- drought commissions at regional and central level
- Outside the areas with declared water scarcity, the competence of the water authorities at the level of municipalities with extended competence and regions remains (restrictions on general water management, emergency handling of waterworks, restrictions on abstractions)

HAMR information system

- Presentation of current and projected drought trends on the website of the Czech Hydrometeorological Institute
- every week on Wednesday, the different types of drought - meteorological, hydrological (for surface and groundwater), agricultural and water scarcity hazards (comparison of available water resources and permitted withdrawals) are presented in a uniform and clear manner for the whole territory of the Czech Republic
- current status and development of drought indicators (data available for surface water since 1981 and for groundwater since 1991)
- warning information on natural hydrological drought for the individual areas of municipalities with extended competence
- the presentation of the current development of local guideline limits for selected water sources defined in the individual regional drought plans is being finalised

Literature:
[1] The current drought situation within the hydrometeorological situation in the Czech Republic [online], available at: https://www.chmi.cz/aktualni-situace/sucho
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Water losses in the Všechlapy reservoir basin and the possibilities of their reduction during the hydrological drought

Miroslav Šobr, Petra Vítková, Anna Junková

1. Introduction

The catchment area of Loučenský brook and Bouřlivec river is located in northwestern Bohemia, in the eastern part of the Ore Mountains and in the Mostecká basin. A number of water courses in this basin are anthropogenically affected due to extensive brown coal mining. Both watersheds fall under the administration of Povodí Ohře s.p. Water losses in the Loučenský brook and Bouřlivec basins (which are the main sources of the Všechlapy reservoir) are detected mainly on the basis of longitudinal profiling of flows and recorded water withdrawals. Flow measurements were carried out on a total of 43 profiles in five different hydrological conditions with a focus on the dry season in 2020 and 2022.

2. Methods and data

The intensity of hydrological drought was assessed in the Bouřlivec and Loučenský brook basins using the method of threshold values (Q_{330}, Q_{355} and Q_{364}) and the method of insufficient volumes. Data from the Lahošť limnigraph (LG Lahošť) were available for Bouřlivec, data from the Duchcov limnigraph (LG Duchcov) for Loučenský potok. Data is available for the period 2006 - 2022. According to the results of the analysis of the hydrological drought, the hydrological year 2020 was marked as exceptionally low water, in which a field investigation was carried out in order to map water losses in the Bouřlivec and Loučenský brook basins in three summer terms, when the hydrological drought gradually increased. The next measurement was carried out in August 2022. The selection of gauge profiles for longitudinal profiling of flows was determined that the measurement was carried out on site before or after surface water abstraction. Furthermore, the amount of water withdrawn and returned was measured. At the same time, the effort was always to carry out at least two flow measurements in the longitudinal profile for smaller tributaries. The first in profile before the tributary to the built-up areas and the second before the confluence with Loučenský brook or Bouřlivec (Fig. 1). Several methods were used to measure flow rates within longitudinal profiling. If possible, we used the most accurate direct measurement method using a calibrated container (volume 1, 10 or 20 litres). In conditions where it was not possible to use the volume method due to the nature of the river bed or the amount of water flowing through, the method of measuring the velocity and the area of the profile (ČSN ISO 748) was used. A FlowTracker device was used to measure the velocity and the area of the profile. In the area of interest, the loss of water by evaporation from the free water surface was calculated from the relationship based on the air temperature from the meteorological station Všechlapy. The formula was derived based on the dependence of the observed vapor and air temperature in the Hlasivo station for the period 1957–2018 [1].

$$VVH = 0{,}0824 \times T^{1{,}289}$$

VVH is vapor from the water surface [mm/month] a T is average monthly air temperature [°C].

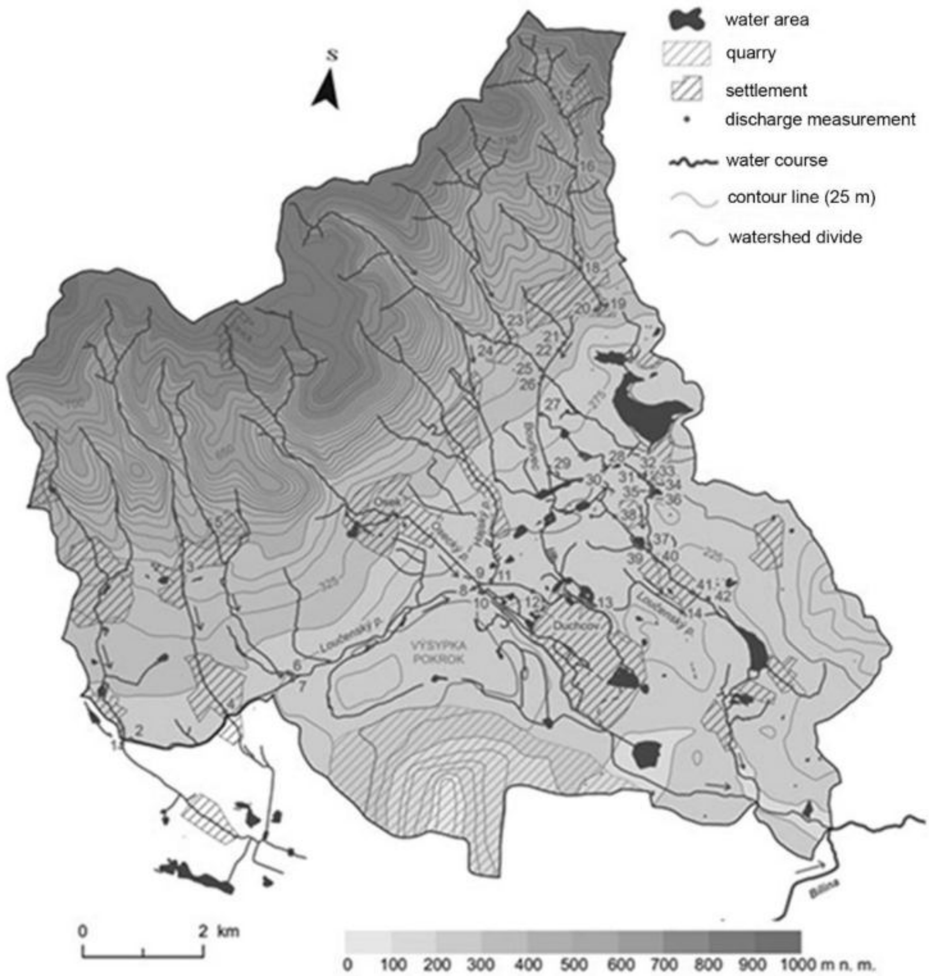

Fig. 1: *Map of the Všechlapy reservoir catchment*

3. Hydrological drought

According to the values of the average annual flows, it can be seen that since 2014 the Bouřlivec and Loučenský brook basins have been experiencing a continuous dry period (tab. 1).

Tab. 1: *Values of average annual discharges and long-term discharge on LG Lahošť and LG Duchcov for the hydrological period 2006-2022 (bold and italic are years with a lower discharge than the long-term discharge)*

Year	LG Lahošť [m^3/s]	LG Duchcov [m^3/s]	Year	LG Lahošť [m^3/s]	LG Duchcov [m^3/s]
2006	0.31	0.46	2015	***0.25***	0.44
2007	***0.26***	0.43	2016	***0.27***	***0.28***
2008	0.37	0.54	2017	***0.29***	***0.40***
2009	0.31	0.49	2018	***0.20***	***0.30***
2010	0.35	0.60	2019	***0.25***	***0.33***
2011	0.37	0.58	2020	***0.17***	***0.21***
2012	0.30	0.53	2021	***0.28***	0.44
2013	0.55	0.58	2022	***0.24***	***0.31***
2014	***0.26***	***0.29***	Q_a	0.29	0.42

The assessment of the hydrological drought from 2006 to 2022 shows that, based on the assessment of threshold values, the drought was most pronounced in the Loučenský brook basin in 2020, in the Bouřlivec basin in 2018 (fig. 2). In terms of insufficient volumes, the highest deficit runoff volume was recorded in 2018 for the Lahošť profile and in 2019 for the Duchcov profile.

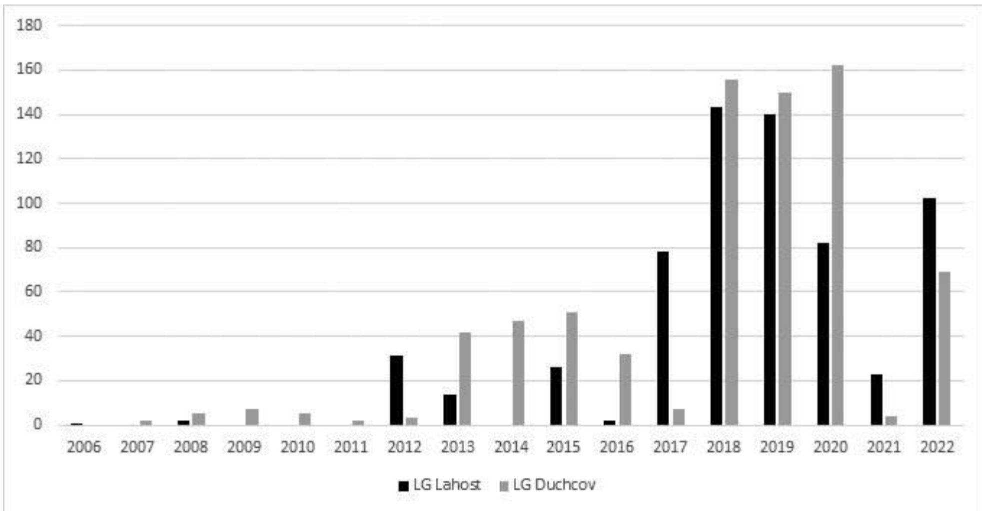

Fig. 2: *The number of dry days according to the Q_{355d} threshold value on the Lahošť and Duchcov profiles in individual years*

4. Assessment of the hydrological balance in the Loučenský brook and Bouřlivec basins based on longitudinal flow profiling

The aim of the longitudinal profiling of flows and hydrological balance assessment was to provide information for possible stabilization and strengthening of inflows to the Všechlapy reservoir and to increase the security of withdrawals from the Všechlapy reservoir for the AGC Flatglass glassworks and the Ledvice power plant, for which it provides water supply in case of failure of the Elbe feeder. In particular, water abstractions affecting the water quantity in the Všechlapy reservoir and local hydrological anomalies such as pumping of mine water and transfer of water from the Fláje reservoir were monitored.

Table 2 shows an example of the measurements made on the Loučenský brook. A check longitudinal flow profiling was carried out in spring 2021. Its purpose was to check how the flow changes when there is an above-average amount of water flowing in the stream and when the abstractions to the pond systems are closed (at Bouřlivec). It was found that the flow in both the Bouřlivec and Loučenský brook increases uniformly, the values of specific discharges are within the expected values. The water is not lost anywhere apart from the measured abstractions.

A comparison of recorded and actual abstractions from the catchment was made. These are watering abstractions that managed to "dry out" smaller watercourses in the dry summers of 2020 and 2022. Pond systems are also a major problem for water loss in the basin. There is no continuous data on water withdrawals, only specific values have been measured each time as part of longitudinal flow profiling. Five locations where this abstraction occurs have been located. At Stormwater the outflow to Hajniště pond (usually a loss of around 2 l/s), to the Dub pond system (a loss of around 8 l/s) and to Kamenitý pond (a loss of around 2 l/s). On the Loučenský brook, part of the water is diverted through the original Osecký brook bed and into the pond above the village of Duchcov (both around 10 l/s). In the case of the Loučenský brook, the water is returned to below the Všechlapy reservoir, while in the case of the Bouřlivec, almost no water is returned from the ponds. The total evaporation from the water areas (about 1.5 km^2) is up to about 16 l/s in summer months, with additional water being consumed for evapotranspiration from the adjacent floodplain vegetation.

Tab. 2: *Selected measured values of discharges during longitudinal flow profiling on the Loučenský brook. The discharge (Q) values are given in l/s, the specific discharge (q) values are given in $l.s^{-1}.km^{-2}$. Localization of profiles see Fig. 1.*

Loučenský brook	14.07.2020		10.9.2020		15.04.2020		25.08.2022	
	Q	q	Q	q	Q	q	Q	q
1 Hygienic rinse	2.5	-	4	-	2.1	-	3	-
2 Relocated track of the Radčický brook	43.8	4.7	3.5	0.4	54	5.8	24	2.6
3 Lomský brook in village Loučná	5.8	1.2	5.3	1.1	99.8	19.9	5	1
4 Lomský brook	0.8	0.14	2.1	0.4	101	17.9	4.5	0.8
5 Loučenský brook in Loučná village	0.5	0.17	0.35	0.12	43	15	0.3	0.1
6 Loučenský brook	0	0	0	0	48.8	9.7	0	0
7 Radčický brook	33.4	1.8	29	1.6	154	8.4	17	0.9
8 Loučenský brook	34.9	1	25.6	0.8	265	7.8	17	0.5
9 Osecký brook	1.5	0.21	0.4	0.1	113	15.8	0.1	0.01
10 Residual channel of the Osecký brook	11	-	10.2	-	18.5	-	5	-
11 Hajský brook	0	0	0.05	0.01	16.3	2.2	0	0
12 Loučenský brook above fish tanks	21.1	0.4	11.9	0.2	369	7.5	12	0.2
13 Loučenský brook near Leontýna pond	8.8	0.2	0.5	0.01	383	7.6	0.2	0.004
14 LG Duchcov	27.6	0.5	7.2	0.1	289	5.6	2.5	0.05

Conclusions

It is necessary to control the compliance with the set rules of water withdrawals in the catchment area of Všechlapy reservoir. Flows on the watercourses already at the end of their source sections before flowing into the first settlements were very low in the summer periods 2020 and 2022. In addition to low rainfall, water abstractions for the needs of gardeners etc. were also a contributory factor. These abstractions were also evidenced in the longitudinal flow profiling, with a number of streams in the summer period experiencing even a small flow that was present in the stream (approximately 10 l/s) being lost or removed after flowing through the settlement. Although these small abstractions may appear to be negligible, they are clearly not negligible in their totality in an extremely dry period and certainly amount to several litres per second in the whole catchment according to our measurements and estimates. It would therefore be necessary to encourage these customers to use, for example, captured rainwater or water stored in sufficiently watery seasons for their needs.

One solution to combat hydrological drought appears to be the use of water bodies that would be suitable for water storage. Hypothetically, the only usable water surface appears to be the flooded residual pit after the Barbora coal mining. If it would be possible to agree with the users of the water area to manipulate the level by e.g. 1 m, a storage volume of approximately 630 000 m^3 could be created at relatively low financial cost, which could subsidise the Bouřlivec with a flow of approximately 80 l/s during the expected low flows in the summer period (e.g. 90 days). However, with the current use of this water area, the above described water storage in the Barbora reservoir is probably unrealistic.

On the basis of the data on the water flows on both streams and the data on the water subsidies to the watercourses, it can be concluded that the Loučenský Brook is the waterier stream and is therefore more important for the Všechlapy reservoir. At the same time, however, Loučenský Brook is fundamentally dependent on water subsidies. The main subsidies for the Loučenský brook are from overproduction from the Fláje waterworks, and from the Bílina mines. The main source of water subsidised to the Bouřlivec is the Giant Spring in Lahošť. In 2015-2019, the total subsidies accounted for between 52 and 82 percent of the water that flowed into the Všechlapy reservoir. In the driest years, the proportion of subsidies declined (2018 and 2019 53 and 52 percent, respectively). If we are to find any reserves in the basin (and if we accept that all existing withdrawals to the plants are needed and not wasted), the above suggests that we need to look for reserves in two directions. In the management of the ponds, where it appears that there is a significant amount of water being lost throughout the catchment, and in the small-scale users who draw water for their own use.

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Revitalisation of rivers and floodplains - Naturschutzgroßprojekt Mittelelbe – Schwarze Elster

Schumacher, Heiko & Puhlmann, Guido

1. Introduction

With its river landscape, the free-flowing Elbe is one of the most ecologically rich natural areas in Central Europe and one of the most valuable for the preservation of natural biological diversity. At the same time, Elbe is also affected by problems such as severe river sole erosion and drying floodplains as a result of the waterway expansion. Emerging effects such as climate change are increasing this negative development.

The area of the strongest sole erosion on the Elbe lies between the cities of Torgau (state of Saxony) and Wittenberg (state of Saxony-Anhalt). Deep erosion here is up to 2 cm per year. This part of the Elbe is an area of outstanding ecological importance. Due to erosion, the river and surrounding wetlands are continuously losing their resilience to the expected consequences of climate change as extreme weather events (drought). The connection between river and floodplain as well as the typical water conditions are steadily deteriorating. Groundwater levels are sinking, oxbow lakes are drying up, valuable habitats and biodiversity are becoming increasingly rare and are acutely endangered. This also poses a threat to the UNESCO Biosphere Reserve "Mittelelbe" and the UNESCO World Heritage Site "Gartenreich Dessau-Wörlitz", as the ecological, cultural and economic quality of the landscape, the river and its floodplains is significantly influenced by water.

In this article, the Naturschutzgroßrpojekt (large-scale nature conservation project, NGP) "Mittelelbe - Schwarze Elster" is presented as an instrument for limiting negative processes and upgrading important habitats on the Elbe in Saxony-Anhalt.

2. Problem-solving approaches and project goals

In view of the problems identified, there is a need for comprehensive action. As a consequence, a concept for stabilizing river sole was adopted in 2009 by the German Federal Government and the federal states of Saxony and Saxony-Anhalt (WSA/BfG/BAW 2009). Since then, the Federal Waterways Administration and the State of Saxony-Anhalt have been responsible. This was followed in 2017 by the "Gesamtkonzept Elbe" (BMVI & BMUB 2017). The federal and state governments are currently establishing the "Pilotprojekt Klöden ", which includes measures to reduce riverbed erosion and the deterioration of the condition of the floodplain. According to German law, the federal government is responsible for the waterway (river) itself and the state is responsible for the wetlands and floodplains (land area). Therefore, measures in the river are planned and implemented by the Waterways and Shipping Administration. These include, for example, the lowering of the existing groynes or the removal of embankments. The State Agency for Flood Protection and Water Management (LHW) and the Middle Elbe Biosphere Reserve Administration are responsible for measures in the foreland. In the section of the Elbe under consideration, the LHW is planning several dike relocation projects.

Further ecologically important measures to enhance the floodplain, such as the reconnection of oxbow lakes, are being planned via the NGP. The main objectives of this project are:

- Reduction of the sole erosion in the Elbe and improvement of the water balance in the floodplain
- Improvement of the hydraulic interconnection of river and floodplain
- Revitalization of the landscape and habitat mosaic of lowland floodplains with the characteristic species
- Preservation and revitalization of valuable floodplain-typical habitats (e.g. small water bodies)
- Strengthening of plants in the floodplain and riparian forest, enhancement of floodplain grassland

The NGP is carried by the Heinz Sielmann Stiftung (Foundation, HSS). It receives funding for planning and implementation from the federal government (Federal Agency for Nature Conservation with funds from the Federal Ministry for the Environment, 75%) and from the state (State Ministry of the Environment, BfN, 15%) and contributes 10% of the costs. These are estimated at approximately EUR 36 million for the entire project. The NGP is divided into a planning part (2020-2023) and an implementation part (approx. 2024-2034).

A close cooperation partner of the HSS is the Biosphere Reserve “Mittelelbe”. The measures taken by the federal government in the river area and those of the NGP in the “Pilotprojekt Klöden” are to be approved in a joint planning approval procedure.

3. The planning space

The planning area in the NGP is 4,937 hectares in size and includes the recent Elbe floodplain and parts of the former floodplain. In terms of nature, it lies in the Breslau-Magdeburg glacial valley and is part of the "Elbe-Elster lowlands" (source: BfN). The Schwarze Elster is part of the planning area over a length of about 14 km from the city of Jessen to its confluence with the Elbe. The area is located in the district of Wittenberg in the eastern part of Saxony-Anhalt and, with the exception of a few areas, part of the Biosphere Reserve “Mittelelbe” (Fig. 1) on the territory of four cities.

There are no settlements in the planning area. The area is mainly used for agriculture and forestry. Grassland use dominates, which is mainly mowing methods. Numerous regularly dry waters (such as the “Alte Elbe Bösewig” or the “Klödener Riss”) and some even more water-bearing (such as the “Großer Streng” or the “Bleddiner Riss”) with countless former flood channels and typical floodplain structures, but also sandy elevations with dry grasslands and forest characterize the area.

The area is characterised by species that are often declining in the planning area, such as common cranes, snipes, whinchats, beavers, dwarf mice, fire-bellied toads, tree frogs, siberian iris or dwarf cypergrass.

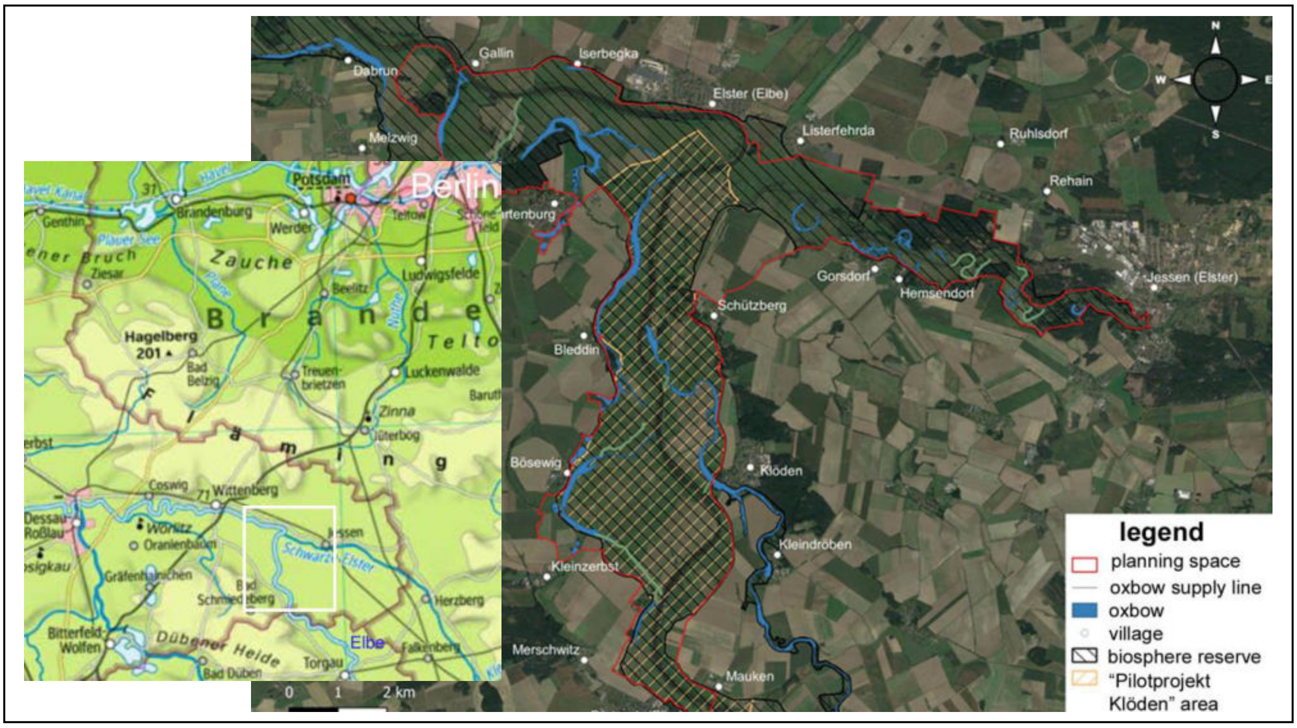

Fig. 1: *The planning space of the NGP Mittelelbe-Schwarze Elster (white frame in the overview)*

4. Project measures

In order to achieve the project goals listed above, further measures such as the re-establishment of floodplain areas or the upgrading of grassland use, e.g. through the transfer of mown material, are planned in addition to the connection of oxbow lakes and the restoration of oxbow lakes. Where land use is not affected, flood channels are to be reactivated. Sediment removal is being planned for numerous small bodies of water. Outside the Elbe floodplains, small oxbows are to be restored in the lower reaches of the Schwarze Elster. In addition, it is planned to make various changes in the course of the Schwarze Elster. Species protection measures and facilities for the public are also part of the NGP.

An example of a major measure is the connection of the “Alte Elbe Bösewig” (Fig. 2). The earlier, winding course was already cut off in the 19th century by a straightening. Due to the deepening of the Elbe and recent very dry years in summer and autumn, the oxbow is now temporarely completely dry - with all the negative consequences for the living and lifeless environment. An inflow of water actual only takes place at elevated water levels and first from undercurrent. A new connection at a water level in conjunction with comprehensive sediment removal is expected to have the following effects:

- Elbe water flows directly into the oxbow lake on about 180 days/year
- Excess water flows back into the Elbe via the outlet channel
- The Elbe bed is relieved, especially in the event of flooding
- In the floodplain, more water is retained longer
- The result is a permanent body of water with a large water surface and large volume

In addition to the consideration of hydraulic and hydrological aspects in the channel and its immediate surroundings, other requirements must also be examined during planning, such as the stability, embankment and flood safety of the protective dikes (by the LHW), utilization possibilities of the sediments or the accessibility of the areas for land users.

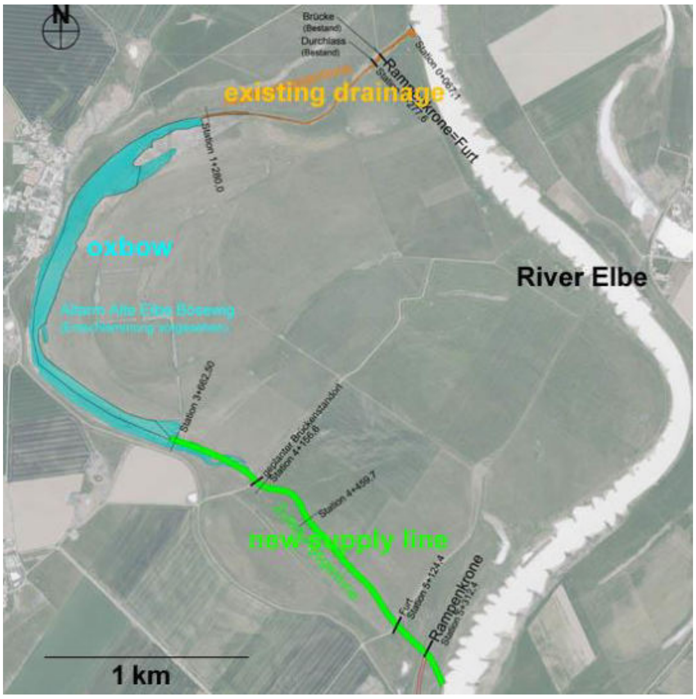

Fig. 2: *Planned oxbow connection (Alte Elbe Bösewig)*

5. Perspective

Anchoring such a large project in a region requires more than just planning activity. Acceptance by land users as well as municipalities and residents is a basic requirement for the success of the project. The basis for the high level of acceptance of the project was laid by years of intensive public relations work - especially by the biosphere reserve administration - since 2009. Combined with the pilot character and the partly joint planning with actors from the federal and state governments, as well as the positive expectations of the actors in the region, the basics for successful project implementation are in place. This offers good conditions for curbing the erosion of the bed and for significantly improving ecological quality by linking rivers and floodplains.

6. Literature

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2D-modelling of water-level-reducing management options at the Lower Middle Elbe

Schramm, Wiebke; Promny, Markus; Hatz, Marcus

1. Introduction

The Elbe river has experienced five major floods between August 2002 and June 2013. Climate projections show that there is a 5% to 30% increase of mean flood flow to be expected in the Elbe catchment within the next decades [1], and further extreme events cannot be excluded. At the same time, high embankments, existing dikes with varying floodplain widths and some strong growth of typical alluvial forest vegetation in the Lower Middle Elbe have created hydraulic bottlenecks. In these areas, the freeboards are partly in deficit, increasing the risk of dike overtopping or breaches. In addition, natural retention areas have steadily reduced to up to 76% of their original size [2].

After the devastating flooding in June 2013, the German Federal Government and federal states (Länder) decided on the joint elaboration of a nationwide flood protection programme (NHWSP), under which the government supports the realisation of large-scale retention measures designed to improve transregional flood prevention [3]. In an ongoing collaborative project between the Federal Institute of Hydrology (BfG) and five riparian federal states (Saxony-Anhalt, Brandenburg, Lower Saxony, Mecklenburg-Vorpommern, Schleswig-Holstein) which started in 2017, the BfG has developed a hydro-numerical 2D model of the Lower Middle Elbe River from Tangermünde to Geesthacht to answer a number of questions relating to freeboard, hydraulic bottlenecks, vegetation development and sedimentation over the last 40 years. As a major project objective, the impact of dike relocation sites, controlled flood protection measures (polders) and other floodplain management options – some inscribed on the NHWSP list of measures [4] – on Q_{100}-water levels were quantified. Final results of the project, including a publicly available report, will be delivered by early 2024.

Below, the modelling approach and the results of the 2D simulations regarding the effects of flood protection and management options are presented and discussed. The article concludes with a summary of the results and the main conclusions drawn in the project.

2. Project area and model design

The 2D HN modelling project focuses on the Lower Middle Elbe region from Tangermünde to the Geesthacht barrage (Elbe km 386-586). This is the only barrage in the basically free-flowing German Elbe river and represents a barrier between the inland and tidal Elbe. The major tributary in the project area is the Havel river, which connects the Elbe to a system of flood retention measures (so called “Havelpolder”). The 2D HN model was created using the open source software Delft3D FM from the Dutch research institute Deltares. Delft3D FM can simulate detailed flows and water levels for hydrodynamical simulations on unstructured grids in 1D, 2D and 3D using a flexible mesh. It has been utilized by BfG in a number of projects related to flood risk analysis in the Havel and Weser river (e.g. [5], [6]).

The model design involved three conceptual steps: calibrated model (i); reference model (ii); and scenario models (iii). (i) The calibrated model incorporates the vegetation data (used to implement roughness), topography, and the course and heights of the dikes available up to 2018. This model state was used for calibration and validation. (ii) The reference model state includes dike relocations completed since 2018 (dike relocations Sandau North and South and near Fischbeck) and contains updated geodata. The reference model state was run at Q_{100} – the design discharge defined by FGG Elbe [7] – to identify hydraulic bottlenecks and to determine the remaining freeboard. It also serves as a reference for the scenario models. (iii) Scenario model states include a range of dike relocation sites, controlled flood protection measures (polders) and other floodplain management options. The various flood risk reduction options were collected in a public workshop held on 14 May 2019, attended by members of a wide range of governmental and non-governmental institutions. The first objective of the project was to model each of these options (see Fig. 1) one by one and analyse the magnitude of the reduction in water levels for a Q_{100} flood event. The second objective involved modelling combinations of these options to determine transregional and synergetic effects. They were therefore ranked according to the greatest reduction achieved at the relevant hydraulic bottleneck and potential feasibility (in terms of local conflicts, availability of territory, etc.). Combinations of uncontrolled retention options (13 dike relocation sites, 4 oxbow reconnections and a series of alluvial vegetation cutting and planting), of existing controlled flood protection measures (Havelpolder with an expected retention volume of 155 million m³) and potential new polder sites in the Karthaneniederung (southern polder chamber with potentially 33 million m³) and Lenzer Wische (potential retention volume 42 million m³) were simulated and analysed using steady-state and unsteady simulations.

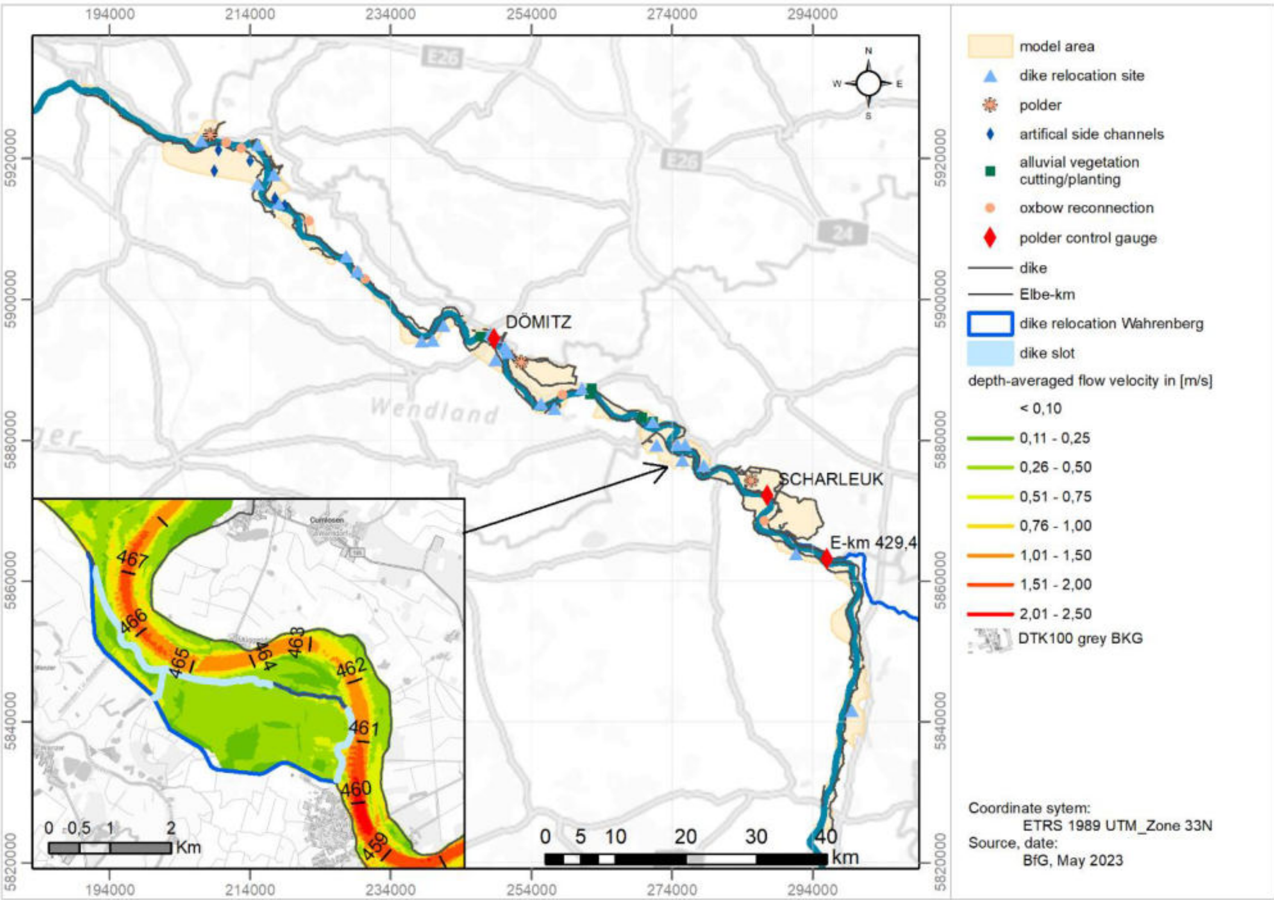

Fig. 1: Model area, flood management options and simulated depth-averaged flow velocity for the example of the dike relocation site Wahrenberg

3. Results and discussion

The present paper focuses on the results for the combinations of flood management options with the maximum impact on water levels, as they illustrate perfectly the need for and the benefits of the large-scale NHWSP-approach. Figure 2 shows the potential water level reductions of uncontrolled measures compared with the reference model state and the maximum positive effect on the water level by controlled measures along the Elbe. As shown in the graph, water level reductions of 7-67 cm can be achieved with **uncontrolled measures** along the entire length of the modelled reach. The positive effects of the Sandau North and South dike relocations (around Elbe-km 410) are not visible in this analysis, because these measures are already included in the reference state and contributed to alleviate a hydraulic bottleneck. Downstream of Elbe-km 562, no retention option was retained, and therefore no impact on water levels was simulated. The Wahrenberg dike relocation (see Fig. 1) has the greatest impact (67 cm, see Fig. 2) due to its large area in the modelled variant (ca. 440 ha). For the **controlled measures**, peak water levels can be reduced by 30 to 85 cm throughout the model area, depending on the shape of the flood peak. In contrast to the locally limited water level reduction caused by dike relocation, polders can reduce water levels especially downstream on a large scale. The June 2013 flood simulation, with its high, narrow peak, reaches the largest water level reduction. The wide, flat 2006 flood peak prompts the smallest effect.

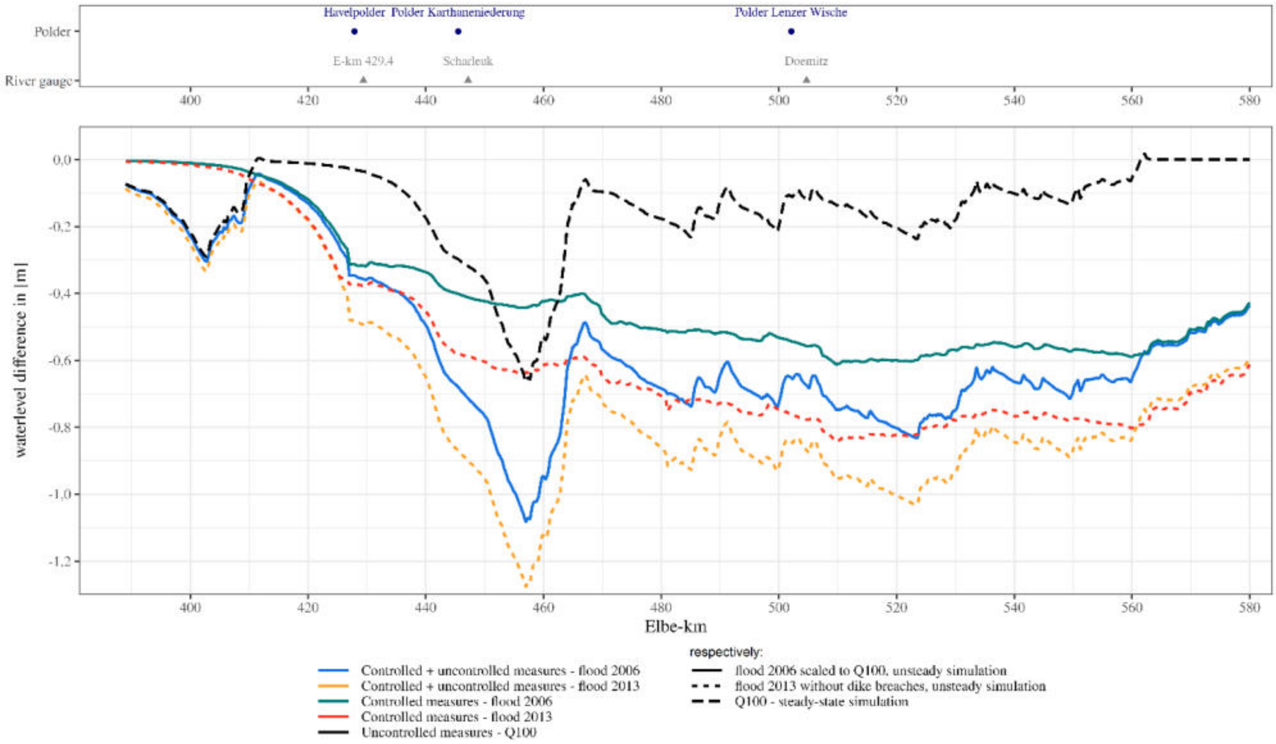

Fig. 2: *Uncontrolled and controlled measures: water level differences w. r. t. the reference state for Q_{100} or respectively for the flood event 2013 (simulated without dike breaks) and 2006 (scaled to Q_{100})*

Comparing the effectiveness of controlled and uncontrolled measures, the results show that large-scale water reduction for controlled (polder) structures is generally much higher including downstream effects due to the removal of a large flood volume from the river – about 15% at the Neu Darchau gauge compared to the uncapped simulations. However, accurate control of the inlet and outlet structures is required to achieve optimal flood peak capping and supposes an exact prediction of water level and discharge. In addition, as Figure 3 shows, the controls of the opening sluices are interdependent, especially when several geographically close polders are activated simultaneously to cap the flattening flood peak. This fact highlights the importance of developing a common polder control strategy.

Uncontrolled retention measures tend to have a much smaller impact on discharges, because they gradually fill during the rising flood water levels. Although they do not remove flood volume, they do widen the river's runoff section, thereby lowering water levels and alleviating hydraulic bottlenecks when placed correctly. Also, according to the FGG-Elbe restrictions, Polders should only be activated for extreme floods of a Q_{100} or higher [7], while dike relocations work for lower floods. Simulations have shown that combining **uncontrolled and controlled measures** (blue and yellow graphs, Fig. 2) enhances the overall effect and specifically improves peak capping. Modelled water level reductions average between 5 and 7 dm, peaking at more than 1.2 m. This type of reduction may be necessary to compensate for existing freeboards of less than 1 m or even less than 0.5 m in large stretches of the Lower Middle Elbe.

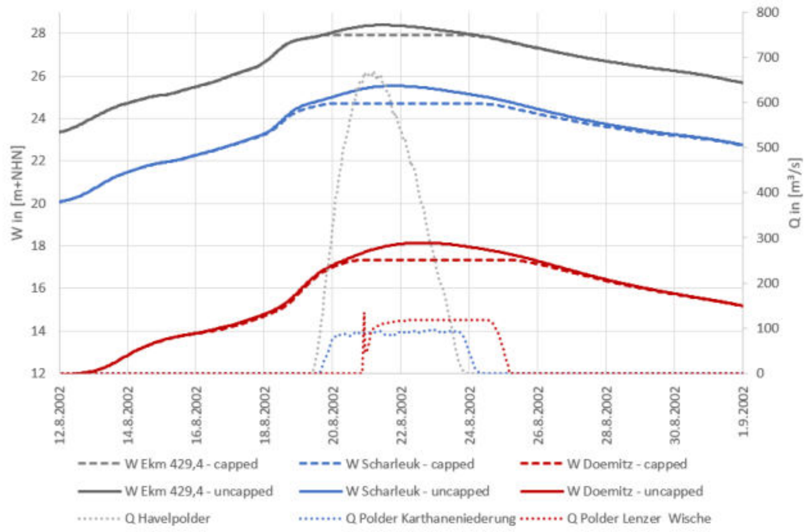

Fig. 3: *Polder weir discharge hydrographs (dotted lines) and flood peak capping (dashed lines) for the 2002 flood event*

4. Conclusion

The 2D modelling project, which was initiated by the Elbe riparian states and BfG in response to the need for an improved transregional flood protection, demonstrates that the effects of retention measures should be analysed in the context of all potential measures along the river. The combined effect of controlled and uncontrolled flow reduction measures results in a large-scale water-level reduction along the Lower Middle Elbe and provides greater safety, particularly in the event of extreme floods and considering the existing freeboard. Joint efforts in flood risk analysis maximise the impact of measures across Länder boundaries, thereby minimising costs and avoiding negative spill-over effects. Coordinated flood risk management between the Länder is essential, especially when it comes to activating polders. The NHWSP supports this process not only financially, but also by providing hydraulic expertise to contribute to the political decision-making process.

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Effects of hydropeaking on reproduction of rheophilic fish and its mitigation

Daniel Bartoň

1. Introduction

Rivers around the world face heavy modifications and discharge regulations, and these changes have strong impacts on riverine wildlife[1], [2]. Dams and reservoirs constructed around the world pose serious threats to rheophilic species[3]. Flow fluctuations and hydropeaking (periodic rapid change in discharge) represent one of the threats to rheophilic fishes in human-modified rivers[4], [5]. Hydropeaking is usually conducted on a daily basis to meet the uneven demand for electric energy during the day[6]. Another example is the need for a sudden increase in discharge to enable water sports such as white water slalom, which is usually not periodic but may nonetheless have an impact on riverine life [7], [8].

Hydropeaking is known to have serious negative impacts on river flora and fauna, including fish [5], [9], [10]. Indirectly, fish can be negatively affected by decreased invertebrate densities, as hydropeaking also causes a decline in river benthos due to extensive drift during hydropeaking periods [11]. With respect to the influence of hydropeaking on rheophilic fishes, negative impacts may occur from the beginning of their life history, as their eggs can be dewatered when the river is off-peak[12]. During peak flow, adhesive eggs of egg depositors may be detached from the substrate in large quantities and be carried away by the current[8]. Fish larvae can also be dislocated during the peak flow [13], as can adult spawning fish[14]. In highly hydropeaking rivers, some fish are even unable to find a shelter during the peak flow[15], [16]. Therefore, potential mitigation measures of hydropeaking may be important to preserve fish in the stretches of rivers influenced by hydropeaking.

Here we present three of our studies dealing with effects of hydropeaking on rheophilic fish during its spawning.

2. Methods

We have used asp (*Leuciscus aspius*) as a model fish for our studies. It is a large predator fish which spawn during early spring in flowing waters. Our study site is tributary of Švihov reservoir – Želivka river. There is great population of asp in the reservoir. The asp is a species protected by NATURA 2000 at many European localities, including the study site. At the research site, adult fish aggregate in the tributary just below the first weir upstream of the reservoir, where they reproduce in a one-month-long period from mid-March to mid-April. Asp eggs are adhesive and usually adhere to rocks and pebbles on the river bottom [17]. The fish choose relatively shallow and fast flowing waters to spawn [8].

Fish are long term monitoring on the site, obtained yearly outside spawning ground by an electrofishing boat (electrofisher EL 65 II GL DC, Hans Grassel, Schönau am Königsee, Germany, 13 kW, 300/600 V). The individuals are being anaesthetized with MS-222 and individually marked with passive integrated transponder tag (PIT tags, OregonRFID, half-duplex, length 32 mm, diameter 3.65 mm, weight 0.8 g, ISO 11784/11785) for subsequent passive telemetry. Tags are applied directly into the body cavity and no sutures are used to close the incision due to their potential adverse effects on fish health. The PIT tag loss is not so high using this method with approximately 2 and 15 % probability in males and females, respectively[18]. The tagged individuals were released immediately after recovery from anaesthesia and their return into normal swimming position.

Egg density is quantified from images taken with an underwater camera (Hero 8, GoPro, California, USA) on a metal stand. The camera stand is moved to a specific location in the river marked with frames. Metal frames (0.3×0.3 m) are installed in the river bottom of protected and unprotected channels before the spawning period. Continuous video is recorded with the camera, and clearly focused snapshots are taken at all sampling locations. Images were taken before and after hydropeaking events. The number of eggs at each site is counted from video recordings.

The research site is influenced by hydropeaking due to the canoe slalom course located 12 km upstream below the Trnávka Reservoir. Slalom operation occurs irregularly due to scheduled water canoe slalom competitions, qualifications and trainings but usually twice a day for one hour. Water discharge usually increases from 3-6 $m^3.s^{-1}$ to 15–18 $m^3.s^{-1}$.

3. Effects of hydropeaking on attached eggs

Impacts of dynamic changes in water flow on adhesive fish eggs are not very well known. In this study we tested whether a sudden increase in water velocity caused by hydropeaking may have negative effect on the adhesive eggs by the combination of field observations and laboratory experiments[8]. The main objectives of the study were to: i) investigate abiotic characteristics of an asp spawning ground, ii) monitor egg densities in relation to hydropeaking events and iii) test detachment rates of the asp eggs in laboratory conditions in relation to water velocity. The asp spawning ground was associated with shallow water depths (0.2–0.4 m) and flowing water (0.1–0.4 $m.s^{-1}$) during base flow. The water velocity that occurred on the spawning ground during the hydropeaking event was measured to be from 0.7–1.2 $m.s^{-1}$. Asp eggs nearly disappeared from the spawning ground before their hatching time probably due to several hydropeaking events. The laboratory experiments showed the significant dependency of egg detachment rates on the water velocity and substrate type with a critical value of 0.7 $m.s^{-1}$. Our data suggested that eggs may be negatively impacted by flow alterations. Avoiding hydropeaking or keeping water velocity below critical values is recommended for the management of rheophilous fish spawning grounds.

4. Effects of hydropeaking on adult fish during spawning

Here, we aimed to test whether the hydropeaking generated 12 km upstream may have negative effect on the position of actively spawning rheophilic fish, asp[14]. Two passive telemetry antenna arrays were used to record fish position on the spawning ground. We monitored the position of spawning fish (545, 764 and 852 individuals) in three one-month long spawning seasons in 2017 – 2019 and related the changes in detection probability on the two antenna arrays to flow conditions, temperature, time of a day and individual fish ID. The fish detection on the spawning ground was negatively affected by the flow change (both increase and decrease) in time. Moreover, probability of fish detection was also influenced by water temperature and time of a day and, as seen from the magnitude of individual random effect variability, the detection probability was rather individual-specific. Hydropeaking resulted in the change of spawning behaviour and likely caused interruption of spawning or shifting spawning outside the optimal area for egg development. We therefore advice to reduce the hydropeaking regime during the rheophilic fish spawning season under fisheries or conservation interests.

5. Mitigation of hydropeaking effects using flow deflector

We investigated whether the effects of a water increase in hydropeaking on a spawning ground may be mitigated by a deflector installed at the top of the weir that diverts flow to other sections[19]. At the research site, rheophilic asp spawn annually in early spring, and their success might be affected by hydropeaking with base discharge ranging from 3 to 7 $m^3.s^{-1}$ and peak discharge ranging from 16 to 25 $m^3.s^{-1}$ occurring 4–7 times during the asp spawning season and egg development period. To protect the adhesive eggs from detachment during peak discharge, a flow deflector (a wooden wall at the selected part of the weir) was installed to regulate discharge on the protected spawning ground. This measure allowed normal discharge under the base flow conditions. During peak flow, a significant portion of the additional water was directed to the part of the river channel where egg abundance was lower and to the mill channel, where asp spawning was not present. While the total discharge increased 4.1 times compared to the base flow, the water discharge in the protected spawning ground increased only 2.7 times. This resulted in more than half of the asp eggs being retained in the protected channel. Although the use of such a measure is limited to specific local conditions where eggs are located just downstream of the weir, it can be a valid solution in highly fragmented rivers with hydropeaking and can lead to higher recruitment of rheophilic fishes.

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Determining the natural water balance as a reference for urban planning on the example of Hamburg

Nele Wotha

1. Introduction

The water balance of an urbanized area such as the city of Hamburg deviates considerably from the undeveloped status quo. In Hamburg's city centre, for example, the water balance components have a ratio of 36:19:45 (evapotranspiration:groundwater recharge:runoff), as shown in Fig. 1 (right). In contrast, a water balance under natural conditions would be characterised by a higher evapotranspiration of 50-80 %, a higher groundwater recharge of 10-30 % and a significantly lower runoff of 10-20 % of the annual precipitation [1]. Soil sealing is a major factor contributing to this situation, as it inhibits the water exchange between soil and atmosphere. As a result, the rainwater remains on the surface causing higher runoff peaks and larger runoff volumes.

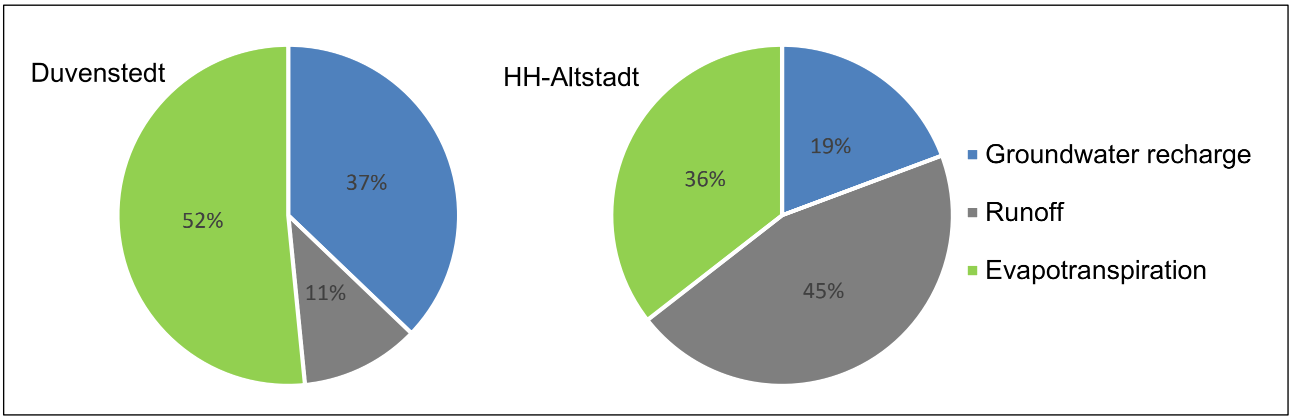

Fig. 1: *Water balance components as ratios of annual precipitation in % for the rural, agriculturally dominated district of Duvenstedt (left) and the densely populated Hamburg city centre (district of Hamburg-Altstadt (right)).*

According to *LAWA* (German Working Group on water issues of the Federal States and the Federal Government), a water-sensitive city combines the functionality of water management with principles of urban design to recreate a nature-orientated water cycle while preserving the amenity of the city [2]. Such established nature-orientated water cycle contributes to climate change adaption and can reduce the risk of flooding from heavy rainfall, summer heat waves and prolonged droughts.

The new *DWA* (German Association for Water, Wastewater and Waste) -series DWA-A/M 102/ BWK-A/M 3 [3] consequently redefines the state of the art for the management and treatment of precipitation runoff. The fourth part describes a simple procedure for the comparison of the local water balance to the water balance of the associated undeveloped status-quo (hereafter “reference state”) of a given area.

With this quantification method it is now possible to design site-specific, effective measures for rainwater management, such as infiltration systems, retention basins or rainwater utilisation. Development plan procedures, which often include a new planning of property drainage, are well-suited for this approach, for example. Here, the reference state can be included as a specification in the planning process, the drainage planning can be aligned with it and the measures can be recorded in the ordinance. If the advantage of the various possibilities of measure combinations is used, deviations of max. 5 to 10 % compared to the reference condition can be achieved [3].

2. Determining the water balance components with mGROWA

mGROWA, developed at the Research Center Jülich, is a conceptual area-differentiated model that simulates the water balance components runoff, groundwater recharge and actual evapotranspiration on the basis of the water balance equation [4]. For Hamburg, mGROWA is applied to determine the reference state under the assumption of a cultural landscape, without any sealed surfaces such as traffic and settlement areas.
When deciding on the model input data, the transferability of the model results to today's conditions must be taken into account, in order to ensure that the resulting reference state can actually be achieved. Therefore, the input data for topography, the dyke lines and the water courses correspond to the current state.

The input data that defines the reference state for Hamburg includes, among others:

- Climate data: Current time series of meteorological input variables
- Land use data: A compilation of (1) today's surface waters, (2) today's peatlands, (3) meadows, (4) ALKIS data that corresponds to a natural-oriented land use and (5) Germany's natural units
- Soil data: It is being integrated through the *Bodenformengesellschaftenkarte* (Soil type community map). For each soil type the parameters field capacity, bulk density and information on the soil horizons affected by groundwater are included in the calculation, among others. Based on the natural soil development, the soil-relevant impacts of agriculture, forestry and horticulture of the past decades are presented, while the impacts of settlement, industry, commerce and transport, which dominate in large parts today, are omitted. The latter are associated with soil erosion, deposition and material input, as well as mixing and sealing, and are therefore not suitable for reference condition.

Once the model calculations are completed, the grid data, which have the unit mm/l, can be aggregated to a desired spatial level if needed and converted to percentage of the annual precipitation.

3. Determining the water balance components with the SCS-method

An alternative method, which is transitionally applied in Hamburg, is the Soil Conservation Service (SCS) method of the U.S. Department of Agriculture. The conceptual method is widely used for predicting direct runoff volume for a given rainfall event mainly for small catchments [5] based on the parameter Curve Number (CN). CN is defined by the parameters soil type, land use, surface conditions and antecedent condition [6] and its parameter values can be selected from tables developed from empirical analysis. Once the runoff component is determined, evapotranspiration can be adopted from a nearby undeveloped or only slightly developed environment. This reference area should have similar infiltration and soil properties as the project area. The groundwater recharge component as the residual completes the water balance.

4. Conclusion

The choice of rainwater management measures within an urban planning project, suiting the local hydrological conditions, contributes to bringing the local urban water cycle closer to a natural one. Two methods for determining limit values for the water balance components evapotranspiration, groundwater recharge and runoff were presented. mGROWA provides comprehensive ready-to-use data as grid data. The challenge here is to retrieve historical data as model input data representing a state which is considered natural. Furthermore, the SCS method can be applied on individual projects without the need to set up a complex model.

By performing water balance calculation at an early planning stage, the land demand of the rainwater management measures can be assessed, made available for consideration and/or integrated into a multifunctional space. Landscape and urban planners have the freedom to choose from a variety of measures, guided by the limit values of the water balance components.

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Odborné příspěvky **Fachbeiträge**

Magdeburský seminář o ochraně vod 2023
Magdeburger Gewässerschutzseminar 2023
11.–12. 10. 2023

Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Vyhodnocení extrémních povodní
Auswertung von Extremhochwassern

The biggest historical flood on Berounka and Střela rivers: the maximum short-term rain intensity in the territory of the Czechia and Central Europe

Bohumír Janský, Libor Eleder

1. Introduction

The flash flood on the rivers Střela and Berounka on 25 May 1872 is one of the most extreme events recorded in the Czechia. The storms with hail and strong winds mainly affected the area between Karlovy Vary, Plzeň and Prague, covering an area of about 2000 km2. The highest rainfall intensity was observed at two locations northeast of Pilsen, where more than 200 litres of water fell in 2 to 8 hours. The subsequent flash flood was unprecedented in its scale, casualty figures (according to various sources, 240-300 deaths) and the extent of damage to houses and infrastructure in the last 150 years.
On the night of 25-26 May, the dam of the Mladotice pond, which was located on the southern edge of the village of Mladotice and with an area of about 92 ha was the largest pond in western Bohemia, broke. Another natural disaster occurred on the night of 27-28 May, when a mass of sandstone collapsed from the western slope of Potvorovský vrch into the valley of the Mladotický brook and dammed it with a massive dam. The resulting lake is unparalleled in the Czech Republic.
The extraordinary May flood and its catastrophic consequences were widely described in the contemporary press, in chronicles of the municipalities and in professional publications. It was analysed by top experts of the time, such as geographer and cartographer Prof. Karel Kořistka [8], professor of Prague technology, hydrologist Andreas Rudolf Harlacher [3] or the founder of the forestry ombrometric network in Bohemia, Emanuel Purkyně [11].
After a hundred years, it was dealt with by Janský [4] [5], Kašpárek [7], Křivková [9], Müller and Kakos [10], and more recently by Jansky et al. [6], Eleder, Kulasová and Daňhelka, [1] or Eleder et al. [2].

2. Causal rainfall

According to Müller and Kakos [10], thunderstorms and torrential rains occurred in western Bohemia as early as the night of 24-25 May. The synoptic situation that day was influenced by a strong undulating frontal boundary that crossed Bohemia from south-west to north-east.
The most affected areas were the watersheds of the Strela, Blšanka and Rakovnický Brook, which were located northwest of the frontal interface in cold air. In this region, a significant vertical change in wind direction was observed due to the fact that a warm southwesterly flow was sustained aloft. On the frontal boundary, a cyclone formed the previous day in Bavaria, which had a significant horizontal pressure gradient and advanced into our territory on 25 May. This resulted in intense outward air movements and strong convective hail storms and exceptionally heavy rainfall.

Convective storms of this type usually cause flash floods on small streams. In our case, however, they affected an area of over 4000 km2 and caused flooding on the tributaries of the Berounka River and its main river.

The most intense rainfall was recorded north of Pilsen in an area where there were no measuring stations at the time. In the village of Žebnice near Mladotice (in the Střela basin), the parish priest measured 9 Austrian inches in 90 minutes with an open container, which corresponds to 237 mm. This is the largest recorded short-term intensity of rain in the territory of the Czech Republic and Central Europe. In Měcholupy (Blsanka basin), 289 mm fell in 12 hours. This area is paradoxically the driest region of the Czechia today. [1]

Fig. 1: Precipitation totals from Mladotice compared to other extreme precipitation recorded in the Czech Republic. The colour of the marker indicates the altitude of the peaks in the vicinity of the place. Altitude: red - above 800 m, yellow: 600-800 m, green: below 600 m.

3. Flash flood

The conventional storm started in the Berounka river basin on 25 May between 1 pm and 3 pm. This was followed by sharp rises in the levels of the Berounka tributaries - the Klabava (2 to 3 m), Litávka (2 to 3 m), Červený Brook (3 to 4 m) and Rakovnický Brook (2 to 4 m). In Beroun, water flooded the square to a height of 2.5 to 3 metres. These rises in water levels occurred within tens of minutes!

The rise in the level of the Střela River reached over 4 m in the middle reaches. The main cause was the breach of the large Mladotick pond (Mlatzer Teich) with an area of about 92 hectares. It was founded by the Cistercian monastery in Plasy probably in the 14th century. Its dam was 5 m high and 150 m long. According to recent calculations, it held up to 3.3 million m^3 of water at a mean depth of 3.4 m. However, the maximum depth at the dam was 12 m. The mill below the dam was completely destroyed and the newly built railway tunnel in the valley of the Střela was flooded to a height of 1 m. It is located 9.5 m above the level of the Střela River. The level in this narrow river valley reached about 10,5 m above the river level. [1]

A total of 109 smaller ponds broke through in the Berounka river basin. The devastating flood catastrophically affected not only the Střela River basin, but also the Klabava, Litavka, Rakovnické potok or Javornice and the entire lower reaches of the Berounka. On the following day, 26 May, at 2 p.m., the Vltava River in Prague peaked at a flow of 3,300 m^3/s, the fifth largest flood in the period of instrumental measurement since 1825.

4. Natural disasters on the Mladotický Brook

Already on the night of 25th to 26th May the dam of the Mladotice pond, which was located on the southern edge of the village of Mladotice and with an area of about 92 ha was the largest pond in western Bohemia. Another natural catastrophe occurred on the night of 27-28 May, when masses of sandstone fell from the western slope of Potvorovský vrch into the valley of the Mladotický Brook and blocked it with a massive 300 m long dam. A lake unparalleled in the Czech Republic was created. In total, the landslide affected an area of around 23 hectares. Two small quarries, a road and a cut of a railway line that was being built at the time were also displaced. The detachment wall is a rock step made of arkosic sandstone, between 30 and 40 m high.

What were the causes of the landslide?

- The stability of the slope of Potvorovský vrch has been disturbed for a long time due to the mining of sandstone blocks, which were used for the production of millstones and important buildings in the surrounding area.
- Also, the excavation of a cut for the railway line, which was already under construction in 1872, contributed to a reduction in slope stability. The notch cut the western slope of Potvorský vrch for 150-200 m.
- However, the most important event was the intense rainfall at the end of May 1872. The slope had already been sufficiently disturbed by numerous cracks, fissures, fractures and the cutting of the track. The overburden was easily penetrated by the massive water torrents. This increased the weight of the overburden, and the layer of clay and grey flakes in the bedrock was also soaked up by the water. After this layer, blocks of sandstone and siltstone then slid down into the stream valley. [4]

Fig. 2: Slope of Potvorov Hill after the landslide. E. Herold.

Fig. 3: Ruptured dam of Mladotický Pond. E. Herold.

Is pond restoration possible today?

Arguments in favour:

- Restoring the pond would create a relatively large water storage in one one of the driest areas of Bohemia.
- The reservoir would positively influence the microclimate of the area.
- The pond would enhance the recreational potential of the nearby Střela River valley.
- Balancing the large extremes of the Mladotický Brook outflow.
- The water could be used for agricultural irrigation, in fire-fighting protection of the area, for fish farming

Arguments AGAINST:

- Rehabilitation of the dam would be quite expensive
- The restoration of the dam is complicated by the railway line that passes close to it proximity (however, it already existed at the time of the pond breach in 1872)
- The pond could not be restored to its original size (92 ha), but about 60-70% of the original area
- The flow of the Mladotický brook is small, it would take 2 to 3 years to replenish it

Conclusion

The extremely intense torrential rain at the end of May 1872 and the following catastrophic flood left significant traces in the Czech landscape that are still visible 150 years later. In the current era of a changing climate, where hydrological extremes are increasing and becoming more frequent, this event may be repeated. Hydrologists and water managers in particular should take this possibility into account in the future.

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Carslbad Historical Floods of 1582 and 1890

Jan Daňhelka, Libor Elleder, Daniel Kurka, Jakub Krejčí, Jolana Šírová

1. Introduction

Reduction of impact of hydrological extremes is only possible if we understand the hazards and associated risks of floods and droughts. Study of historical flood extremes (outliers) might be critical source of information for design of flood protection measures and flood response planning nowadays. Two major known floods of Teplá River occurred in May 1582 and November 1890.

In May 1582, torrential rainfall in the upper part of the basin caused severe flash flood. More than 50 fatalities were reported and 54 houses (of approximately 100) damaged. In November 1890, intense precipitation caused rapid flood that damaged large areas of the city center. Major of the city Carl Knoll had been the only victim reported. Flood in 1890 initiated discussion of the need for flood protection of the city leading to the construction of the Březová reservoir.

2. Reconstruction of 1582 Flood

There are two contemporary reports about 1582 flood: Johannes Sommer witnessed the flood and described it in introduction to the 3rd edition of book of his brother Fabian Sommer in 1609 [1], Clemens Stephani came to Karlovy Vary 3 days after the flood and published a special report on flood [2]. Flood mentions in the city cronicle by J. F. Polz are not contemporary and do not provide additional information. Karlovy Vary 1582 flood is often considered as the oldest documented flash flood in the territory of the Czech Republic.

Both sources agree that the cause of the flood was the thunderstorm with heavy downpours and lightning. Sommer situated the most intense storm to a vicinity of Teplá town (around 2 p.m.). He also reported “not much” rain in Carlsbad but very dark clouds. The flood caused a breach of ponds around Teplá including Podhora pond [1, 2]. In consequence, the flood arrived to Carlsbad suddenly around 5 p.m. [1, 2]. The water carried a lot of debris and caused damage to all bridges and footbridges, killed “50 or more people” [2] and damaged 54 houses out of which 36 were completely destroyed [2]. There are several mentions related to maximal flood level as summarized in table 1.

Tab. 1: *List of flood damage description used for flood level estimation for 1582 flood*

Flood level description	Estimated relative high	source
stable has been flooded to the ceiling, but a horse surprisingly survived	1.8 – 2.3 m	[2]
water raised above the door	1.8 – 2.0 m	[2]
water nearly reached a bow window	2.5 m	[2]
the flood level reached 4 ells above the Hot Spring	2.25 – 3.0 m	[3]
buildings not reported to be flooded: church, cemetery, pharmacy, city hall		[2]
the water level on the main town square reached as high as over 2,5 m and in some parts of the town even above 4 m	2.5 – 4.0 m	[4]

It is assumed that the city kept its territorial extent and plots during its reconstruction after disastrous 1604 fire. Thus we have reconstructed the map of Carlsbad in 1582 (Fig. 1). The reconstruction of a terrain remains more uncertain due to lack of information. However, the vicinity of Hot spring has been artificially maintained for a long period to protect the Hot spring from wild breakouts to the Teplá River bed. In addition, a development of Hot Spring sources is well documented back to 1571. There are six (I - VI) main historical sources (some with shallow boreholes) in a small area of app. 16 m^2 on a right bank of Teplá River. The elevation of the source used in 1582 (marked as IV) is 378.8 m a.s.l. The flood level of 1582 might be estimated to 381.25 to 381.8 m a.s.l.. That corresponds well with the estimated depth of 2.5 m at Tržiště (Main square).

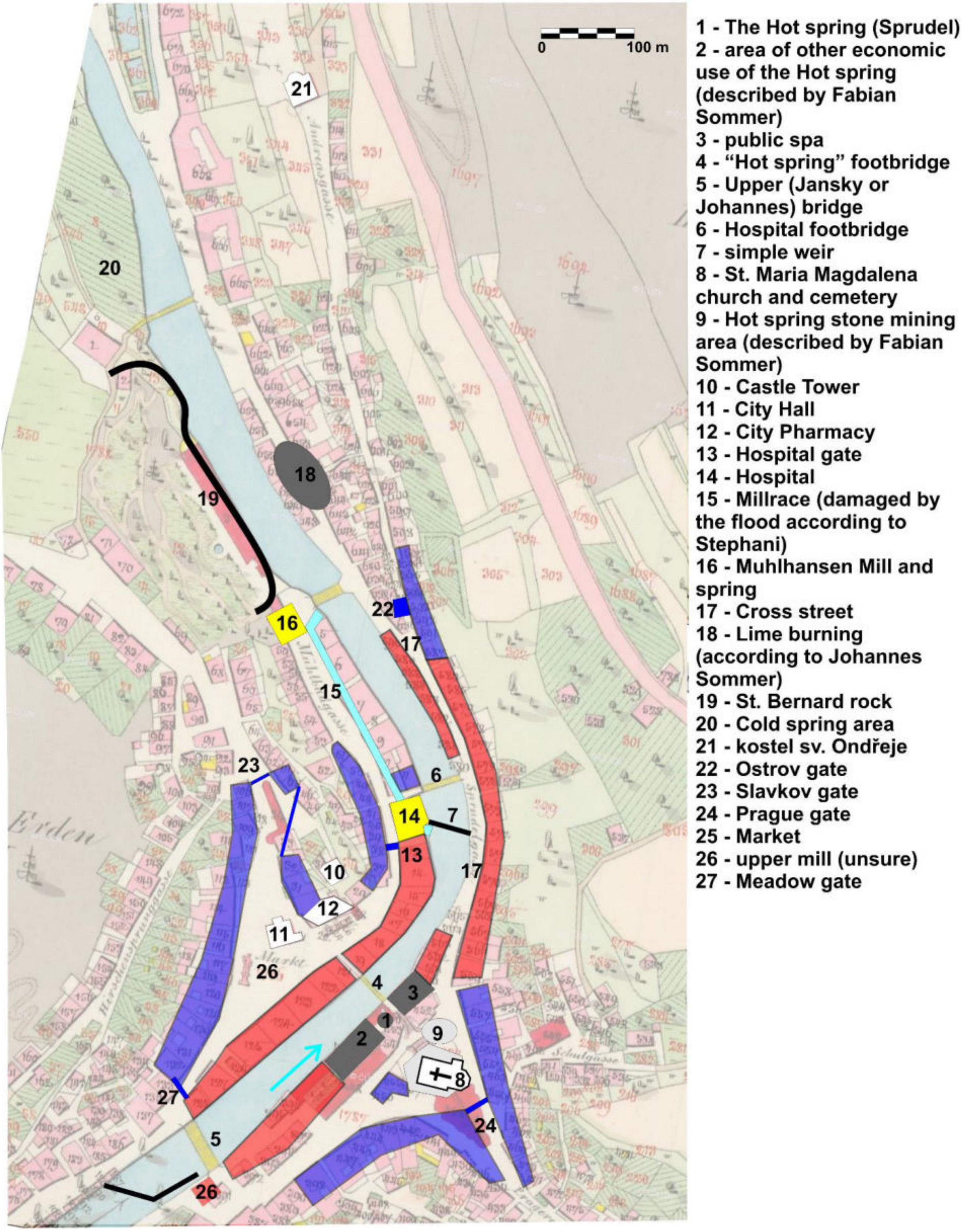

Fig. 1: *Reconstruction of Carlsbad at a time of 1582 flood*

3. Reconstruction of 1890 Flood

Forty five cross-sections have been documented after the flood 1890 these include bridge profiles, pond outlets as well as nature channel cross-sections. There were 6 cross-sections and long section available for the Teplá

River in the city of Carlsbad. Peak flow discharges has been estimated in selected profiles using Ganguilet-Kutter equation in contemporary report [3]. The peak flow in Karlovy Vary city center was estimated to app. 400 $m^3.s^{-1}$. However to calculate this peak discharge mean flow velocities of more than 5 $m.s^{-1}$ were assumed in some profiles what appear unrealistic and not trustworthy given the present day operational experience. Later evaluation of 1890 flood [5] used five different equations (Kutter, Siedek, Christen, Hermanek and Bazin) to compute the peak flow, it concluded with the estimate of 330 $m^3.s^{-1}$ in Carlsbad (mean flow velocity still remaining close to 5 $m.s^{-1}$)..

Six cross-sections (confluence of Teplá River, Lomnický Brook and Cínový Brook upstream from Carlsbad and three cross-section of Teplá River in Carlsbad city center) have been digitalized and the peak flow has been estimated using HEC-1 and WinZPV software (WinZPV is used in daily operational practice of the Czech Hydrometerorological Institute for processing of hydrological data. It provides graphical interface to analyze cross-section discharges and velocities based on Mannig equation).

Our peak flow estimates for profiles at Old Meadow are 235 to 300 $m^3.s^{-1}$ (mean flow velocity 1.8 to 2.3 $m.s^{-1}$) and at todays Post 235 to 275 $m^3.s^{-1}$ (mean flow velocity 3.5 to 4.1 $m.s^{-1}$),

4. Comparison of 1582 and 1890 Floods

Based on estimate of 1582 peak flow level above the Hot spring (see above) and reported 1890 water level from the same location, we can compare water levels of both floods (Fig. 2). Comparison suggests that 1890 water level had reached higher, but the cross-section are was comparable for both events: estimates for 1582 range from 93 to 128 m^2, estimates for 1890 are from 97 to 114 m^2. Therefore, we can conclude that peak flows for both extreme floods were comparable and could reach between 235 and 300 $m^3.s^{-1}$. However, the description of temporal development of 1580 flood proves the flash flood nature of the flood. Torrential rains at Teplá were reported to occur at 2 p.m., flood arrival to the Carlsbad was reported around 5 p.m. with peak around 8 p.m. and recession after the midnight. On the other hand, the flood volume of 1890 surely exceeded the flood volume of 1582 flood. Still the volume of 1582 flood might be estimated to be between 12 and 16 mil m^3, making its transformation by the Březová reservoir a challenge.

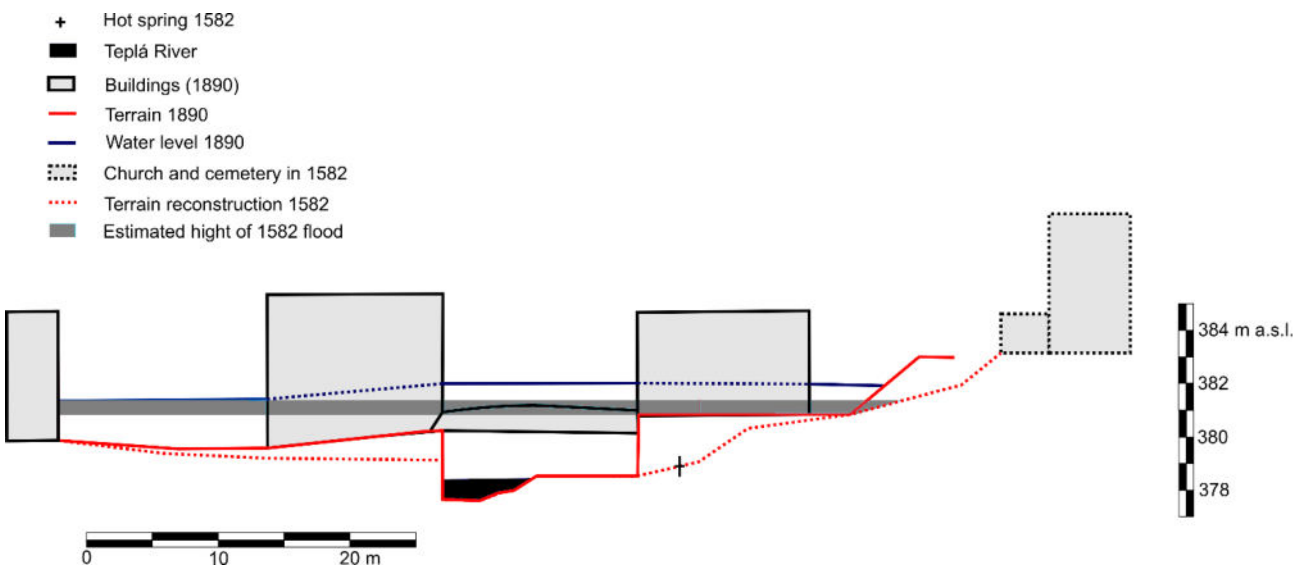

Fig. 2: Hot Spring cross section reconstruction for 1582 and 1890 floods.

5. Conclusions

Floods are extreme phenomena in nature, therefore to properly estimate the flood hazard, historical floods might provide valuable information to complement instrumental records. While 1890 flood was notoriously known and reflected in the flood protection planning of Carlsbad, Here we reconstructed extreme flash flood of 1582 adding to overall knowledge of flood hazard from Teplá River.

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The Abundance of Historical Flow Data on the River Elbe - a Worldwide Peculiarity

Jörg Uwe Belz, Martin Helms, Federal Institute of Hydrology

Two major projects of the Federal Institute of Hydrology (BfG), supported by the Federal Waterways and Shipping Administration, experts from the federal states and universities are expanding the pool of historical flow data (Q) on the Elbe far into the past. This not only concerns complete, quality-checked long daily value series for the most important gauges on the German Elbe since 1890, but also the reconstruction of a closed series back to 1727 for the Magdeburg-Strombrücke gauge. To the authors' knowledge, the latter is the longest complete series of daily flows in the world.

Project "Historical discharge data for the Elbe at the Magdeburg-Strombrücke gauge since 1727"

As early as the middle of the 17th century, a gauge attached to a bridge pier was used in connection with the control of the Magdeburg floating mill "Rathsmuehle" on the River Elbe. According to Faist [1], this gauge was used to document the February flood of 1655. Since then, the gauge has changed location several times, but has always remained on the river-branch "Stromelbe" in the city area.

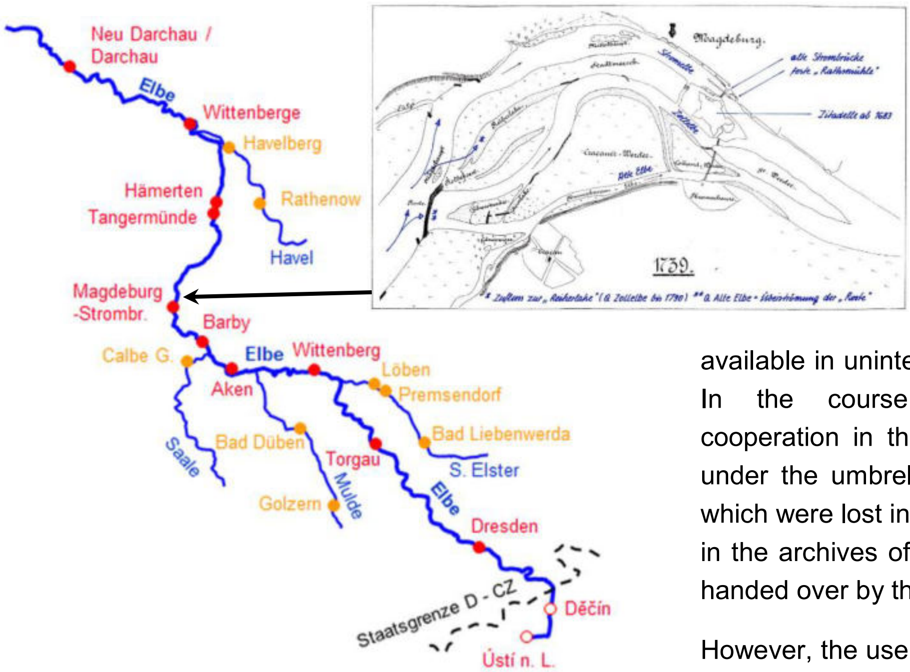

Fig. 1: Important gauging stations in the German and near-border Czech catchment area (red: Elbe gauges, yellow: tributary gauges) as well as detailed sketch of the Magdeburg stream division area, condition around 1739, as a print of a manuscript from the collection Faist [3]

From 1727 at the latest, the Magdeburg gauge (today: Magdeburg-Strombrücke, cf. map in Fig. 1) was read daily; at least since that year, water level lists (including a smaller reconstruction for the years 1809-1817) have been available in uninterrupted succession ([1], [2]). In the course of the German-Czech cooperation in the field of hydrology, settled under the umbrella of the ICSE, these data, which were lost in Germany but well preserved in the archives of the CHMU in Prague, were handed over by the Czech side.

However, the use or evaluation of hydrological data, especially in the form of long time series, is not usually done on the basis of water levels; due to its sensitivity to morphodynamic changes in the longitudinal and transverse profile flowing through it, the water level W is not a measured variable that allows consistent temporal or spatial comparisons. In the case of Magdeburg, the validity of the pure W-data additionally suffers from the local division of the river into several arms (cf. Fig. 1), the water flow of which cannot be reliably determined by the water level at the "Stromelbe"-branch alone. The essential variable here must rather be the flow rate Q. However, reliable and systematic flow measurements have only existed in Germany since the end of the 19th century, initially determined using the so-called "Woltmann propeller".

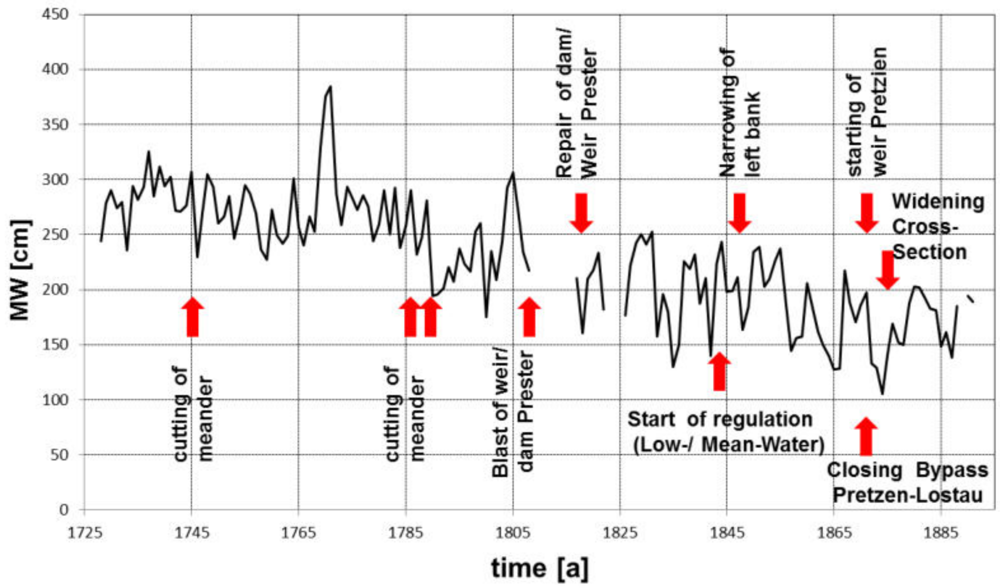

Fig. 2: Magdeburg stream division area: Significant anthropogenic impacts since 1727 [1]

In this respect, despite the lack of geobasic data for modelling, it seemed technically appropriate to attempt to convert the long Magdeburg water level series from 1727 onwards into flow values using empirical methods based on analogue observations. In view of the lack of (direct) flow measurements, the focus of this conversion from W to Q was on the reconstruction of the historical profile and gradient conditions, including the changes in the various arms of the river and hydraulically effective structures over time. Faist et al. [1], [3] undertook this by analysing old sources (pictorial representations such as drawings and engravings, but also sketches and maps). Based on known historical W-Q relationships (cf. Faist [4], [5]), hydraulically relevant structures or changes were evaluated with regard to their effects on the W-Q relationship (Fig. 2). The main influencing factors were the given weir geometries, the gradient conditions and the cross-sections of the arms of the river through which the flow passed (Fig. 3), as well as the changing positions of the gauges. In this way, a total of twelve rating curves were established for the period from 1727 to 1899, with which the daily values of the historical W can be converted into associated Q. For hydrological work on the Elbe, e.g. for questions of dimensioning or the statistical classification of rare extreme events, but also for climate impact research, this is a valuable treasure trove of data; the work was published as [1]. However, all users of these data must of course be aware that the individual values do not have the quality level of flow values collected today: Considerable uncertainties are to be assumed, but in some cases cannot be quantified

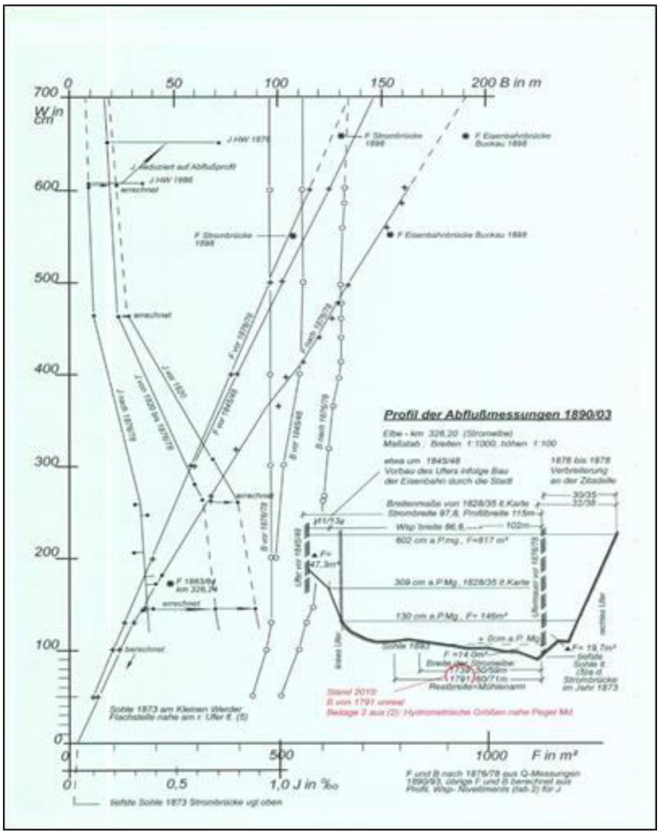

Fig. 3: Discharge profile and hydraulic values at the Magdeburg-Strombrücke gauging station (drawing Faist [3])

exactly. Verification work for hydrological plausibility or for the elimination of inconsistencies still contained is not only appropriate, but also expressly desired by the BfG.

Project "W-Q Elbe 1890": gauging station-related discharge curves and flows in the period 1890-2006
The BfG project "W-Q Elbe 1890" (reference period 1890-2006) was initiated because the data situation Q at many German Elbe gauges was partly inconsistent and partly incomplete until the first decade of the 21st century. The aim of the project was therefore to guarantee a solid data foundation for hydrological work and administrative action on the German River Elbe for the hydrologically significant gauges.

The initial situation was characterised by the fact, that for the hydrologically most important discharge gauges on the German inland Elbe (cf. gauging map Fig. 1) there were often no rating curves for large periods of time, or they were incorrect or insufficiently differentiated. It should be emphasised in this context that at times there were (or still are) strong but irregular dynamics in the W-Q relationships, which at the same time were often countered by a lack of discharge measurements. Therefore, changes in the W-Q relationships were often detected too late, and rating curves were updated too seldom or not in time.

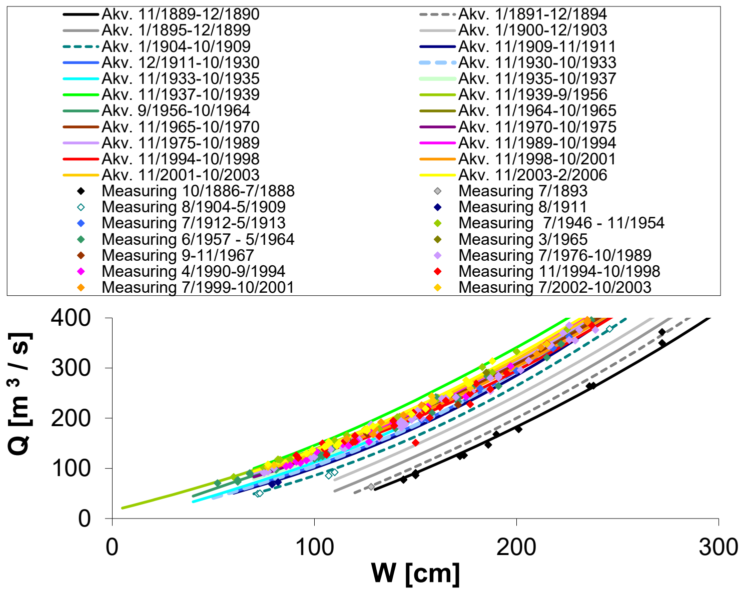

Fig. 4: Low water segments of the revised discharge curves (Akv.) of different validity periods at the Dresden gauge as well as discharge measurements in these validity periods.

In addition, further problems were observed. These included the summer-winter differentiation of the flood (HW) segments as well as the multiformity of some discharge curves; retention effects during extreme HW events, ice effects; anthropogenic influences (e.g. medium and low water regulation, war influences; long-term changes in wave runoff characteristics in sections of the Elbe; uncertain or previously missing wave runoff characteristics in sections of the Elbe; medium and low water regulation;, uncertain or missing discharge series of tributaries; shifting of gauges and gauge datums; data losses; different versions of rating curves used; and, as spatial specifics, the complex situations in the Magdeburg area (especially the Umflut channel) and at the mouth of the River Havel.

The solution to all these problems required an inter-gauge approach with coordinated methods: the rating curves used so far were critically examined and, if necessary, plausibility checked, missing rating curves were reconstructed. For this purpose, diagnostic W-Q diagrams were created in which previously used or newly derived rating curves of different validity periods (GZR) were plotted together with (direct) discharge measurements of these GZR in order to obtain information about the suitability or necessary changes of the rating curves.

Another method of this approach was the simulation of the wave runoff in the Elbe and its most important tributaries with a translational diffusion model TDM validated on the basis of reliable discharge series [6]. In the subsequent diagnosis, the simulated discharge values from upstream gauges and the discharge values observed at downstream gauges (calculated from water levels and rating curves) were related to each other, e.g. in scatter diagrams, in order to analyse their consistency in a temporally differentiated manner and across gauges. In addition to diagnosis, the TDM also contributed to the reconstruction of previously unavailable discharge series.

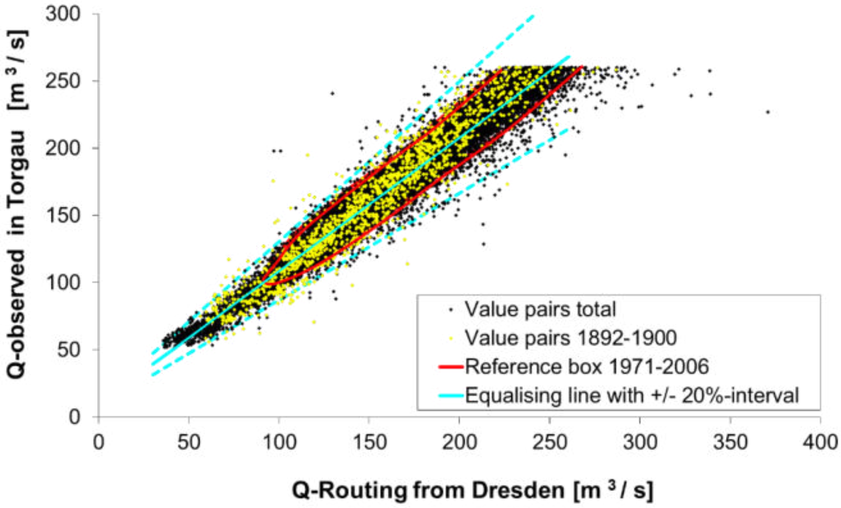

Fig. 5: Scatter plot of the discharge series calculated (observed) from rating curves versus routed discharge series for the comparison between Dresden and Torgau on the River Elbe.

Further indications were provided by balancing the filling of individual discharge events at neighbouring gauges as well as longitudinal developments of statistical flood discharge characteristics.

If the diagnosis showed the necessity, rating curves or their segments were modified.

The results consist of 328 plausibilised new rating curves or tables with tQ series derived from them. They were extensively quality-checked by BfG during and after completion of the project and additionally coordinated with regional experts. Among others, [7] provides a concise overview of the procedure and results. A final publication is in preparation.

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Odborné příspěvky **Fachbeiträge**

Magdeburský seminář o ochraně vod 2023
Magdeburger Gewässerschutzseminar 2023
11.–12. 10. 2023

Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Dopady změny klimatu na vodní zdroje a ekosystémy
Auswirkungen des Klimawandels auf Wasserressourcen und Ökosysteme

What adaptation measures to limit the effects of climate change in the Czech Republic will lead to the security of water resources?

Pavel Punčochář

Water resources of the Czech Republic

The water resources of the Czech Republic are limited, they depend solely on atmospheric precipitation and their volume per capita is approximately 500 m^3/year (the average in Europe is 4 560 m^3/ capita/year, /1/). If precipitation is not retained and does not disappear by evapotranspiration, the remaining water flows out of the territory to neighbouring countries. Climate change is documented by the gradual and steady increase in average air temperature caused by the increasing concentration of greenhouse gases in the atmosphere. The consequences are significant changes in the water regime, accompanied by increased occurrence of hydrological extremes - droughts and floods. While there is a wide range of available climate scenarios, the 'medium' scenario suggests that, unless greenhouse gas production is substantially reduced, average air temperatures will continue to rise, and evapotranspiration will increase significantly.

To assess the expected impacts of climate change on the water regime, it is useful to show what our average annual available water resources and their uses look like in the 'low water period' of 2014-2020 (Table 1).

Tab. 1
The average annual rainfalls over the given period and the percentage of distribution of their use.
Source:/2 /.

Period 2014-2020	bil. m^3/year	% share
Rainfall total	49,9	100
Surface water resources	4,23	8,5
Ground water resources	0,91	1,8
Surface waters abstractions	1,20	2,4
Ground water abstractions	0,36	0,72
Surface water abstractions for drinking water supply	0,32	0,64
Groundwater abstractions for drinking water supply	0,27	0,54

According to hydrologists, this period is one of the driest in the history of rainfall measurements in the Elbe basin in terms of drought and water scarcity, see /3/. The data shows that our total available annual water resources represent 5.14 billion m3 of water, which is approximately 10.3% of the annual rainfall in the years mentioned. Surface water sources accounted for 8.5%, groundwater sources for 1.8%, and an even smaller proportion of the total rainfall falling on our territory is used for drinking water (waterworks abstractions).
The retention of rainwater in reservoirs and ponds in the Czech Republic has a historical tradition. The approximate volumes accumulated in reservoirs and fishponds are presented in Table 2 and capture approximately 7% of the average annual rainfall over the period. In terms of accumulated volumes in reservoirs in European countries, the Czech Republic ranks approximately 15th in a comparison with 19 European countries (see analysis by the European Environment Agency https://www.eea.europa.eu/data-and-maps/figures/proportion-of-annual-renewable-freshwater-resources-stored-in-reservoirs-in-european-countries).

Provision of drinking water resources

47 reservoirs serve as a source of drinking water and their storage volumes cover 52% of the water supply volume in the Czech Republic without any problems. Water abstractions from these reservoirs for drinking water have never been restricted even within the last 30 years, which includes the driest seven-year period in

the history of rainfall measurement /5/. Even when storage volumes have fell below 30% of total capacity, the abstractions were not restricted, as shown in Table 3.

Tab. 2
Water volumes accumulated in reservoirs and fishponds on the territory of the Czech Republic /4/.

Reservoirs and ponds	Number	Water volume in million m^3
Significant valley reservoirs	165	3 342
Small reservoirs	500	34
Fishponds	approximately 24 000	600$^{+)}$
Total accumulated	---	3 976

+) of which sediments may account for 100-200 million m3

It is important that the volumes withdrawn in the summer period were always replenished during winter and spring. An analysis of the rainfall patterns in the Czech Republic shows that the annual rainfall does not change (Fig. 1), but rather may increase slightly, which is essential for the sustainability of storage in reservoirs and for ensuring the sufficiency of water resources in the Czech Republic.

Tab. 3
An overview of drinking water reservoirs managed by the River Boards, state enterprises, and their exploitation for water supply over the last 30 years (1990-2020), during which abstractions for drinking water supply were never reduced even though storage volumes dropped in some cases below 30% of the total accumulation. /Source: Databases of the River Boards, state enterprises/.

River Board, state enterprises	Number of reservoirs	Number of reservoirs for drinking water supply	Storage volume for use (mil.$m^{3)}$	Number of reservoirs with a drop in storage volumes below 30%	Restrictions on withdrawals for waterworks
Vltavy	45	10	319,1	5	0
Labe	37	5	34,5	4	0
Ohře	32	15	11,3	3	0
Moravy	38	13	94,4	8	0
Odry	13	4	256,3	1	0
In total	**165**	**47**	**715,6**	**21**	**0**

48% of the Czech Republic's drinking water volume is prepared from groundwater sources whose regional availability and continuous replenishment from precipitation are not guaranteed. The occurrence of snow cover in winter has been decreasing significantly, groundwater recharge has been delayed, and increasing episodes of heavy rainfall have been leading to rapid surface runoff and reduced infiltration. Approximately 75 % of the available volume of groundwater is abstracted for drinking water, which is significantly higher than the 25,8 % abstracted of surface water sources. It is therefore evident that the availability and sustainability of groundwater resources is more at risk than surface water resources in available from reservoirs. The experience from 2014-2020 confirmed this fact, as groundwater sources were not sufficient in many cases, and the population had to import drinking water from water supply systems that had sufficient capacity, especially from reservoirs. Generally, the water shortage in that period was solved without major problems. The very significant contribution to the situation has, of course, been the reduction in water consumption in the Czech Republic by more than half in the last 30 years (consumption in 1990 was 298 L/capita/day, while in 2021 it reached 138 L/capita/day). Thus, the Czech Republic ranks among the EU countries with the lowest water consumption per capita. Only 3 European countries have lower water consumption per capita: Slovakia, Malta and Estonia.

All these facts create an important challenge for the owners and operators of public water supply systems (municipalities and cities): to examine their drinking water sources and to ensure appropriate effective measures for their sufficiency and especially their sustainability. If there are available and economically acceptable capacities of existing and relatively not distant water resources, it is urgently needed to interconnect water supply systems or reinforce existing natural sources of drinking water. If these options are not feasible, entirely new sources for drinking water should be developed, preferably by building a new dam valley reservoir for the accumulation of surface water.

Climate change effects on water resources

Current climate scenarios have a wide range, the “medium” scenario suggests that, unless greenhouse gas production if not substantially reduced, average air temperatures will continue to rise, and evapotranspiration will increase significantly. Europe’s average air temperature was expected to increase by + 1.5-2^{o} C after 2040. However, the temperature trend is accelerating in Europe and an increase of +2^{o} C is already expected around 2030 /6/. In addition, a further increase after 2040-2050 cannot be ruled out and an increase of up to +3^{o} C can be expected. The EU’s strategy is clear: to achieve carbon neutrality in 2050. Emissions would have dropped down to the level observed at the beginning of the industrial revolution.

Unfortunately, this European aim has not been applied globally; emissions from countries on other continents continue. Therefore, it is urgently necessary to orient water management strategy towards adaptation of measures to both ensure sufficient water resources in Europe and prevent flooding situations, especially from flash floods. The growth of the average air temperature by 1-2^{o} C in the Czech Republic increases the potential evapotranspiration by 40 - 80 mm /year, resulting in the loss of 3.12 - 6.24 billion m^3 of annual precipitation. This action will not only reduce the volume of water in the soil profile and limit the extent of infiltration, but it will also lead to a decrease in water flows in watercourses.

Thus, if the climate trend remains unchanged, then it is necessary to increase the accumulation of water in reservoirs for the elimination of the expected drop of flow rates in the water courses. If the water balance in basins is insufficient in the future, an extra storage in new reservoirs will be required according to the urgency of providing water supply and other economic withdrawals. Sites for their location are spatially defended in the "Master Plan for Surface Water Accumulation" (available at www.eAgri.cz). The current water welfare and continued availability of water in most European countries causes that the public underestimates the effects of climate change and leads to opposition to the construction of new dam reservoirs. The criticism is based on the negative effects of cross structures in watercourses on aquatic ecosystems and also causes undesirable changes in the landscape structure. Their irreplaceability in providing water supply stability in contrary to scarce groundwater resources in certain regions, is broadly neglected.

Savings in drinking water consumption are often discussed with the aim to reduce withdrawals from existing water sources. In the Czech Republic, further significant reductions are unlikely, even if further 25% of the current level of consumption was saved, this would result in savings of approximately 154 million m^3 of water, which is approximately 3.2% of the available water resources. This volume cannot compensate the expected losses of water resources due to evaporation and evapotranspiration.

Recently, the growing focus has been occurring on recycling discharged treated wastewater from urban wastewater treatment plants, especially for irrigation in agriculture (see EU Regulation 2020/741). As a rule, a relatively slight accent is made on the obligation to additionally treat this water, which entails costs, and also the risk assessment of its use. The possible introduction of this “secondary” recycling will cause decrease discharges of treated water from wastewater treatment plants back into receiving watercourses, which will lead to the drop of their water flows. Recycling for irrigation is undoubtedly important in countries where water consumption for irrigation is around 30-50% and no other water resources are available during the vegetation season. The recycling for irrigation in agriculture is not relevant for the Czech Republic as the agriculture water use is approximately about 3% of total water consumption, while the European average is 58.3%. Recycling of technological waters in industry is of lasting importance not only for saving water resources but also for the reduction of loads by discharged wastewaters.

Outlook

The current European and global trends against the construction of dams (generally of cross-cutting structures on watercourses) represent a serious obstacle to the provision of sufficient water resources. Generally presented recommendations aimed to nature-based measures. An increase of water volume in the soil profile and in the landscape, which are of course very important, nevertheless they will not bring economically usable water resources. Those cannot be created without storage. Decisive measures to ensure sufficient and sustainable water resources in the Czech Republic will be provided by interconnection of water supply systems, by enlarged water management systems and by the increase of accumulation of rainwater precipitation in existing or newly built reservoirs. Adequate and sustainable water resources are a prerequisite for a prosperous economy and a good quality of life for the population. The priority challenge of water management is therefore to ensure sufficient future water resources, in the context of ongoing climate change. The provision of sufficient water, especially drinking water, remains and will certainly remain an overriding public interest.

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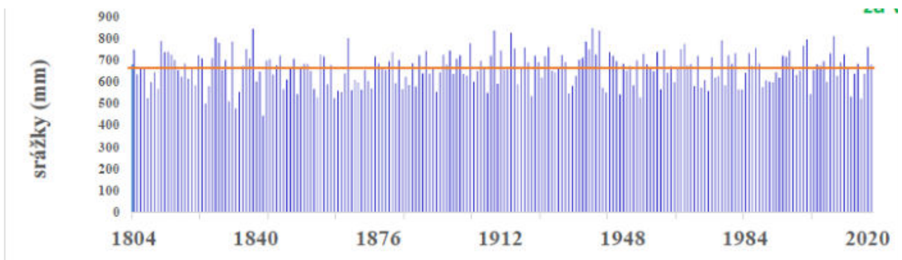

Fig. 1

Precipitation trends in the Czech Republic in the period 1800-2021. /Source: Data of CzechGlobe, by the courtesy of the authors/.

Adapting inland waterways to climate changes – Services, challenges and perspectives for the Elbe river catchment

Stephanie Hänsel, Enno Nilson, Dörthe Eichler

Introduction and Motivation

Dealing with the impacts of climate change is one of the key social and political challenges of the 21st century. Adaptation to the impacts of climate change becomes increasingly important, besides climate change mitigation efforts. The "ship-waterway" system is an integral part of international and national logistics chains, particularly for Germany with its centres of business and industry along the waterways. This system needs to be timely adapted to changing boundary conditions, such as the progressing climate change. Thereby, the potential impacts of climate change in the far future need to be considered already in present planning processes, as transport infrastructures have a long lifetime of up to 100 years and more. This is even more important as a significant amount of waterway infrastructure reaches its designated lifetime in the coming years and decades and related investment decisions have to be made soon.

Regional climatic changes are already visible in observed climate data in the Elbe river basin. Changes in extreme precipitation – encompassing heavy precipitation as well as drought – are of high relevance for different sectors including waterborne transportation, water supply and quality, building industry and energy industry. Increasing event occurrences are to be expected during the coming decades for both extremes. This leads to increased risks and damages in the aforementioned sectors. Thus, analysing and assessing the variability and changes in hydrometeorological parameters and extremes is of high relevance for evaluating climate change adaptation necessities and specific measures.

Climate information and services are needed to fulfil the legal obligations of considering climate change impacts in all planning activities and to achieve the objective of maintaining the transport system in a resilient and sustainable condition. In Germany, the Federal Waterways and Shipping Administration (WSV), as a subordinate authority of the Federal Ministry of Digital and Transport (BMDV), is responsible for the operation, maintenance and construction of the federal waterway Elbe and thus a main user of available climate services.

The hydrometeorological perspective: Variations and changes in the Elbe river basin

Germany's national meteorological and climatological service Deutscher Wetterdienst (DWD) provides highly resolved data sets of observations as well as of climate projections for the large river basis of Germany. These datasets are the basis for the regional analysis of observed and projected hydrometeorological changes in the Elbe river basin. Furthermore, they are used for evaluating climate change impacts using specific impacts models like the hydrological modelling done by the Federal Institute of Hydrology (BfG). The provided datasets, products and services support relevant stakeholders in their climate change adaptation decisions.

The analysis of the climate observations and projections shows that besides a mean air temperature rise also the frequency of hot days, tropical nights and heatwaves is increasing. Precipitation totals and spatial as well as temporal pattern are also changing, but the trends are less obvious as compared to the temperature-derived indices due to the large spatial and temporal variability of precipitation. Nonetheless, a slight increase in annual precipitation totals is observed in Germany – particularly pronounced during the winter season.

The hydrological perspective: New hydrological extremes?

Climate changes always result in changes in the hydrological cycle. Various meteorological extremes are directly followed by hydrological extremes (e.g. drought and flood events). However, additional effects such as water uses and water management have to be considered to fully understand hydrological dynamics in the Elbe catchment.

The hydrological dynamics of the Elbe are complex and its adequate representation in simulation models is complex and a challenge .. Water resources are already managed today, and will be managed in future. However, detailed data on the former and future management are often missing and need to be (re-)constructed. Furthermore, the available amount of water is low in the catchment of the Elbe as compared to other central European rivers. Observed and simulated changes e.g. in the key parameter "river flow" are thus very sensitive to changes or uncertainties in climate data and water use in the respective catchment. Finally, the climate projections currently used for adaptation in Germany show distinct differences to the observed very dry conditions, especially for the near future (mid-21st century).

Services of the DAS Core Service "Climate and Water": Offers, Challenges, Perspectives

The close link between meteorological and hydrological extremes is expressed, among other things, in the DAS core service "Climate and Water". This service is providing data and information products for climate adaptation in Germany since 2020. It is run in cooperation of Deutscher Wetterdienst (DWD), the Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG), the Federal Maritime and Hydrographic Agency (BSH) and the Federal Institute of Hydraulic Engineering (BAW). The products are based on observed time series (past analysis) as well as simulated time series (past and future analysis).

The presentation demonstrates the services of the DAS core service ‘Climate and Water’ for the adaptation of water management in the Elbe catchment to possible new hydrological extremes, using the waterway management as an example. It also shows approaches of the BfG with respect to "attributing" climate and water management change in flow time series. Finally, proposals for dealing with (well known) discrepancies between simulation and observation are presented for discussion in the context of practical climate adaptation.

Climate change adaptation for waterways – Climate services for and specific activities of the German Federal Waterways and Shipping Administration

Since 2015, the consideration of potential climate change impacts is becoming mandatory in more and more infrastructure planning processes in Germany. The main objective of adaptation is to maintain the transport system in a resilient and sustainable condition despite increasing climate change effects. Therefore, it is necessary to capture the impacts of climate change and weather extremes on the specific strategic responsibilities and object-related responsibilities of the WSV and to consider them systematically in adaptation planning by developing risk mitigation strategies.

An updated and comprehensive data basis that allows a quantitative and local assessment of the speed and extent of impacts is an essential requirement for considering the climate change impacts in planning and decision-making processes. These data, tailored reports, training courses as well as continued advisory services are provided by the DAS Core Service ‘Climate and Water’.

The new legal requirements of the German Government have to be implemented nationwide in planning activities leading to an immediate need for action. It is necessary to consider all river basins and to provide the necessary design values simultaneously, as planning activities are currently driven forward in all river basins.

Impact assessments and analyses of compound climate change effects are particularly challenging. Both, science based, and pragmatic approaches are needed to support adaptation planning. To demonstrate our approaches, we use the Geesthacht weir and lock as a show case. The structure is situated at the boundary between the inland and the tidal Elbe, so that estuarine and riverine climate effects (storm surges, high low flow conditions) have to be considered. We present our approach to cover the range of potential extreme (future) water levels in this area.

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Kryry dam – adaptation to climate change and hydrological extremes with the water management systems in the area of influence of the Ore mountains and Doupovské mountains

Jan Svejkovský

1. Introduction

The area at the foothills of Ore mountains and Doupovské mountains has a long-term deficit of precipitation. In the current conditions there is not sufficient water for the irrigation of agricultural land without restrictions. The water in this region is abstracted particularly for the irrigation of valuable hop fields. In the summer months, especially in recent years, the abstraction of water for agricultural purposes has been prohibited, in order to maintain sufficient water in river ecosystem.

The town of Kryry is located in the Louny district of the Ústí Region, in its southernmost part at the border of four regions – Ústí Region, Carlsbad Region, Pilsen Region and Central Bohemian region.

Fig. 1: *Visualization of Kryry dam [1]*

Through the long-term conceptual work of the state enterprise Povodí Ohře Kryry, Senomaty and Šanov dam locations were selected and parameters of the reservoirs were proposed in order to establish water resource system that will ensure sufficient water resource in dry periods. These reservoirs will store water from the upper catchment and will also be fed through the newly proposed pipeline that will convey water from the already existent, Nechranice reservoir. The system will provide sufficient and durable water supply resource as well as will contribute to flood protection not only in the current climate conditions, but also with a prediction to the year 2100.

The lack of water in the local rivers and streams is a long-term problem that the Kryry reservoir is supposed to help solve. Climate change cannot be ignored and it is necessary to respond adequately to the situation. The

Kryra reservoir will supply the subject area with water in the dry season and also help supply the other reservoirs Šanov and Senomaty in the Rakovník region. The entire water management system will be strengthened with water from Ohře.

Technical solutions in the form of water reservoirs with so-called soft revitalization measures close to nature, which are being prepared, for example, in the Petrohrad area. The idea is to achieve such a combination of measures that will be maximally effective and also in harmony with nature.The design of Kryry dam is now in the phase of pre-project preparation, i.e. in the stage of obtaining all essential information, designing the key parameters of the dam objects and the relations of the proposed structure to its surroundings.

2. Purposes and parameters of the Kryry dam

- Ensuring minimum residual flows in the Podvinecký stream and further in the Blšanka river,
- Improving flows for irrigation of agricultural land,
- Transfer of water for irrigation of agricultural land to the Rakovník region,
- Partial reduction of flood flows,
- Fishing,
- Recreation,
- Production of electricity in a hydro power plant.
- River : Podvinecký stream (→ Blšanka → Ohře → Labe)
- Catchment area: 84,11 km²
- Average annual flow: 0,185 m³/s
- Total consumption: 0,144 m³/s
- Dam: earthfill dam
- Dam height: 21,7 m
- Dam lenght: 360 m
- Dam crest: 327,20 m n. m.
- Storage: 6,986 mil. m³
- Retention: 0,773 mil. m³
- Total capacity: 8,948 mil. m³
- Flooded area: 123,6 ha

3. Irrigation

The long-term drought in the area also has an adverse effect on the groundwater level. Thus, the fertility of the local landscape cannot reach its potential, which is closely related to the overall development and prosperity of the region.

Together with the associated smaller reservoirs, the Kryry reservoir will ensure higher flows in the streams and thus become a source of water for irrigation. The planned pipeline will transport water from the Kryry reservoir to the Rakovnický and Kolešovický streams, with the help of the Senomaty and Šanov water reservoirs being prepared, they will provide the necessary amount of water for irrigation and industry in the Rakovník region.

4. Flood protection

The town of Kryry is located in the floodplain of the Blšanka river, which has already overflowed its banks many times. People remember the last significant flood from the summer of 2013. Several entire streets with dozens of houses were affected.

In the entire course of the Blšanka river and its tributaries, the flow cannot be regulated in any way, so the river level is currently not under control. This is exactly what the construction of catch basins solves. The Kryra reservoir on the Podvinecký stream, a tributary of the Blšanka, is designed in detail as multi-purpose. In addition to the storage function, it should be able to solve the role of flood protection if necessary. The dam is designed in such a way that a controllable retention space will be defined in the reservoir just in case of a flood.

5. Recreation

As a multipurpose project, the Kryry reservoir combines the useful with the pleasant. The location offers rich recreational opportunities for residents and tourists. It offers opportunities for water sports and fishing.

The reservoir will increase the attractiveness of the region and contribute to its overall development. At the same time, it will create new job opportunities for residents.

6. Project timeline

2017 Case study of Kryry dam on Podvinecký stream,
2019 Resolution of the Government of the Czech Republic on the implementation of preparations for the Kryry dam,
2020 Resolution of the Government of the Czech Republic on the property settlement of immovable property,
2021 Start of pre-project,
2022 Update of the Principles of Territorial Development of the Ústí Region,
2023 Initiation of EIA process,
2030 Issuance of a building permit,
2032 Construction initiation,
2041 Commissioning of the Kryry dam.

7. Comprehensive solution design strategy

A multi-stage complex water management solution resistant to climate change evaluated until the year 2100 found a robust system of water reservoirs supported by transfers of water from a balanced active profile – from the Ohře River below the Nechranice water reservoir. [2] The water management system will consist of the Kryry reservoir on the Podvinecký stream in the Podbořany region and the Senomaty reservoir on the Kolešovický stream and Šanov on the Rakovnický stream in the Rakovník region. The entire system will be supplemented by a pipeline from Ohře to the existing Vidhostice reservoir, from where to the Kryry reservoir and Velký rybník to Rakovnický potok, and then from Oráčov to Kolešovický potok. All reservoirs will ensure sufficient water management function of the system.

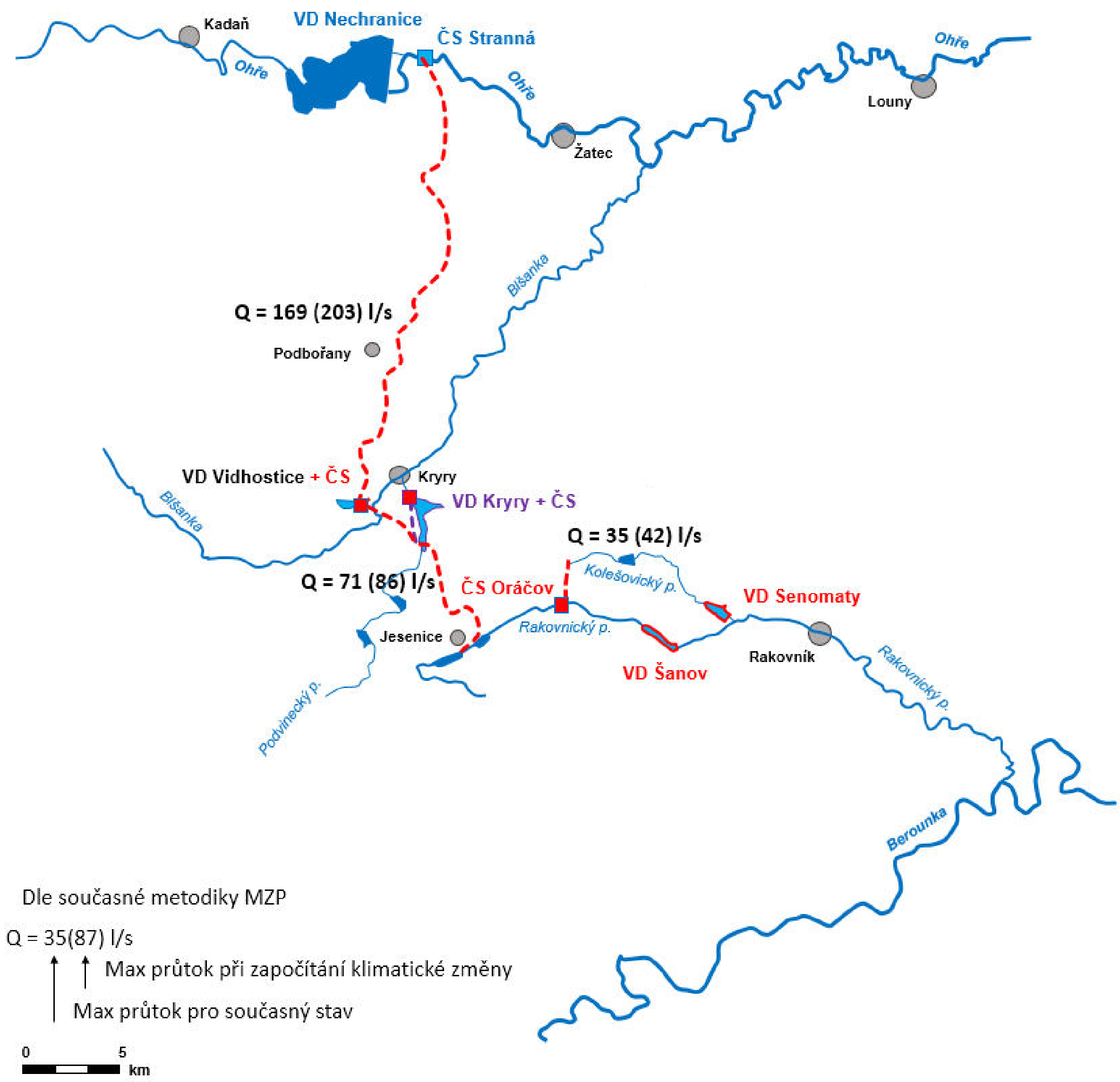

Fig. 2: Scheme of pipeline to supply of water [3]

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Drought in the catchment of the Rappbode dam - management to ensure the supply of raw water and the minimum water flow of the Bode River in the dry years 2018 – 2022

Detlef Cöster

Preliminary remark

Over the last 12 years (2011-2022) the average water availability in the catchment of the Rappbode dam has decreased by approx. 20% compared to the long-term average (1971-2000). In the last 5 years (2018-2022) it has even decreased by approx. 25%. This decline resulted from a decrease in precipitation, an increase in mean temperatures and the associated extension of the growing season and increased evaporation. A significant reduction in snow reserves was also observed. Nevertheless, with an adapted dam management, it was possible to ensure a secure drinking water supply from the Rappbode dam. Especially with regard to the climate forecasts for Saxony-Anhalt and the Harz Mountains, it is important for dam management to adapt to possible further changes. According to the climate forecasts prepared for Saxony-Anhalt, a decrease in the climatic water balance will cause stream discharge to decrease in the long term and we must expect increasingly longer dry periods (low water levels) [1].

The Rappbode dam has a height of 106 m and a full storage volume of 109.1 million m³. With a long-term average inflow of 95.0 million m³, an average of 45.6 million m³/a raw water was withdrawn over the last 12 years (2011-2022) and delivered to the Wienrode water treatment works, which is operated by the Fernwasserversorgung Elbeaue-Ostharz GmbH. This amount of raw water corresponds is enough to supply approx. 1.2 million inhabitants with drinking water and accounts for 37% of the total drinking water volume that is supplied in Saxony-Anhalt [2].

The Rappbode dam is the main dam in the Bode dam system, a network of 6 dams. In addition to providing raw water for drinking, the Rappbode dam serves to protect against flooding, increase low water levels for the Bode River and generate energy. The catchment of the Rappbode dam has a total area of 274 km² and consists of two sub-basins. The first sub-basin with an area of 116.5 km² is the direct catchment of the Rappbode Dam, and drains into the rivers Rappbode and Hassel with their respective pre-dams. The second basin with an area of 157.5 km² drains into the rivers Warme Bode and Kalte Bode (united Bode). From this sub-basin, up to 13.0 m³/s of water can be transferred to the Rappbode dam via the Königshütte dam (transfer dam) and a 1.7 km long connecting tunnel (transfer tunnel).

Meteorological conditions

Due to the low mountain range location with the Brocken massif (900 to 1,142 m above sea level), the highest precipitation in the Rappbode catchment falls in the Upper Harz Mountains at 1,600 to 1,800 mm/year (Brocken station of the German Weather Service). Due to the rain shadow effect of the Brocken massif (leeward area), precipitation decreases relatively quickly to the east. At the bottom of the catchment, at the Rappbode dam, the annual precipitation is between 650 and 700 mm. The average long-term area precipitation is approx. 1,000 mm/year.

In the observation period 2018-2022, the mean annual precipitation at selected stations has decreased significantly (see Table 1). The mean annual precipitation in the period 2018-2022 decreased by between 20.2% (-265 mm at the Schierke station of the German Weather Service) and 12.2% (-119 mm at Sorge station of the German Weather Service) compared to the reference period 1971-2000.

***Tab. 1:** Mean precipitation totals (data according to German Weather Service and dam company [Rappbode dam])*

weather station [altitude above sea level]	period 2018-2022	period 1971-2000	period 1991-2020	difference 2018-2022 to 1971-2000	dev. in % 2018-2022 to 1971-2000	difference 2018-2022 to 1991-2020	dev. in % 2018-2022 to 1991-2020
Brocken [1,142 m]	1,574	1,820	1,784	-246	-13.5	-210	-11.8
Braunlage [607 m]	1,076	1,282	1,321	-206	-16.1	-245	-18.5
Schierke [609 m]	1,044	1,309	1,296	-265	-20.2	-252	-19.4
Sorge [508 m]	855	974	1,061	-119	-12.2	-206	-19.4
Rappbode-dam [430 m]	560	696	707	-136	-19.5	-147	-20.8

As expected, the decrease in precipitation levels at the selected stations in the catchment area of the Rappbode dam also results in a decrease in the areal mean precipitation (see Table 2). For example, the areal mean precipitation in the years 2018-2022 decreased by 19.2% (-196 mm) compared to the reference period 1971-2000. The average reduction was greater in the summer months (summer half-year) at -25.3% (-117 mm) than in the hydrological winter months (winter half-year) at -15.2% (-85 mm).

***Tab. 2:** Area precipitation in the Rappbode dam system (information according to German Weather Service and dam company [Rappbode dam])*

year	winter-half-year in mm	deviation from the mean (1971-2000 [561 mm]) in %	summer-half-year in mm	deviation from the mean (1971-2000 [463 mm]) in %	year in mm	deviation from the mean (1971-2000 [1,024 mm]) in %
2018	551	-1.8	201	-56.6	752	-26.6
2019	558	-0.5	378	-18.3	966	-5.7
2020	500	-23.9	462	0.0	963	-13.2
2021	324	-42.2	394	-14.9	718	-29.9
2022	445	-20.7	294	-36.5	739	-27.8
MW (2018-2022)	476	-15.2	346	-25.3	828	-19.2

In recent years, the decline in precipitation has been particularly large in the months of November, March and April, which are important for dam management. The summer months of June, July, August and September were also clearly too dry. February, on the other hand, was particularly wet. The precipitation levels in January, May and October were mostly average. Furthermore, the air temperature at the selected stations was above the long-term average. For example, at the Schierke station of the German Weather Service, the mean annual temperature in 2018-2022 increased by +1.9 degrees compared to the reference period 1971-2000. The increase in air temperature leads to a longer vegetation period and increased evaporation, and thus has a negative effect on the climatic water balance and the water supply in the catchment of the dams. Due to increased winter temperatures and declining precipitation, a marked reduction in snow reserves was also observed. Both the mean snow depth and the number of days with a closed snow cover decreased. For example, at the Schierke station of the German Weather Service (609 m above sea level) the average snow depth between 1 Nov and 30 Apr in the period 1971-2000 was 27 cm. However, over the last 5 years (2018-2022) it was only 13 cm. Also, the number of days with a snow depth >= 10 cm decreased from 88 days (1971-2000) to 41 days (2018-2022).

Water availability and raw water demand in the Rappbode dam system

The long-term mean annual inflow to the Rappbode dam was 95.0 million m³ in the period 1971-2020. Of this, 43.6 million m³ came from Rappbode's own catchment (45.9%) and 51.4 million m³ was transferred from the Bode catchment via the Königshütte dam (54.1%). In the last 12 years (2011-2022), however, the mean inflow has fallen to 74.3 million m³, a reduction of 21.8%. In the last 5 years (2018-2022) it was only 69.3 million m³ (-27.0%). Of the average annual inflow volume for the years 2011-2022, 37.3 million m³ (50.2%) came from the Rappbode dam's own catchment and 37.0 million m³ (49.8%) was transferred from the Königshütte dam. The water supply in the catchment area of the Rappbode dam has decreased by 14.4% from 43.6 million m³ (mean 1971-2020) to 37.3 million m³ (mean 2011-2022). Moreover, the water availability in the catchment of the Königshütte transfer dam has decreased by 22.2% from 107.9 million m³ (mean 1971-2020) to 83.9 million m³ (mean 2011-2022).

In the long-term average (1971-2020), 79.6% of the total annual inflow occurred in the hydrological winter half-year (75.6 million m³) and 20.4% in the summer half-year (19.4 million m³). This changed in the last 5 years (2018-2022): 93.6% (64.9 million m³) of the annual total occurred in the winter half-year, whereas it was only 6.4% (4.4 million m³) in the summer half-year.

Figure 1 shows the annual inflow volume and the annual raw water requirement demand in the period from 1971 to 2022. It is evident that since 2009 the annual inflows have decreased significantly compared to the previous decades. The average annual inflow in the decade 2011-2020 was 76.3 million m³ and was thus 30.6 million m³ (-28.6%) lower than in the decade 2001-2010 with at 106.9 million m³. The average raw water requirement for the years 2011-2022 was 45.6 million m³/year, which was still well below the average annual inflow of 74.3 million m³ so that there was an average annual water surplus of 29.2 million m³ the last 12 years. Since the inflow volume has fallen to 69.3 million m³ in the last 5 years (2018-2022) and the raw water requirement has increased to 46.8 million m³, the water surplus has fallen to 22.5 million m³ in the last 5 years.

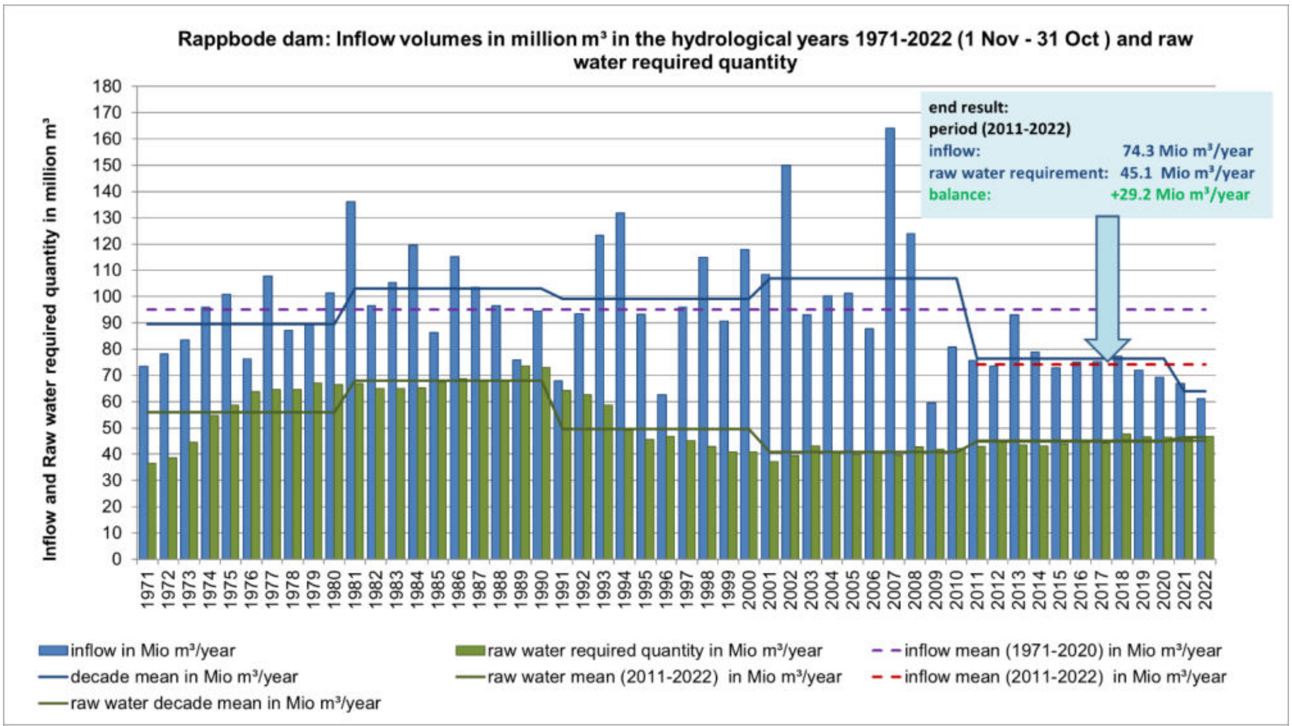

***Fig. 1:** Rappbode dam inflow volume and raw water demand in the years 1971-2022*

Proven operating method to secure the raw water supply and minimum environmental flow for the Bode River

According to the operating plan for the management of the Bode dams, the target storage volume of the Rappbode dam is 95.0 million m³ in winter (1 Nov - 30 Apr) and 105.1 million m³ in summer (1 May - 31 Oct) . Consistently managing the dam according to the operating plan including these targets proved successful during the previous drought years, also thanks to the hydrological winter inflows, which are still sufficient. The successful implementation of the operating plan for the period from November 1, 2017 to December 31, 2022 is shown in Figure 2. Despite the reduced inflow volume, it was possible to achieve or almost achieve the summer water level target in every drought year. Based on the experience of the last few years, with the reduced inflows observed in March and April, it was necessary to attain the summer target volume already in March.

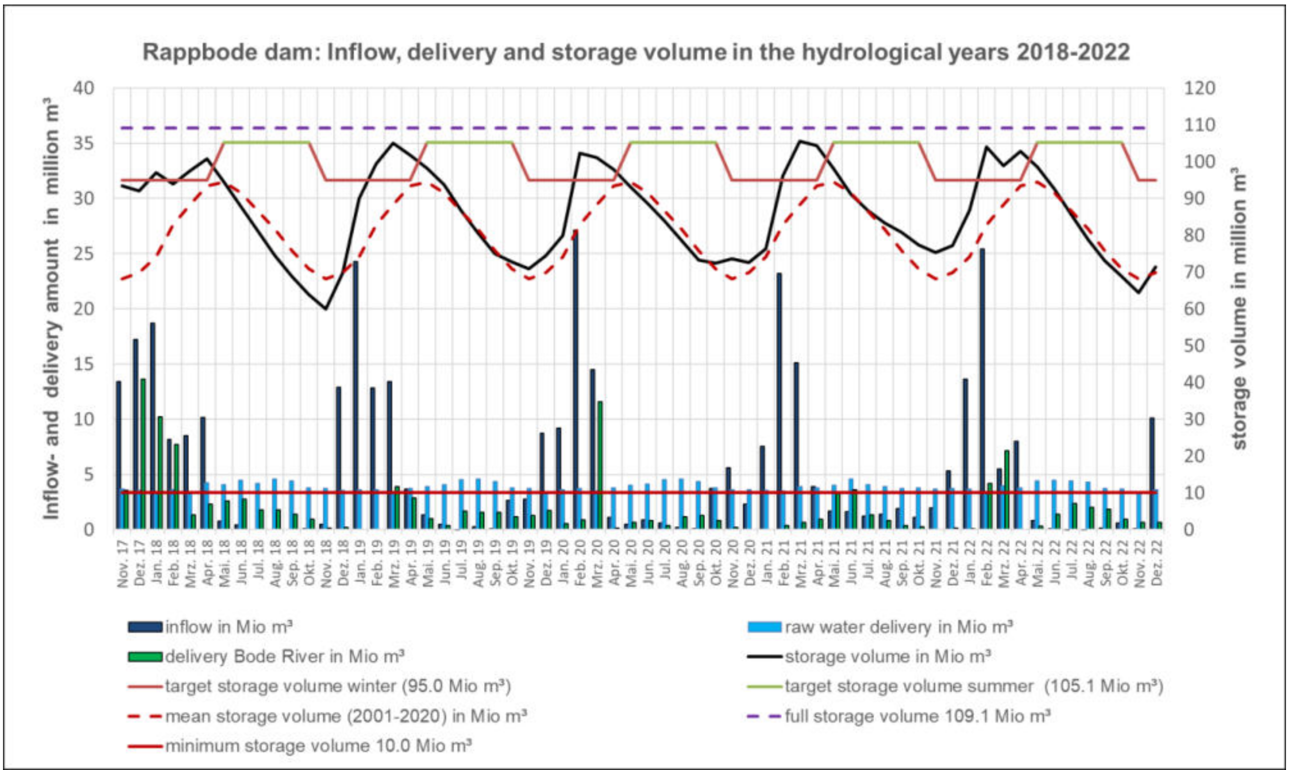

Fig. 2*: Rappbode dam: inflow, delivery and storage volume in the period from 11/01/2017 to 12/31/2022*

In addition to providing sufficient raw water for drinking water treatment, it was also possible to deliver enough water to the Bode River to ensure a minimum discharge of 1.0 m³/s. For instance, in the drought year 2018, a total of 8.4 million m³ of water was released from the Rappbode dam over 210 days to raise the low water level in the Bode River, and in the drought year of 2022, 7.2 million m³ of water was released over 221 days.

As the evaluations showed, all water management tasks of the Rappbode dam could be fulfilled even in the dry years 2018-2022.

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Groundwater drought reflection in the Czech part of the Elbe river basin in 2014–2020

Radek Vlnas, Anna Lamačová and Martin Zrzavecký

1 Introduction

Air temperature increase in combination with below-normal precipitation resulted in a hydrological drought in Czech Republic that lasted from 2015 until spring 2020. Groundwater droughts usually lag behind streamflow droughts. The major aim of this study was to evaluate the groundwater drought both in shallow aquifers and deep aquifers with a focus on major litostratigrafic units with a significant water accumulation potential in the Czech part of the Elbe river basin in the period of 2014–2020.

2. Data and methods

Shallow aquifers were evaluated in 5 coordination areas of the international Elbe river basin district: Upper and middle Elbe (HSL), Upper Vltava (HVL), Berounka (BER), Lower Vltava (DVL), Ohře and lower Elbe (ODL) located in the Czech part of the Elbe river basin. Three hydrogeological regions with deep aquifers representing Cretaceous and Tertiary sediments were evaluated. Two hydrogeological regions were located in the northern part of the Czech Elbe river basin, North Bohemian Cretaceous basin that stretches between the Jizera and the Lower Elbe rivers and East Bohemian Cretaceous basin located in the eastern part of the Upper and middle Elbe. South Bohemian basins are located in Upper Vltava coordination area.

A 186 shallow boreholes and 22 deep boreholes were selected for the analysis. Monthly means were converted to the empirical Cumulative Frequency Curve [1] and compared with long-term values of the reference period 1981–2010 (shallow boreholes) or 1991–2010 (deep boreholes). Groundwater levels were divided into seven classes moderately (15–25%), much (5–15%) and extremely (< 5%) below normal, normal (25–75%), moderately (75–85%), much (85–95%) and extremely above normal (> 95%).

3. Shallow aquifers

Groundwater levels in the shallow aquifers were generally normal in 2014. Although the level was much below normal in the spring, it rose throughout the year to a much above normal in the fall (Fig. 1). The moderately above normal groundwater conditions in early 2015 began to deteriorate rapidly throughout the area. The drought was most pronounced during the summer in the HVL and HSL coordination areas. Overall, water levels were much below normal in 2015. Drought continued in 2016, but conditions varied regionally. Drought was most pronounced in the HSL coordination area, where levels were extremely below normal during the summer. In the HVL and BER coordination areas, drought was only present in April and May, and overall levels were normal there in 2016. Overall, the much below normal levels continued in 2017. In 2018, the level had been declining since January and the extremely below normal level condition prevailed throughout most of the year. The drought was most pronounced in the HSL coordination area, where extremely or much below normal levels were recorded at 90% of the monitoring sites in August. Overall, 2018 was the driest year since observations began (since 1971). The extremely below normal levels continued in 2019, although the summer drought did not reach the previous year's minimums in most areas, except in the HVL and BER coordination areas, where the drought was more pronounced. Extremely below normal water levels prevailed until May 2020. However, during the second half of the year, water levels improved in the HVL, DVL and HSL coordination areas, even reaching much above normal level in November. However, there was only minimal improvement in the BER and ODL coordination areas. Overall, the level status in 2020 was much below normal.

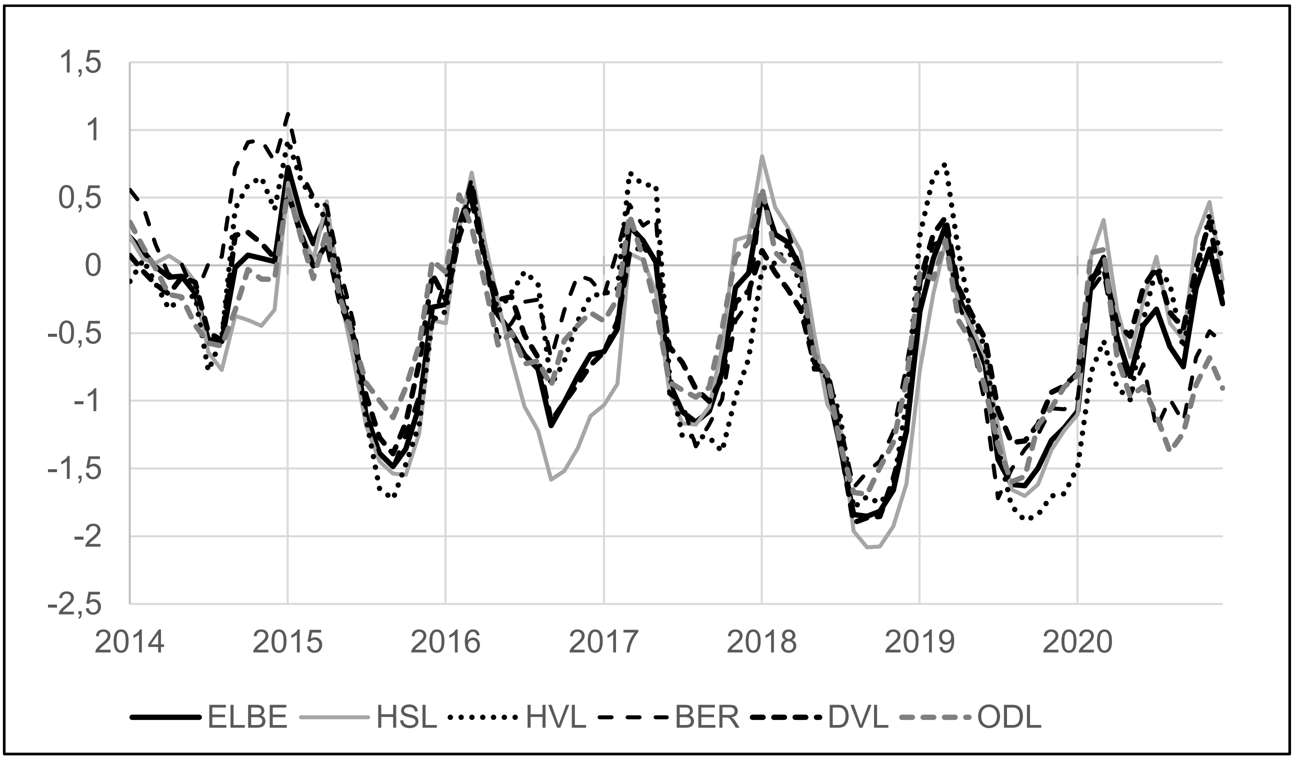

Fig. 1: *Standardised groundwater level in the Czech part of the Elbe river basin (ELBE) and individual coordination areas: Upper and middle Elbe (HSL), Upper Vltava (HVL), Berounka (BER), Lower Vltava (DVL) and Ohře and lower Elbe (ODL) in the period of 2014–2020.*

4. Deep aquifers

Overall groundwater level of the South Bohemian Basin and the North Bohemian Cretaceous basin was moderately above normal in 2014, while the condition of the East Bohemian Cretaceous basin was normal. In the following years, the levels of both the South Bohemian Basin and the North Cretaceous were declining, so that by 2017 the level was already much below normal and from the second half of 2018 mostly extremely below normal. The level continued to fall until the end of 2019 (Fig. 2). In 2020, the level in the North Bohemian Cretaceous basin stagnated, while in the South Bohemian basins was slightly increasing. In the East Bohemian Cretaceous basin the groundwater level also was declining for a long time to an extremely below normal level in 2019, but increased in 2020 to a much above normal level in November.

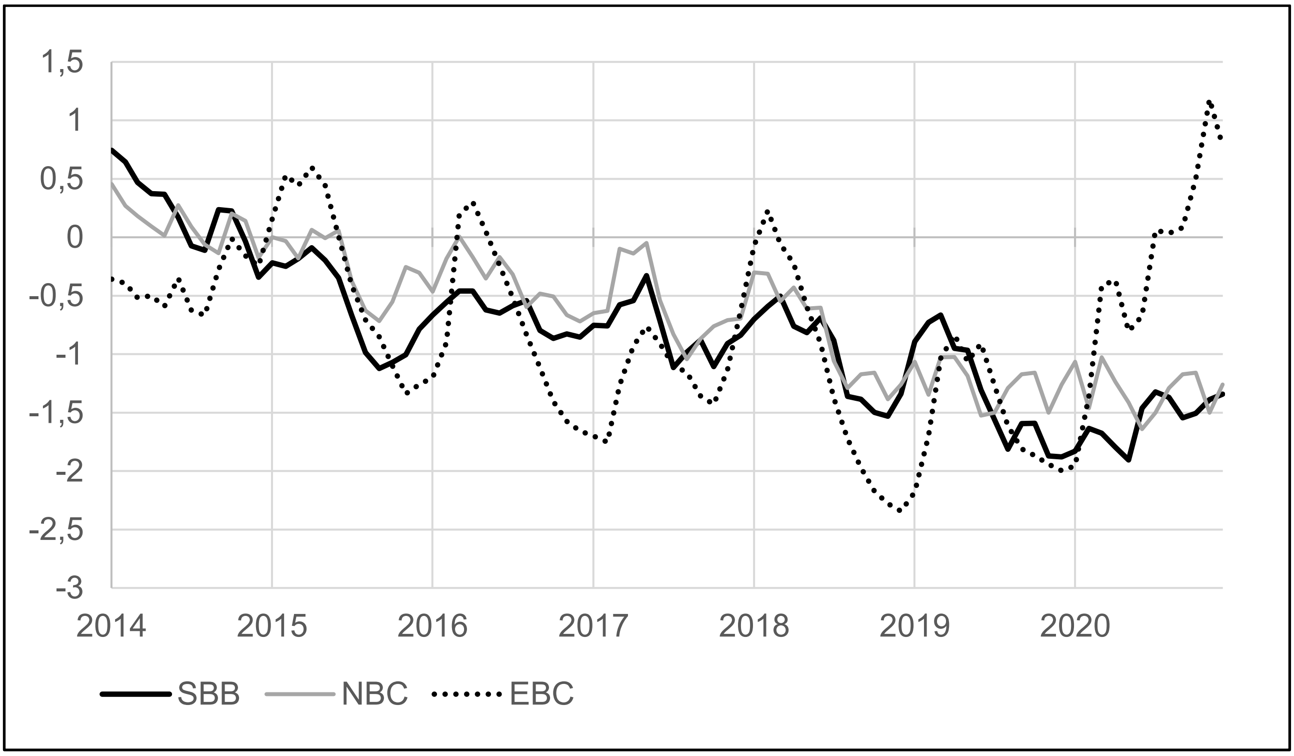

Fig. 2: *Standardised groundwater level in hydrogeological regions South Bohemian basins (SBB), North Bohemian Cretaceous basin (NBC) and East Bohemian Cretaceous basin (EBC) in the period of 2014–2020.*

5. Conclusion

The most severe drought was detected the year 2018 in both shallow and deep aquifers. The drought occurred in particular in the area of Upper and Middle Labe river basin district where is also located the area of North Bohemian Cretaceous Basin that stretches between the Jizera and the Lower Elbe rivers and that belongs to protected area of natural water accumulation. The drought continued until the spring 2020. Then the situation started to improve notably since June of 2020 and in case of shallow aquifers a normal water level prevailed in most coordination areas (with the exception of Ohře and lower Elbe, where the drought persisted throughout most of the year). However in the deep aquifers especially in North Bohemian Cretaceous Basin and South Bohemian basins the drought from past years continued and the water level of the late cretaceous sediment (mostly Turonian) remained extremely below normal.

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Dry period in Saxony in the period 2014 to 2020 and its impact on the environment

Petra Walther and Stefanie Weißbach

1. Introduction

After the flood of 2013, a climatically long and continuous section at a very high thermal level began in Saxony. The effects on the water balance first became apparent in the Elbe in 2015. In the years 2018 to 2020, due to low precipitation and high temperatures, there was extreme dry soil, a Saxony-wide groundwater drought and extremely low water in the rivers with consequences for the water ecology and dependent nature conservation assets. The management of the dams became more and more complicated due to the scarcity of water.

In addition to the effects on the water balance, forests were severely damaged due to the prolonged drought, yields in agriculture and horticulture fluctuated extremely and air pollution by ozone rose to a high level.

In the article, the interdisciplinary evaluation of the drought in Saxony for the period from 2014 to 2020 is presented. Details can be found in [1].

2. Climatological evaluation and classification, comparison to historical dry periods

Since the beginning of the meteorological drought after the flood in 2013, a precipitation deficit has built up in Saxony, which increased significantly from 2018 onwards. Compared to the long-term average value of the 1991 - 2020 series, the soil in Saxony has been missing more than half of the average annual precipitation since 2018.Precipitation deficits of this magnitude are also known from the past. However, since 2018 extremes for air temperature and hours of sunshine occurred that have not yet been observed on this scale. The last 30 seasons , all seasons have been consistently warmer, making it the longest contiguous excessively warm section since 1881. This is also roughly true for the hours of sunshine since 1951. This constellation led to a drought, especially from 2018 onwards (Figur 1), their consequences are then briefly presented.

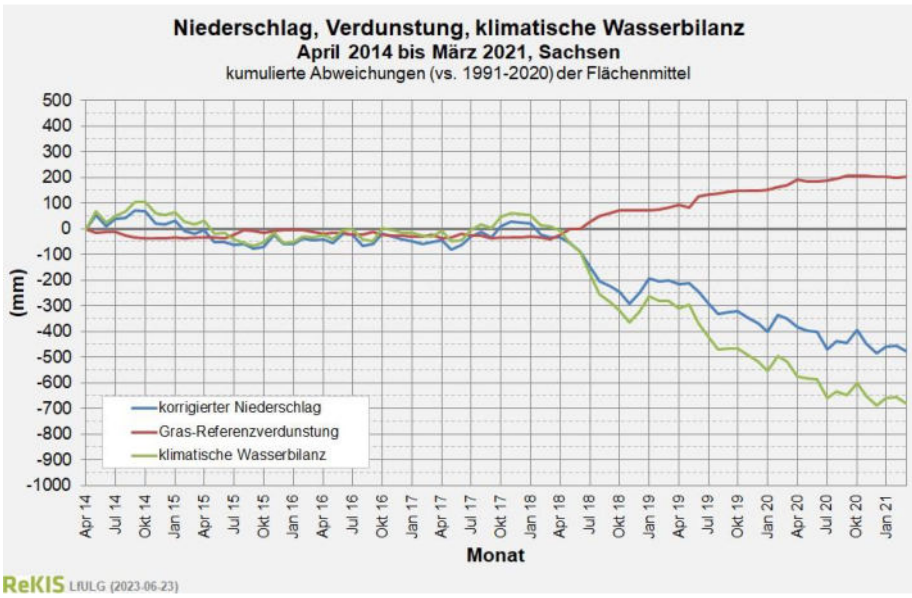

Fig. 1: Development of precipitation, grass reference evaporation and climatic water balance from 2014 to 2020

3. Statistical analysis of low water parameters and classification of annualities

In Saxony, the quantitative assessment of the low water from 2014 to 2020 was based on the average daily flows of 34 stream gauges and statistical low water parameters determined from them. For more detailes see in [1].

The evaluation showed that 2014 and 2015 were already dry years. At the stream gauges of most rivers annual discharges below average were observed. In the years 2016 and 2017, when there was not quite as little rainfall, the situation in the rivers did not ease everywhere. The following years 2018, 2019 and 2020 were dry, especially the year 2019 was very dry on average for the year. In terms of duration and discharge deficit, the low water level in 2018 was the most extreme year in many river basins in the period under consideration from 2014 to 2020. The low water level lasted for more than half a year, and in some cases the situation was more extreme than in the years 1934, 1962 to 1964 and 1976.

For the first time, an extreme value statistical evaluation of the low water level in the water budget year (01 April to 31 March) was carried out for the water levels. Among other things, the parameters duration and discharge deficit were used for this purpose. Here, the low water in 2018 resulted in annualities of over 100 years (Figur 2). In the water budget years (WHJ) 2019 and 2020, annualities between 50 and 80 years were only recorded for individual stream gauges, otherwise mostly between 10 and 25 years. In the other WHJs, only the low water level in the WHJ 2015 in the Lusatian Neisse and Spree with annualities of 10 to 20 years was statistically striking.

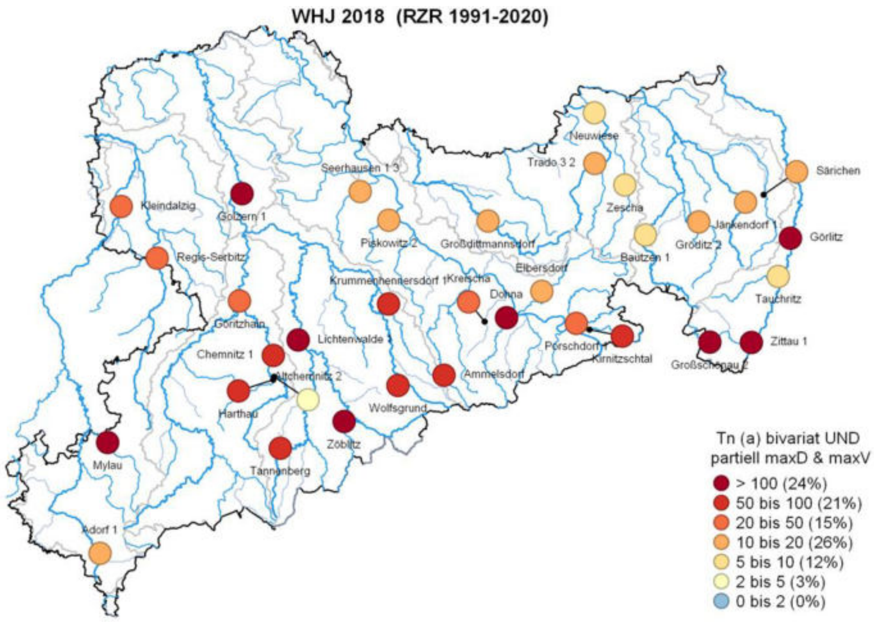

Fig. 2: *Annual periods for the water budget year 2018, the duration and the runoff deficit for selected stream gauges*

4. Impacts on soil, groundwater, water quality and air quality

The drought from 2014 to 2020 affected soil, groundwater, water quality, and air quality. Low soil water reserves, lack of groundwater recharge and sharply decreasing groundwater levels have been identified, especially since 2018. A very extreme drought situation occurred in the groundwater. The period from 2018 to 2020 had the greatest intensity of all groundwater droughts observed in Saxony so far.

The low water flow and the warming of the waterbodies during the drought had an impact on the water quality and thus also had a direct impact on the habitat of many organisms. In the evaluation of the substance behaviour at low water, it was found that the concentrations of pesticides and metals in the waterbodies have decreased, but that the constituents that enter the waterbodies through wastewater discharges have increased significantly.

The drought or rather low-precipitation episodes have influenced the concentration of air pollutants such as particulate matter and ozone. In the long dry phases, more particulate matter was measured in the air, as there was no leaching from the rain and the air was increasingly stirred up (road dust, agriculture, etc.). The many hours of sunshine and the high air temperature in the summer months affected the ozone chemistry.

5. Impacts on resources water in reservoirs, agriculture and forest

The evaluation of the dry period from 2014 to 2020 has shown that the water supply and the availability of water for dam management can be significantly reduced. At the same time, the supply of raw water was never endangered during this period and also not in the extreme year 2018. The filling levels in the dams had reached their lows in 2018 (Figur 3). This also had an effect on the quality of the water. During this time, the networking of the dams and the interconnected management have proven their worth, the optimisation of which continues to be of decisive importance.

Fig. 3: *The heavily lowered dam Lehnmühle, picture: Petra Walther*

The drought, especially in the years 2018 to 2020, has had a massive impact on agriculture. The extreme year with the lowest yields was 2018. During this period, the forest was also massively weakened by the drought (Figur).

Fig. 4: *Forest damage in Saxon Switzerland, picture: Petra Walther*

6. Measures, particularly in river basins affected by mining

In the river basins of the Spree, Schwarze Elster and Lusatian Neisse, which were influenced by lignite mining, but also the Weiße Elster, the discharge situation was very tense. Especially in eastern Saxony, the situation was particularly extreme in 2018, 2019 and 2020. The existing natural availlability of water was not sufficient to meet all water dement requirements. The required minimum discharges in the rivers and the geotechnical minimum water levels in the post-mining lakes could hardly be maintained. Regional and transnational cooperation has been established and conditions have been created to counter the water management effects of the lignite phase-out and climate change and to support structural change in the coming years.

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Odborné příspěvky Fachbeiträge

Magdeburský seminář o ochraně vod 2023
Magdeburger Gewässerschutzseminar 2023
11.–12. 10. 2023

Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Polutanty a jejich dynamika ve vodním prostředí
Schadstoffe und deren Dynamik im aquatischen System

Monitoring the dynamics of pesticides leaching during rainfall-runoff events

Dobiáš J., Metelková A., Liška M.

1. Abstract

Main water quality monitoring of Povodí Vltavy, State Enterprise provides stable and long-term results [4]. However, point samples doesn´t capture the dynamics of water quality changes during the short hydrological events, which are frequent. Without further examination, the overall balance and range of pollutants can often be underestimated [5]. During the rainfall-runoff events plant protection products are flushed out mainly from surface, rarely from point sources of pollution [2,3,6,7]. The concentration of these substances can therefore increase or be diluted by several orders of magnitude within tens of minutes depending on suddenly increasing flow rate [1]. These changes in surface water quality last for a short time. Moreover, some pesticides (or their metabolites) occur only during these hydrological events [3].

Based on the need to capture these short episodes, an automatic sampling station was put into operation since 2012 [1,3]. Located gradually in two agriculturally used sub-catchments of the most important reservoir in Czech Republic (Švihov drinking water reservoir on the Želivka river). In 2023, possibilities of this monitoring are expanded by another fully mobile automatic sampling station. The results of the monitoring of rainfall-runoff events are presented in this paper.

These additional results describe the pollution in the catchment area of the reservoir and allow to better target the range of monitored substances. Further, they are used as a basis for corrective measures and recommendations of practice for sustainable agriculture [6]. The dynamics of nutrients and specific organic substances leaching during rainfall-runoff events turns out to be so significant, that without that we can only estimate the highest concentrations and total amounts [1].

Keywords: pesticides, automatic sampling, rainfall-runoff events, Švihov reservoir

2. Introduction

The occurrence of plant protection substances in surface waters is very dynamic and influenced by many variable factors. To obtain accurate substance balances and the qualitative occurrence of these substances, we encounter certain limitations of standard operational monitoring. Based on these requirements and needs, in 2012 the operation of an automatic sampling station on the Čechtický brook in the lower part of the Švihov water reservoir was started. In 2021, the station was moved to the upper part of the watershed on the Bořetický brook, where it is operating till today. In 2023, options were expanded regarding the emergency water monitoring by acquiring a mobile sampling station (Fig. 1). The stations are equipped with the automatic sampling accessories, online transmission, flow measurement and other basic parameters, possibly precipitation measurement, audio-visual transmission, and solar panels. The 14-day sampling scheme is divided into the continuous sampling (two-day mix samples) and sampling during hydrological events (point samples), which can be triggered by sudden change of the measured parameters, most often the water level.

Pesticides and their metabolites are subsequently determined in the laboratories of Povodí Vltavy, State Enterprise using a liquid chromatography method (LC) with mass detection based on the triple quadrupole principle (MS/MS). Three groups of these substances are analysed (triazine herbicides, chloracetanilides and urons) [1].

Fig. 1a, b: *Stationary and mobile sampling stations.*

3. Results

Since the station was put into the operation, samples from continuous sampling and 28 rainfall-runoff events (from March to November of the respective year) have been analysed. Already published older data [1] are now supplemented by new results, which are highly variable and can be divided into the several hydrological scenarios.

A frequent case of a rainfall-runoff episode on smaller streams is a rapid and sudden increase in pesticides and their metabolites. An example is the event captured on 24.6.2021 (Fig. 2). The concentration of the pesticide terbutyazine increased with the flow from 13 ng/l to 2020 ng/l within eight hours. The same trend was observed also for the herbicide pethoxamide used on rapeseed oil (before the increased flow, it was below the detection limit of 10 ng/l, then 2220 ng/l) and metobromuron (herbicide for potato growing), which increased from 38 ng/l to 2760 ng/l (Fig. 4). Similarly, metabolites of terbulazine (Fig. 2), their lower concentrations compared to the parent substance demonstrated the recent application on the farmland. Another frequently observed phenomenon is the increased occurrence of plant protection products before the actual highest flow rates or on the contrary for a longer time after. The herbicide metribuzin had a concentration maximum during the rainfall-runoff episode in the Bořetický stream before the increased flow rates (from 179 ng/l to 1360 ng/l, Fig. 4). Conversely, the highest concentration of metazachlor in the episode recorded on 12.9.2021 (Fig.3) appeared 9 hours later after the increased flow (from 45 ng/l to 8780 ng/l). The last example of quantitative and qualitative changes of plant protection products in the surface waters during rainfall-runoff episodes is dilution of concentrations (Fig. 5, 6).

Thanks to the continuous monitoring on the Čechtický and Bořetický brooks during rainfall-runoff episodes were recorded many short-term increases and/or decreases in concentrations. For example, cyprosulfamide (maximum captured concentration: 5900 ng/l, average annual concentration: 52 ng/l), linuron (max.: 9540 ng/l, average: 213 ng/l), quinmerac (max.: 5690 ng/l, average: 432 ng/l), bentazon (max.: 4500 ng/l, average: 149 ng/l). Furthermore metabolites, e.g. metazachlor ESA (max. during the episode: 1770 ng/l, average: 2840 ng/l) and already forbidden alachlor ESA (max. during the episode: 652 ng/l, average: 993 ng/l), these concentrations decreased during higher flows compared to the annual average. Mass balance analysis demonstrate an increase in pesticides and metabolites in the most of these rainfall-runoff scenarios. During the three-day period before the rainfall-runoff episode recorded from 24.6.-27.6.2021 (Fig. 2), 215 g of pesticides and their metabolites flowed from the sampling site on the Bořetický brook, during the 3 days of the highest flows it was 742 g. Similarly, during the episode 14.4.-16.4.2023. Although there was a decrease in the concentrations of most substances due to persistent rains (Fig. 6), the total ratio was an order of magnitude higher (81 g in two days in the period before the episode and 269 g during the increased flows).

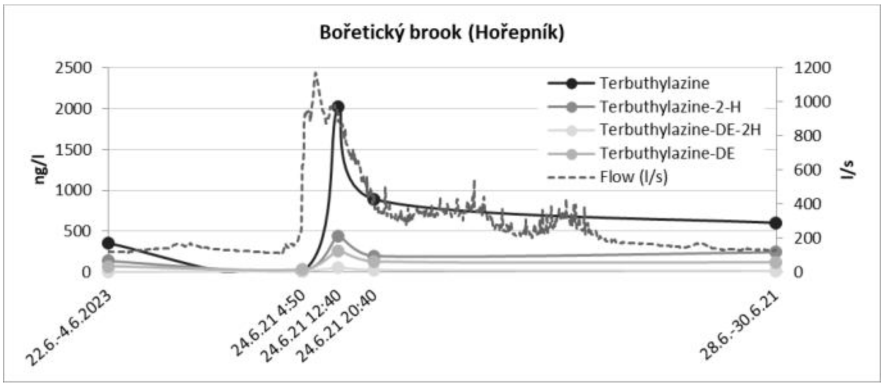

Fig. 2: *Increase in concentrations of terbuthylazine and its metabolites during the rainfall-runoff episode 24.6.2021.*

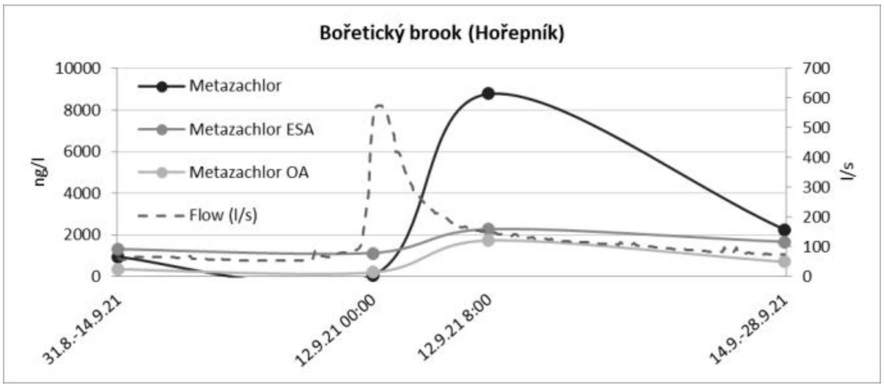

Fig. 3: *Delay in elevated concentrations of metazachlor and its metabolites during the episode 12.9.2021.*

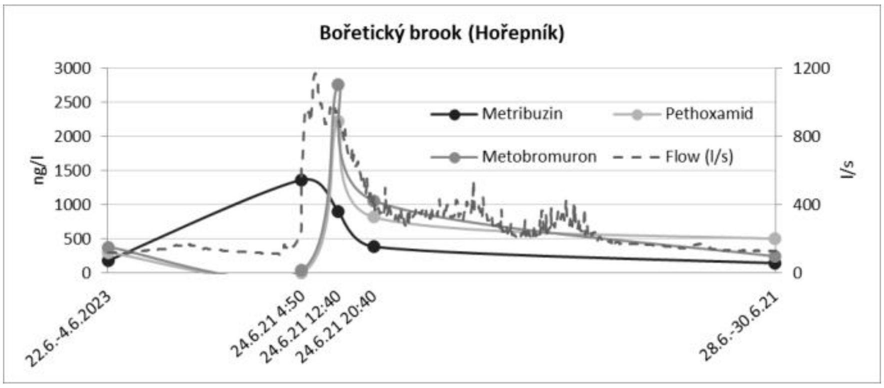

Fig. 4: *Elevation of selected pesticides and their time shift against increased flow during the rainfall-runoff episode 24.6.2021.*

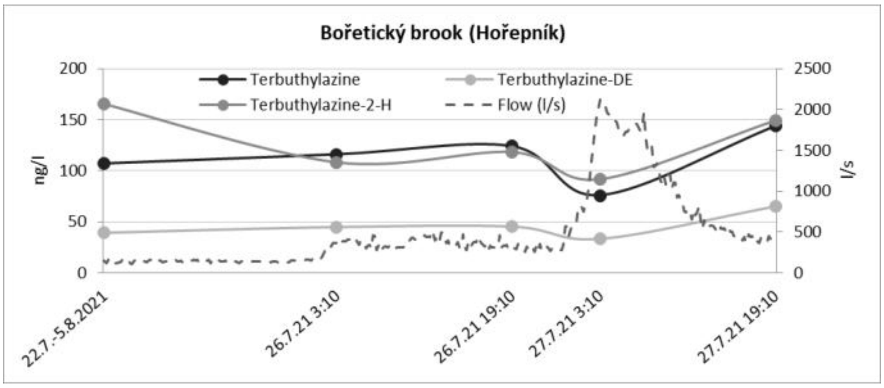

Fig. 5: *Dilution of concentrations during the summer rainfall-runoff episode 26.7.2021.*

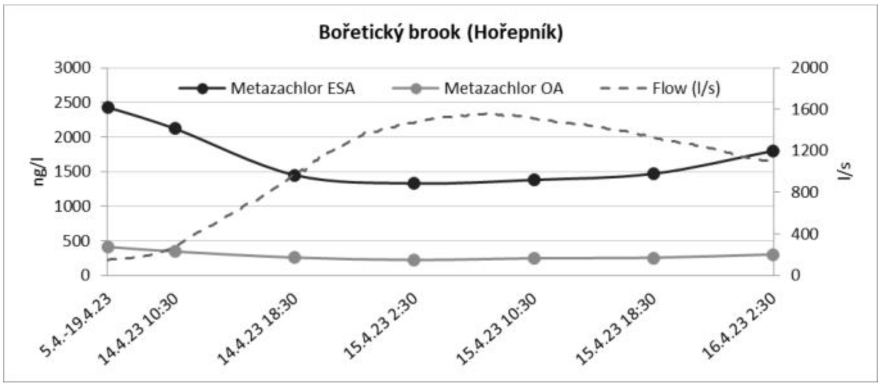

Fig. 6: *Reduction of metazachlor concentration during long-lasting rainfall in the Bořetický brook basin (14.4.2023).*

4. Discussion

During rainfall-runoff episodes, the concentrations and total amount of pesticides and their metabolites in surface water changes significantly. The concentrations may decrease and/or increase just before, during, or immediately after increases in flow rates. However, the total mass balance of substances is usually significantly higher and without continuous monitoring often underestimated. The pesticides entry from agriculturally used areas is influenced by many interacting variables. The most important factors are the season, intensity of application on the farmland, runoff type (surface, subsurface), the intensity of precipitation, and the persistence of substances in the soil or water environment. Last but not least, distance of the agricultural area from the sampling location and the terrain slope.

A significant change in concentrations often occurs during the application period after the short and heavy rainfalls (Fig. 2, 3, 4). The time shift of the maximum concentrations of pesticides in relation to increased flows is usually caused by the type of runoff, possibly the season and the intensity of applications. Contaminated water can be pushed in front of the increased flow (Fig. 4), or vice versa, washed out more slowly later (Fig. 3). Dilution of concentrations occurs more often with metabolites by leaching from the soil horizon (Fig. 6) or during the summer period (Fig. 5). For accurate interpretation and monitoring of the surface waters, not all the mentioned data are usually available, continuous monitoring is thus an important tool for understanding the dynamics of pesticides in surface waters and it is essential for proposing corrective measures.

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Effects of Heavy Precipitation Events on the Element Composition of River Water – Model Region Ammer

Nils Ribbe, Wolf von Tümpling

1. Introduction

Climate change leads to an increase of extreme weather events in Europe [1]. In order to understand better their background and to optimise impact assessment and mitigation, Swabian MOSES 2021 was launched under the coordination of the Karlsruhe Institute of Technology (KIT) in cooperation with five Helmholtz Centres, 3 universities and the German Weather Service (DWD) [2]. The interdisciplinary hydro-meteorological field campaign focuses not only to atmospheric studies but also to the surface water of rivers affected by heavy rainfall. Based on trace element determinations in water samples before, during and after heavy rainfall events in June 2021 in the catchment area of the Neckar near Tübingen, element pattern distributions will presented with the aim of source identification.

During heavy rainfall events, only part of the rainwater infiltrates. Large amounts of water run off superficially into streams and rivers. In urban areas, road dust and other trace elements and possibly pollutants washed into the sewage system. If the combined sewer systems overloaded during heavy rainfall events, the rainwater is released untreated into neighbouring waters. In the case of unvegetated areas, the precipitation causes soil erosion and discharges into the neighbouring water bodies. River sediments are remobilised by the increase in flow velocity in the river [3].

Different pathways of rainwater as well as the remobilisation of river sediments should lead to different dissolved and particle-bound element pattern distributions before, during and after a heavy rain event. Based on the typical element patterns, sources of surface inputs can be distinguished, e.g. via sewage treatment plants, and their influence on the water body can be estimated.

For this reason, time series sampling was carried out in the flood waves during heavy rainfall events in June/July 2021 on two rivers in Baden-Württemberg. For a comprehensive picture of the element transport processes, a large number of trace and quantitative elements as well as lanthanoids and actinoids were selected for pattern recognition.

2. Material and Methods

As a hotspot for heavy rainfall events, an area east of the Black Forest above the Swabian Jura was the focus of the investigations carried out within the framework of Swabian MOSES. The surface water investigations took place on two rivers in the catchment area of the Neckar near Tübingen with the Steinlach near Dusslingen and the Ammer near Pfäffingen.

In the results section, a heavy rainfall event that occurred on the Ammer on 20/21 June is discussed in detail in order to compare it with other events that were also investigated (Ammer: 29/30 June; Steinlach: 23/24 June). Based on a sampling at normal water discharge (baseflow; approx. 0.2 m3/s) on 27.05.21, the event-related sampling was carried out. In addition to a quarter-hourly measurement of the flow, water samples for the element analysis were taken between 20.06.21 21:45 h and 20.06.21 02:45 h at half-hourly intervals and additionally on 20.06.21 12:30 h. Water samples were taken at the same time.

To determine the dissolved element concentrations (c_{gel}) and the pseudo-total concentration (c_{total}), corresponding subsamples were taken. For the measurement of c_{gel}, aliquots were filtered. The stabilisation was done with 3 drops of conc. HNO_3, just as the unfiltered subsamples for the c_{total} determination. For the measurement of c_{total} from the unfiltered subsamples a microwave digestion (1.5 ml HNO_3 and 1 ml H_2O_2 on 20 ml sample, T = 100 °C, tramp = 8 min, thold = 10 min) was performed at the Helmholtz Centre for Environmental Research - UFZ Magdeburg.

The quantitative determination of Ca, Mg, Al, Mn, Fe and Zn has been carried out by ICP-OES (Perkin Elmer Optima 7300DV, USA). Selected trace elements, lanthanides and actinoids (Ba, Cs, Li, Rb, Sr, B, As, Co, Cr, Cu, Ni, Pb, Sn, Bi, Mo, Sb, Ti, V, W, Y, Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, Tb, Tm, Yb, Th, U) were analysed by ICP-MS/MS (Agilent 8800 ICP-QQQ, USA). In accordance with Good Laboratory Practice (GLP), certified control standards (NIST 1640a, TMDA 64.3, SLRS-2) were measured for each element and recovered with sufficient accuracy (± 10 %).

The graphs shown in the results section produced using Origin 2021.

3. Results and Discussion

From the measured c_{total} and c_{gel}, the concentration of particulate-bound elements (c_{part}) was calculated according to the formula $c_{total} = c_{gel} + c_{part}$. For many elements, c_{total} is nearly equal with c_{part}, as they were not detectable in the dissolved phase of the river water.

With regard to their behaviour during heavy rainfall events, the elements can be divided into different groups. Figure 1 a) to c) shows the concentration curves of three elements, each representing a group of elements with similar concentration curves.

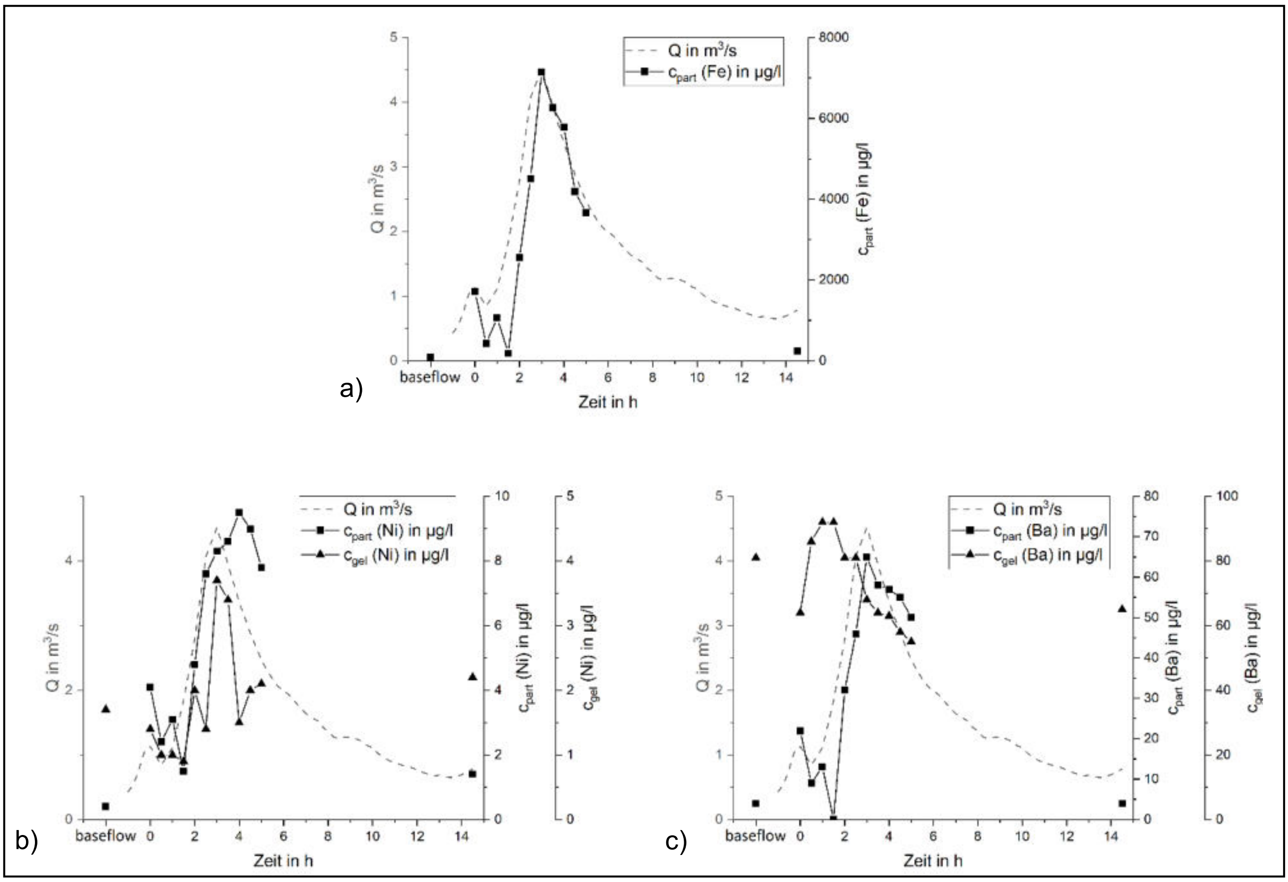

Fig. 1: *a) to c) Exemplary graphical representation of three distinguishable concentration curves using the example of iron (a), nickel (b) and barium (c).*

On the one hand, there are elements that have been detected in the water mainly in particulate form and whose concentration rises sharply with the flow during a heavy rainfall event and then falls again after the maximum flow has been reached (Figure 1 a). This is the case for the elements Cs, Al, Co, Cr, Fe, Mn, Pb, Sn, Zn, Bi, Ti, W, Y and the lanthanides and actinides (except uranium). The turbidity of the water, which also increases with the flow rate, indicates a relation between the concentration curves and the mobilisation and transport of suspended solids [2]. According to modelling by Liu et al. [3] for the area of influence of the Ammer River, these solids originate primarily from urban surface runoff at given flow rates. The contribution of bank and river bed erosion to the amount of suspended particles in the water is negligible.

The same relationships are also found for the elements Rb, As, Cu, Ni, Sb, and V (Figure 1 b). However, the special feature here is that at normal water levels they occur in low concentrations predominantly in the dissolved phase of the water. Only with increasing flow do particulate-bound fractions appear in the river water and exceed the dissolved concentrations (factor 2 to 5). The increase in the particle-bound concentration of the above-mentioned elements is an indication that large-scale, diffuse erosion of soil particles is taking place, which emits into the water body. During lower water levels without influence of rainwater, these elements are detected to be dissolved in the water and enter the surface water via the near-surface groundwater. The observed slight increase in c_{gel} is due to the dissolution of corresponding trace elements from the soils washed into the river.

In contrast, there are also elements whose concentration in the dissolved phase of the river water increases slightly at the beginning with increasing flow and decreases at a certain point in time (Figure 1c). This is the case for the elements Mo, Mg, Ca, B, Sr, Li, U and Ba. A similar concentration curve during heavy rainfall events on the Ammer has already been observed for nitrate [4]. The authors established a correlation between the nitrate concentration in the river water and the overflow of the rainwater and wastewater treatment plants. During a heavy rain event, all rainwater falling on sealed surfaces is channelled into the sewage treatment plants for treatment. When these reach their capacity limits, they release untreated rainwater and wastewater into the Ammer. At the beginning of the rainwater and wastewater discharge into the river, the proportion of nitrate-rich wastewater is still very high, whereby an increase in the nitrate concentration in the river water can be observed. As the rain progresses, the wastewater is increasingly diluted by the low-nitrate rainwater in the effluent of the treatment plant. As a result, the input of nitrate from the treatment plant into the river decreases continuously. Since Ca, Sr, B, Li, Mg and Ba have already been detected in high concentrations in the effluent of wastewater treatment plants [5], the relationship observed for nitrate can be transferred to the elements mentioned. The similar concentration course for Mo and U suggests an enrichment of the affected elements in untreated wastewater.

The other investigated heavy rainfall events show comparable element patterns. However, there are differences in the concentrations depending on the amount of rain and the flow rate. The heavy rain event of 29/30 June resulted in a flow of 11.43 m3/s in the Ammer, which according to Liu et al [3] is sufficient for riverbed and bank erosion to contribute significantly to suspended sediment mobilisation. Thus, the amount of suspended solids increased and with it the concentration of particulate elements in the water (factor 2 to 4). The elements associated with untreated rainwater and wastewater are present in lower concentrations in the river water due to the heavier rainfall at the beginning, but show the known temporal concentration pattern. The heavy rainfall event of 23/24 June on the Steinlach near Duslingen led to significantly higher concentrations of particle-bound elements (factors 2 to 3) at flows comparable to the first-mentioned event on the Ammer (max. 4.6 m3/s). This is due to the steep slopes of the Steinlach catchment area, which quickly flushes large amounts of surface runoff into the river during heavy rainfall events [6].

4. Conclusion and Outlook

The investigations carried out within the framework of Swabian Moses 2021 were able to identify three different input pathways of elements during heavy rainfall events. Besides urban surface runoff and diffuse erosion, sewage treatment plants play an important role. In order to assess the consequences of these inputs for water quality in accordance with the requirements of LAWA [7], it is planned to examine the trace element content in relation to the quantity of suspended matter and to provide the necessary data on the suspended matter concentration in the water.

- **Acknowledgements**

Thanks are due to all those involved in the Swabian Moses project who, in particular, realised the sampling and provided the flow measurements. We would also like to mention the GEWANA from the UFZ Magdeburg and especially Ms Block (responsible for the digestion of the unfiltered water samples) and Ms Ohlwein (responsible for the ICP-OES measurements).

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Large-scale nutrient and carbon dynamics along the river-estuary-ocean continuum

Norbert Kamjunke

1. Approach

Nutrient and carbon dynamics within the river-estuary-coastal water systems are key processes to understand the flux of matter from the terrestrial environment to the ocean. Here, we analysed those dynamics by following a sampling approach based on the travel time of water. We started with a sampling of River Elbe from the source. After a subsequent investigation of the estuary, we followed the plume of the river by raster sampling the German Bight (North Sea) using three ships simultaneously (Fig. 1).

Fig. 1: *Sampled river stretches of the Czech Elbe (light blue), German freshwater Elbe (green), tidal Elbe (red) and German Bight (dark blue).*

2. Results

In the river, we detected intensive growth of phytoplankton (Fig. 2) connected with high oxygen saturation and pH values and undersaturation of CO_2, whereas concentrations of dissolved nutrients declined. In the estuary, the Elbe shifted from an autotrophic to a heterotrophic system: Phytoplankton died off upstream of the salinity gradient causing minima in oxygen saturation and pH, supersaturation of CO_2, and a release of nutrients. In the shelf region, phytoplankton and nutrient concentrations were low, oxygen close to saturation, and pH in a typical marine range. We detected a positive relationship between pH and oxygen saturation and a negative one between pCO_2 and oxygen saturation.

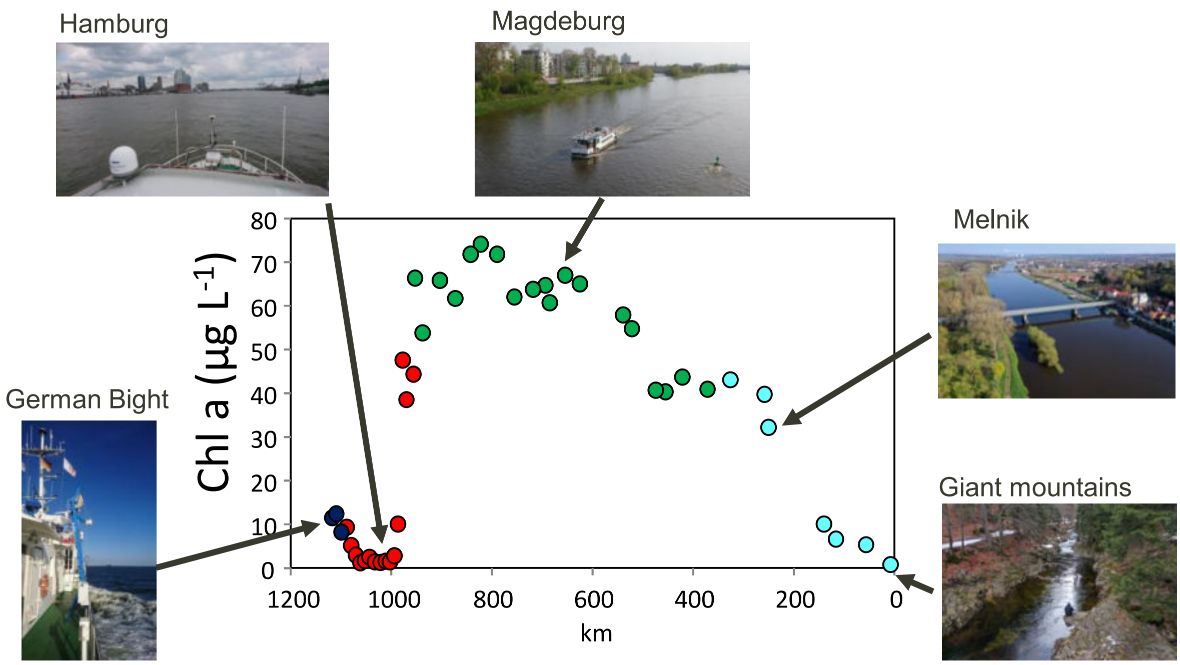

Fig. 2: *Concentration of chlorophyll a with increasing values in the Czech Elbe (light blue), maximum concentrations in the German freshwater Elbe (green), a distinct minimum in the tidal Elbe (red), and slightly increased values in the German Bight (dark blue).*

3. Implication for coastal waters

Corresponding to the significant particulated nutrient flux via phytoplankton, flux rates of dissolved nutrients from river into estuary were low and determined by depleted concentrations. In contrast, fluxes from the estuary to the coastal waters were higher and the pattern was determined by tidal current. Overall, the approach is appropriate to better understand land-ocean fluxes, particularly if it is performed under different hydrological conditions including extremes [1].

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Combining information from in situ data and remote sensing to provide near real time information of water quality in the Elbe River

Christian Schmidt, Thomas Heege, Gregor Ollesch

1. Introduction

In contrast to the wealth of information available on floods, including forecasts of water levels and real-time updates on current conditions, it is often more difficult to obtain information on critical water quality conditions and the state of river ecology. Since 2018, central European rivers, including the Elbe, have been experiencing severe low discharge conditions that exacerbate existing water quality issues, such as high nutrient concentrations [1]. The Elbe, for instance, commonly experiences phytoplankton growth in the summer, leading to chlorophyll-a concentrations frequently exceeding 150 µg/l. Consequently, oxygen depletion becomes a concern, particularly in the Hamburg Harbour area. During periods of low discharge, this zone of low oxygen concentration can extend upstream to the weir at Geesthacht, as observed in both 2018 and 2022. Therefore, there is a need for spatially resolved, near real-time information on crucial water quality parameters, primarily focusing on chlorophyll-a, to effectively assess and address critical water quality conditions.

2. The GlobeWQ project

The GlobeWQ project attempts to improve water quality information on the one hand globally but also for selected regional use cases by incorporating data from in-situ observations, satellite remote sensing, and water quality modelling. The Elbe River is one of the use cases where the GlobeWQ approach is demonstrated. The GlobeWQ information platform for the Elbe has been developed through a co-design process in cooperation with the River Basin Community Elbe (RBC Elbe; in German “Flussgebietsgemeinschaft (FGG) Elbe”).

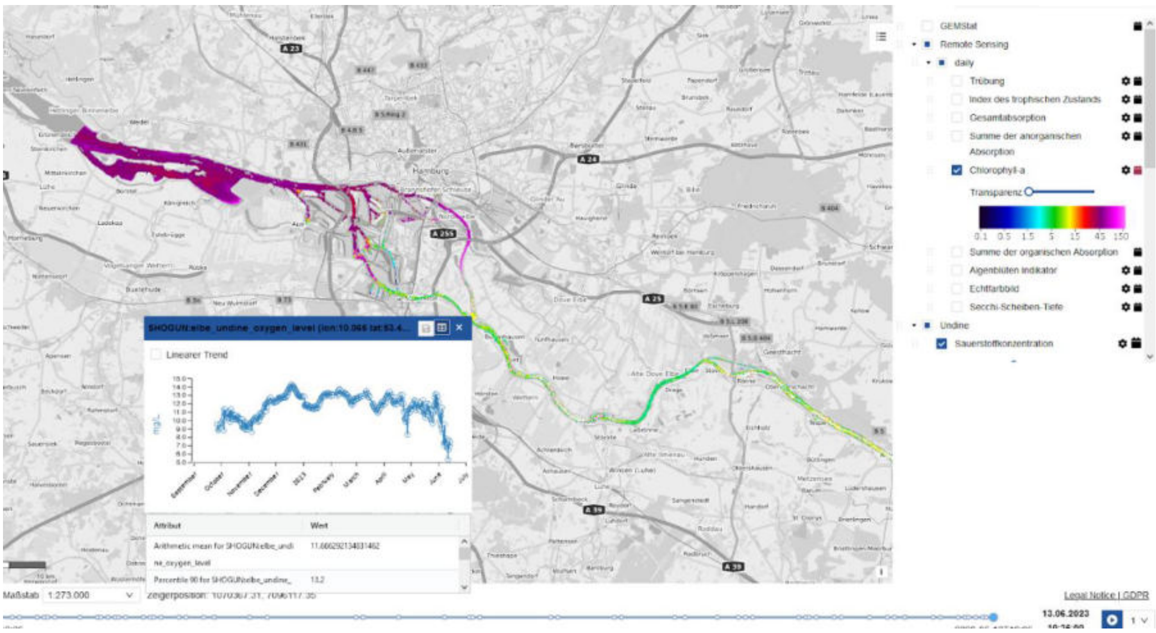

Fig. 1: *Satellite-derived chlorophyll in the river Elbe displayed on the GlobeWQ platform*

3. The GlobeWQ platform for the Elbe

In-situ data from automatic monitoring stations of the federal states are regularly updated in a daily time step by an interface with UNDINE and aggregated on the GlobeWQ Elbe platform. Up-to-daily multispectral Landsat 8 and 9, Sentinel-2 A/B and Planet SuperDove satellite data are processed automatically for the area from

Schnackenburg downstream to the tidal part of the Elbe River. Thus, spatial and temporal gaps of the in-situ monitoring are significantly reduced for parameters accessible from satellites, such as chlorophyll-a, turbidity or cyanobacteria. The GlobeWQ platform combines the different data and allows easy access to the integrated information. The combination of parameters allows a rapid examination of the chlorophyll-a dynamic and forms the basis for interpretation. The GlobeWQ "Elbe" platform can be accessed under at [2]. Figure 1 shows a screenshot of the situation in the tidal part of the Elbe River and Hamburg Harbour in mid of June clearly indication elevated chlorophyll-a concentrations in the Hamburg Harbour. The time charting tool shows a sharp decline of dissolved oxygen concentrations starting in early June measured at the water quality station Bunthaus.

4. Next steps: River early warning system – digital twins for river networks

The catastrophic fish die-off that occurred in August 2022 in Poland and Germany at the Oder River highlighted the necessity for transnational river monitoring. To support this, the next technological advancement is the development of digital twins, which serve as digital representations of the river networks.

These digital twins can provide essential tools for understanding, managing, and protecting river systems.

As first step, an early warning system combining various meteorological, hydrological and biological data, has been developed to identify the main factors driving water quality and ecological conditions early enough to guide decision making processes in response to critical river conditions. Data from all sources – satellite, in-situ and model data – are used to in most complete manner describe the various ecosystem drivers and stressors. Multi-causal risk factors were elaborated to setup a pragmatic alert system, focusing on the major risk drivers. An example of a first version is given in Figure 2, showing the different water risk levels along the upper Oder river in July 2022.

Furthermore, the refinement of river-system descriptors, major drivers, and multi-causal risk thresholds into a more versatile toolkit is a topic that warrants discussion. Ultimately, we target cost-efficient solutions based on a transferable, comprehensive understanding of river systems, that shall be applicable to other river systems, such as Elbe.

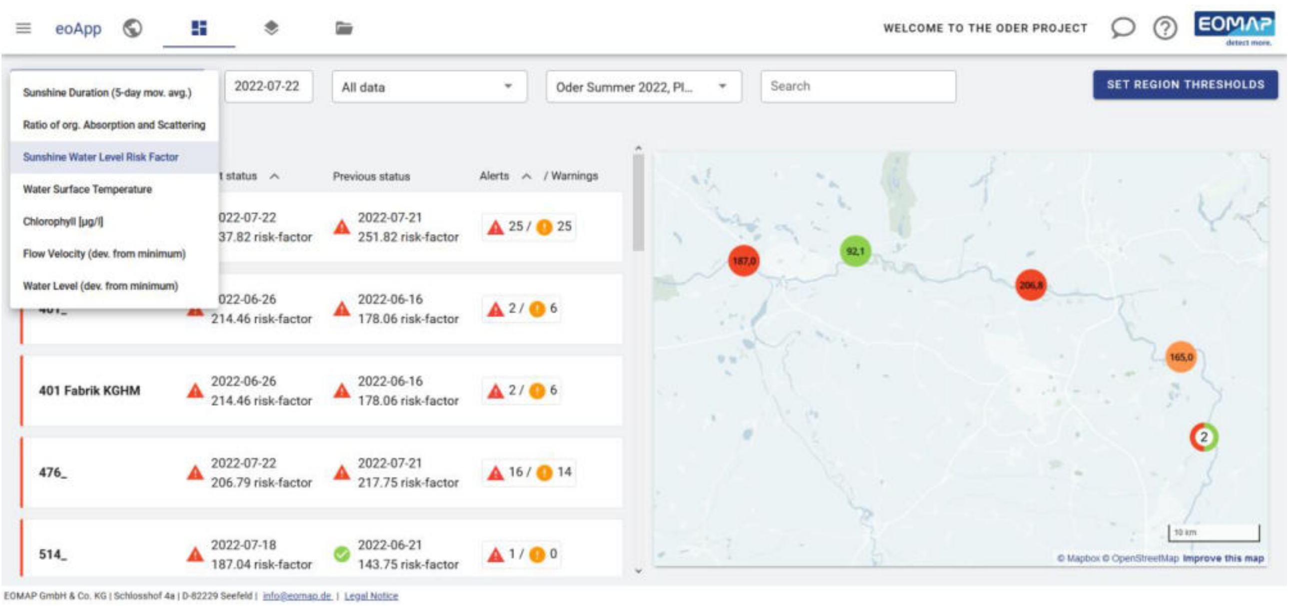

Fig. 2: *Early warning system implemented in the eoApp® by EOMAP for the river Oder, visualizing combined risk factors.*

In summary, the prototypical digital twins provide a comprehensive view of the state of water quality and ecological conditions, facilitate data-driven decision-making, and contribute to sustainable water resource management. A close cooperation with different river management stakeholders, research institutions and industry is required to establish to establish a versatile decision support toolkit.

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Pharmaceuticals in the Elbe: Production and Transport in the Czech Part of the Elbe Basin

Josef K. Fuksa, Milan Koželuh, Martin Ferenčík

1. Introduction

The occurrence of pharmaceuticals in rivers is a natural consequence of state of development and comfort of contemporary population. As a wide range of specific organic compounds, they are often resistant to bacterial communities in WWTPs and recipient rivers, or converted to other specific intermediates. Analytics of pharmaceuticals based on reliable LC-MS/MS technics are common for last ten years only and both the range of compounds determined and limits of sensitivity are in an intensive development even now. The main source of pharmaceuticals in the Elbe basin are municipal WWTPs, discharging relatively stable amounts of “standardly treated waste water” into rivers. Nevertheless, rivers are systems with extreme changes of both water temperature and water flow, which phenomena have a basic influence on resulting/determined concentrations of pharmaceuticals discharged and on their fate during river transport downstream. Therefore, we tried to elaborate a budget of production and transport of most frequent pharmaceuticals in the Czech part of the Elbe basin for last 5 years (2018-2022).

2. Methods

Concentrations of pharmaceuticals were determined as a part of standard monitoring of river water quality by LC-MS/MS techniques, with sensitivity limits at levels 10 – 50 ng/l. Standard monitoring profiles (see Table 1) were sampled in monthly intervals. Data of discharge were obtained from CHMI database or from a public database Hydra 2 (2021-22). Mean daily discharge (Q_d) or mean of series of measurements during the sampling day were than multiplied by concentrations and the daily transport [g/day] was calculated. Thus, we obtained 12 “transport situations” per year and a total set of 60 data. Series with less than 25% of data under limits of detection of entire drugs were employed only, using the level of limit to substitute a real concentration, because omitting them would lead to a more substantial overestimation of means etc. In fact, the rule was necessary only for the “upstream” profile BUDE. For list of pharmaceuticals taken into assessment, see Table 2. Data on consumption of pharmaceuticals were obtained from the database of State Institute for Drug Control (based on DDD – defined daily doses) and were recalculated according to population in basins of monitoring profiles and to published data on pharmaceuticals metabolism and excretion. Except Ibuprofene, drugs in question are excreted mostly as a mother compound by patients. For Diclofenac consumption data are substantially underestimated because DDDs are not specified for ointments.

3. Results and Discussion

The results are summarized in graphs on Fig 1 and 2-4. Three of drugs – Metformin, Oxypurinol (physiological metabolite of Allopurinol) and Gabapentin - exhibit much higher concentrations and the transport, so special graphs were constructed for them – Fig. 1. Mean concentrations of drugs are reflecting combination of discharge from WWTPs and actual flow (Q_d) at the recipient profile, fluctuations of flow being substantially higher than concentrations ones. Comparing Elbe and Vltava, data on concentrations show higher differences in the longitudinal profile of Vltava, according to distance and two important reservoirs (Orlík and Slapy with total retention time over 100 days) between profiles BUDE and POD (upstream end of Prague City). At profile Zelčín (ZEL), ca. 50 km downstream of Prague, the increment of Prague WWTP seems to be not very significant on background of resistant drugs transported from upstream parts of the basin. Data from an intermediate profile confirm no significant decrease of concentrations or transport. On the other hand, only relative small sources of wastewater occur on Elbe (WWTP capacity vs. Qd), compared to dominating Prague City on Vltava. Quite different pattern show data calculated as transport (grams per day or kilograms per year) – a clear increment complies with increasing magnitude of the river. Data of transport allow us to summarize transport by Vltava and Elbe at the confluence (profile ZEL+OBR), and compare them with transport through the frontier profile Hřensko/Schmilka (HRE). Here (Fig. 3) the loss of Metoprolol, one of less resistant drug from our list, could be indicated, caused by absence of important (WWTP capacities vs. river discharge) sources between profiles(ZEL+OBR) and HRE or between BUDE and POD on Vltava.

Table 1: Control profiles. Data on Q are calculated as means for the sampling days.

River:	Profile:	CODE:	River km:	Population [thousands]:	Basin area [km^2]:	Q 2018-22 [m3/s]:
Vltava	Hluboká	BUDE	228,9	234,8	3 349	23,1
Vltava	Podolí	POD	56,2	1 954,3	26 675	102,0
Vltava	Zelčín	ZEL	4,5	3 550,3	28 043	102,9
Labe	Valy	VAL	954,4	807,4	6 334	40,2
Labe	Obříství	OBR	842,1	1 662,5	13 714	60,6
LABE+VLT	confluence	OBR+ZEL	837,2/0,0	5 212,9	41 756	163,5
Labe	Hřensko	HRE	726,6	6 368,5	51 352	202,6

Third step of assessment included comparison of transport of drugs to theoretical consumption upstream monitoring profiles, e.g. transport recalculated per entire numbers of inhabitants. In general, over 80% of population in CR is connected to full scale biological WWTPs and in bigger cities, more than 90% could be expected as connected to a big and efficient WWTP. Data are demonstrated in graphs on Fig. 3, showing relatively uniform pattern in all profiles. Simple conclusion is that for resistant drugs the load to rivers (even with standard WWTPs) is controlled mainly by drug production, e.g. by number of people on sewerage systems. Relations between concentrations and actual flow in recipient river (Qd) show a higher dilution at higher discharge in many cases, but a more precise research is complicated by unpredictable action of sewerage overflows coinciding with high flows. Relatively high transport “per capita” in profile VAL could be explained by a relatively short distance between the monitoring profile and discharge of Pardubice WWTP. City of Prague discharges approximately 2, 6 % of mean flow at the receiving profile, for other bigger cities in the basin the ratio is under 1%. In general, the season 2018-22 was relatively dry, on ca. 70% of long-term discharge, which did not eliminate situations – rare, short and unpredictable - with a massive overflow from sewerage systems. Concentrations of most drugs, not of all ones, show a negative correlation to actual flow, bur a more detailed analysis is complicated by the overflow situations.

There are three sources of error or uncertainties: error of analytic procedures, error of sampling and error of flow measurements and calculations. Nevertheless, we assume that main source of drugs are big cities with continuously working WWTPs and relatively small share of yearly wastewater production discharged in overflow events, especially on bigger rivers. Thus, data obtained in monthly intervals could be used for budget calculations. Here a fourth source of uncertainty appears – preciseness of available data on drug distribution and relations between their sale and true consumption/excretion. As shown in Table 2, transport of some drugs exceeds ten per cent of amounts consumed in the basin and passed through WWTPs, drugs affecting brain and nerve system having an important position. We try to show relative importance of drugs frequently occurring in Czech rivers, levels of their concentrations being comparable with those in German Elbe and its tributaries. It makes evidence on similar levels of both drug consumption and wastewater treatment. We do not deal with influence of the drugs on the river ecosystem and next water use, but it is important to keep in mind that during long dry periods, expected as climate change, the real concentrations of drug residues in rivers would significantly exceed the present state.

Table 2: Drugs analysed, their yearly consumption and transport through the profile Hřensko.

CODE:	Name:	CAS number:	Distribution [tons per year]:	Transport through HRE [kg per year]:	% of drug transported through HRE
METFOR	Metformin	657-24-9	227,8	6 060	2,66
OXYPUR	Allopurinol (Oxypurinol)	2465-59-0	22,8	5 487	24,07
GABA	Gabapentin	60142-96-3	16	1 555	9,72
CAR	Carbamazepine	298-46-4	3,5	216	6,18
DIC	Diclofenac	15307-86-5	>> 3,1	308	> 10
IBU	Ibuprofen	15687-27-1	152,4	180	0,12
METOPRO	Metoprolol	51384-51-1	11,1	181	1,63
TRAM	Tramadol	27203-92-5	3,2	314	9,80
SULFAMET	Sulfamethoxazole	723-46-6	3,1	247	7,96
CLARITHRO	Clarithromycin	81103-11-9	4,0	145	3,62
VAL	Valsartan	137862-53-4	1,6	178	11,13
VENLA	Venlafaxin	93413-69-5	2,9	144	4,98

4. Conclusions

- We present the first attempt to calculate budget of 12 most frequent drug transport through Czech part of the Elbe. Most of drugs in question are excreted by patients as the mother compound and their degradation in municipal WWTPs is low or weak.
- The budget: In the period 2018-22 6 tons of Metformin, 5,5 tons of Oxypurinol (metabolite of Allopurinol) and 1,5 ton of Gabapentin is transported through frontier profile Hřensko. For other nine frequently occurring drugs transport values are well under 0,5 tonne per year.
- Differences of drug concentrations among profiles observed does not differ extremely, differences in transport being caused by water flow primarily. Drug inputs in the profiles are mostly controlled by population numbers upstream the profiles.
- As reliable standard technologies of abatement of drug residua in WWTPs do not exit, it is important to study wide spectrum of drugs in rivers and details of their transport to rivers and their fate during transport to the oceans. Substantial input could occur during overflow of sewerage systems bypassed the WWTPs.
- During long dry seasons, the load of drugs and other specific pollutants could make a serious problem even when all (present) legislative limits for discharging are respected.

5. Acknowledgements

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Norway grants

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Fig 1: Mean concentration and transport characteristics for Metformin, Oxypurinol and Gabapentin. For Legenda see Tab. 1 and 2. Profile (ZEL+OBR) represents the sum of transport at the Labe and Vltava confluence.

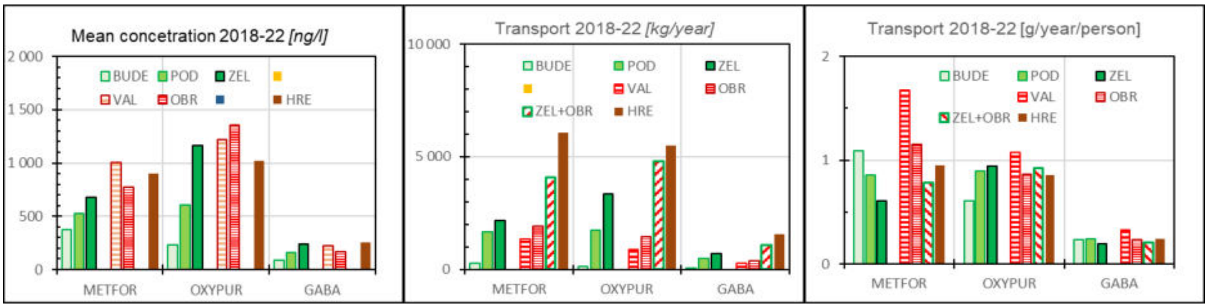


Fig: 2: Mean concentrations of lower concentration drugs. For Legenda see Fig. 1.

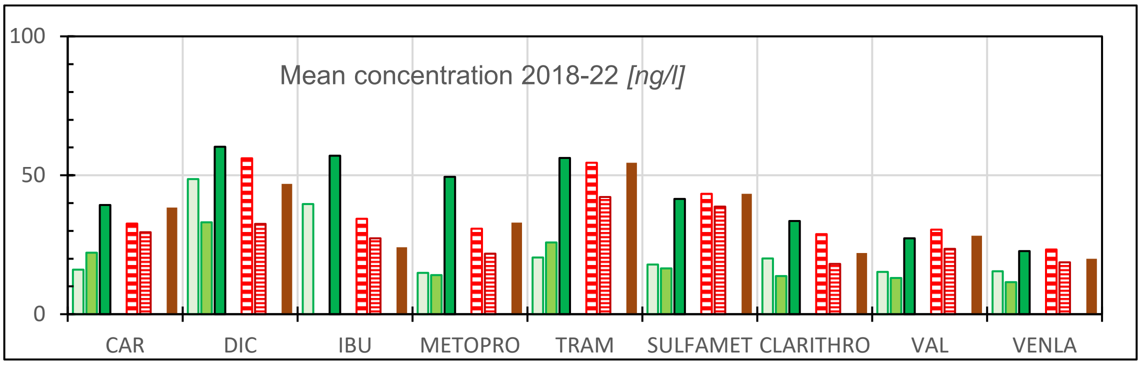


Fig: 3: Mean transport characteristics of lower concentration drugs. For Legenda see Fig. 1.

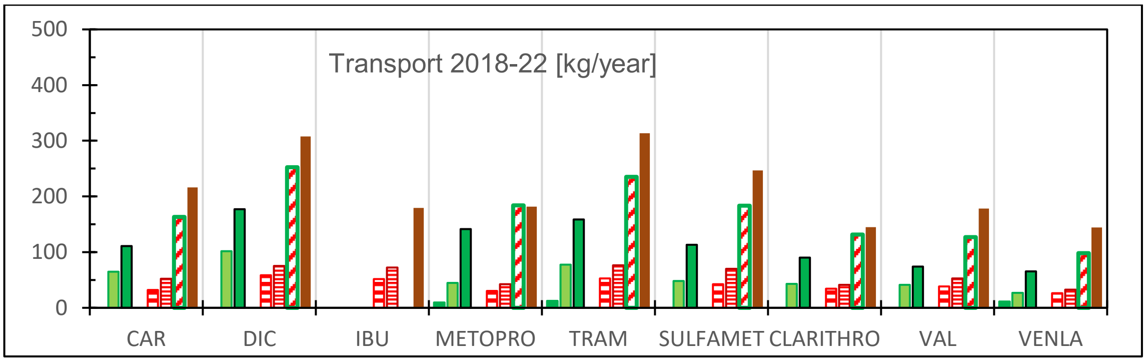
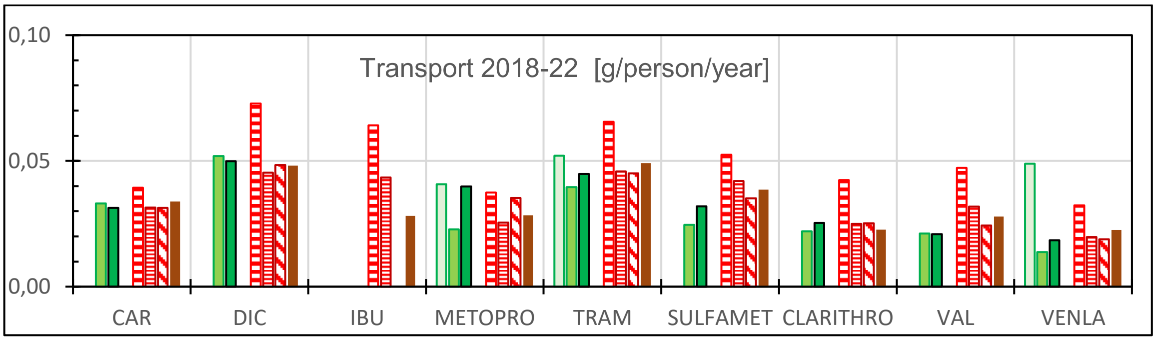


Fig. 4: Transport calculated in grams per year per person living upstream the profile.



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Using satellite data on forest state to predict stream water chemical components in the Elbe catchment

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1. Introduction

Surface water quality in forested areas depends on land use changes, properties of the vegetation type, and local hydrological and landscape characteristics. Sudden forest disturbances, either anthropogenic or natural, may disrupt long-term water quality dynamics. This is exacerbated by water properties' changes being closely connected to a range of meteorological and hydrological conditions, which recently are under the effects of globally increasing temperature and precipitation fluctuations. Timing and history of disturbances and the environmental conditions are site-specific. Therefore, we need to compare multiple systems in order to capture and better understand the factors driving water quality fluctuations. There is an urgent need for methods to compare the effects of disturbances and their effect on environment characteristics by monitoring multiple sites over several years. Here, we tested whether remote sensing of forests may be such a tool.

Bark beetle infestations have become a major disturbing factor for forests in recent years. They affect large areas of mature coniferous forest of Norway spruce (*Picea abies*), including those situated at high altitudes [1]. Subdominant deciduous trees like European beech (*Fagus sylvatica*), rowan (*Sorbus aucuparia*), birch (*Betula pubescens* and *B. pendula*), and maple (*Acer pseudoplatanus*) are not infested by the spruce bark beetle. In periods when conifers disappear, deciduous trees can have a temporary advantage. Later during the forest succession, they are outcompeted and usually replaced by regenerating spruce trees. Such growth of deciduous and coniferous trees varies both temporally and spatially. This affects the chemical properties of soil and consequently, water quality in streams and downstream water bodies. For example, concentrations of many ions have been shown to increase in disturbed stands immediately after tree dieback, while increased dissolved organic carbon (DOC) has shown delays of several years [2, 3, 4]. Changes in forest development may thus influence the water quality of a large catchment. However, it is difficult to assess forest state in detail in several catchments in parallel.

Here, we present a remote sensing-based forest state catchment-scale index, that we tested for the Plešné Lake catchment. Once validated, we applied this index for three further catchments (Čertovo, Laka, Plešné, and Prášilské), all situated in the Šumava Mts. (Czech Republic) and three of them (except for Čertovo) draining to the River Vltava, and ultimately, to the River Elbe (Labe). This index allowed to correlate the change in forest state to draining water properties. We predicted that changes in water quality in disturbed catchments could be related to the proportion of healthy, damaged, or regenerating coniferous trees, and regenerating healthy deciduous trees. Our hypotheses were: 1) immediate responses of water chemical conditions are more due to meteorological and hydrological influences than to changes in forest structure, and 2) water quality properties respond with the same delay to forest disturbances in all catchments of the same mountain range.

2. Methods

The four study catchments of Prášilské, Laka, Plešné, and Čertovo lakes are geographically close and located in the same mountain range (Šumava Mts., Czech Republic) at similar altitude, but they differ in extents of forest disturbances and recoveries. Details on the catchments can be found in [2, 3, 4, 5, 6] and in references cited therein. The four catchments were between 0.57 and 1.12 km^2 in size and situated between 1002 and 1378 m a.s.l., all originally forested and all in protected areas. The catchment bedrock is formed by granite in the Plešné catchment, mica-schist (muscovitic gneiss) and quartzite in the Čertovo catchment, mica schist in the Prášilské catchment, and mica schist and granodiorite in the Laka catchment. From a hydrogeological point of view, the dominant rocks have low permeability, with water flow limited to bedrock fissures and surficial aquifers formed in weathered zones.

Water samples from tributaries (Plešné Lake) and lake outlets (all lakes) were collected from January 1997 to December 2017 at 3-week intervals. During sampling, water was pre-filtered through a 40 µm sieve to remove coarse particles. In the laboratory, samples were filtered either through membrane filters (0.45 µm; ions) or through glass-fibre filters (0.4 µm; other analyses). The water quality characteristics were analysed as detailed in [2, 3, 4, 5].

We calculated the damage index **cFII** [4] for a **c**atchment-scale assessment of forest health, based on the forest infrared index (**FII**), for which we purchased the data from the Czech Forest Management Institute of the Ministry of Agriculture of the Czech Republic (Ústav pro hospodářskou úpravu lesů, UHUL; http://geoportal.uhul.cz/mapy/mapyzsl.html). Data were available for the years 1984, 1986, 1987, 1991 – 2007, 2009 – 2017. The FII was constructed using Landsat 8 multispectral satellite scenes (spatial resolution of 30 m × 30 m), by normalizing the ratio of forest reflectance in the infrared bands of the SWIR (short wave infrared) and NIR (near-infrared) spectra. The FII at the catchment scale (cFII) was calculated by averaging the weighted factors of forest damage in the catchment area and its linear normalization in the range from 0 (no disturbance) to 1 (complete damage).

We compared the cFII with annual tree counts from Fluksová et al. [6], using linear models. Numbers of tree of different categories (saplings and healthy, dead standing, and dead broken trees) were available for the years 2000, 2003, 2005, 2007–2011, 2013 and 2015. To calculate the proportion of deciduous and coniferous trees and the proportion of coniferous stands that were healthy in contrast to those that showed signs of severe damage, we used the FII index of UHUL. The effect of their proportions, of the cFII, and of air temperature, precipitation, and catchment outflow, on the chemical properties of water were tested by linear parametric models and visualized using general additive models (gam's).

3. Results and discussion

The catchment scale damage index cFII in the Plešné catchment increased significantly with the decreasing number of healthy trees as determined by Fluksová et al. [6], and with the increasing number of dead standing trees. The cFII thus largely reflected the manual counts, and we considered it validated. For further details of the validation see [4].

The results for the four study catchments showed increasing temperature, and relatively stable precipitation and catchment outflow (Fig. 1). While the recovery from acidification was visible in the H^+, SO_4^{2-}, and inorganic aluminium (Al_i) concentrations (except for Laka), it seemed to play less of a role in shaping the chemical signature of the lake's outlow than forest health in recent decades.

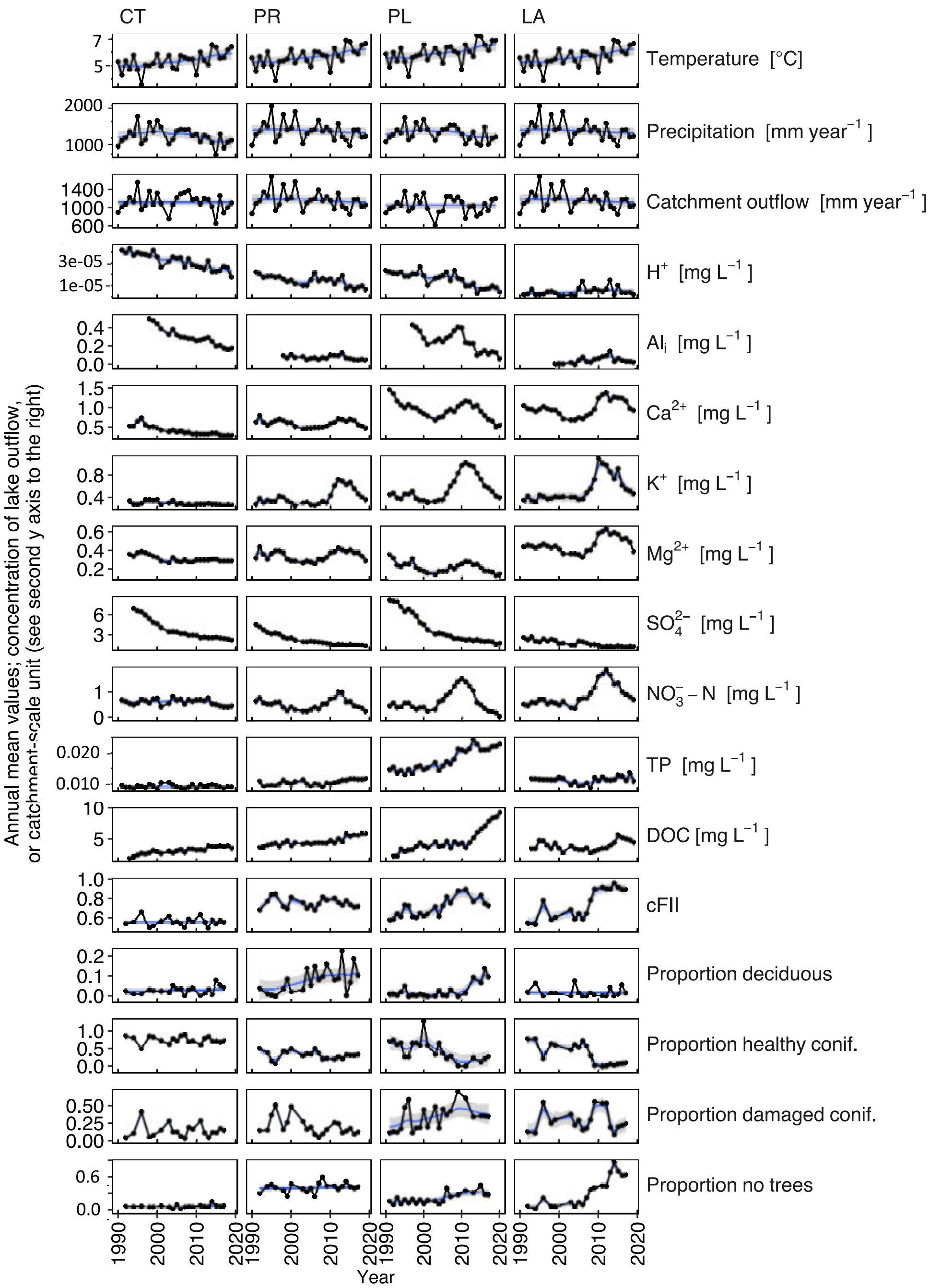

Fig. 1: *Changes in water chemical characteristics, climatic and hydrological characteristics, cFII index and proportions of forest types over time (black dots). GAM smoothening was used to fit the trends, depicted as blue lines with grey confidence intervals. "Proportion deciduous" = proportion of deciduous-tree-dominated raster cells; "Proportion healthy conif." = proportion of healthy-coniferous-tree-dominated raster cells; "Proportion damaged conif." = proportion of damaged-tree-dominated raster cells; "Proportion no trees" = proportion of raster cells without trees older than 20 years. Lake catchments: CT = Čertovo, PR = Prášilské, PL = Plešné, LA = Laka.*

The water quality measured at the lake outflows was different for the four catchments. It reflected the development of forest components and health better than the meteorological (temperature and precipitation) or hydrological (discharge) variables. Most of the outflow properties (e.g., concentrations of Al_i, H^+, K^+, Ca^{2+}, Mg^{2+}, alkalinity, dissolved organic carbon (DOC), NO_3-N, and total phosphorus (TP), showed catchment-specific patterns over time (Fig. 1).

The DOC concentrations responded most pronouncedly. They started to increase in the most disturbed Plešné and Laka catchments 7 and 6 years, respectively, after the peak in tree dieback. In the Prášilské catchment, which was disturbed several times during the last 3–4 decades, in contrast, there was no significant increase. The significant time delays with which other compounds responded to the disturbance ranged from 0 years (NO_3-N, total nitrogen, Ca^{2+}, Mg^{2+}, Al_i) to 5 years (total organic nitrogen) and were catchment-specific. For full results see the Supporting Information in [5]. The TP concentrations only showed a response to forest disturbance in Plešné Lake catchment, with a steady increase, exacerbated during the disturbance.

The study demonstrates the impact of extent of forest disturbances and the forest structure changes that these disturbances cause on the water composition, but also shows catchment-specific characteristics that are important for water composition. The cFII and the tree proportions predict some of the patterns in chemical and physical properties. However, the underlying geology also plays a role, as shown by the increase in TP in the Plešné catchment.

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Implementation of measures- which costs are reasonable?

Socio-economic approach to find and finance the most cost-effective combination of sediment remediation measures in the international Elbe river basin

Sprenger, Judith, Carls, Ilka

1. Unavoidable or disproportionate?

The Elbe is a large, international river basin with complex claims for use – for example from shipping, fishing, nature conservation or tourism. It is characterised by serious historical pressures from former mining or industrial sites. At the same time, it has a high ecological significance in large parts, including being the UNESCO Biosphere Reserve Elbe River Landscape.

The principle of river basin-wide integrated management introduced with the EC Water Framework Directive (WFD) is ambitious and in particular the consideration of economic effects in the selection of cost-effective measures (combinations), Art. 11 with Annex III WFD as well as the determination of cost disproportionality of measures in the context of Art. 4 (4) and (5) WFD still remains challenging in Europe.

This can also be observed at the River Elbe where a river basin-wide analysis of the most cost-effective pollutant remediation measures to improve sediment status has not yet been carried out, resulting in a lack of measures for reasons of cost disproportionality. This inevitably leads to the problem being merely shifted within the river basin, as can be seen, in the persistently high pollutant loads in the sediments of the Elbe catchment area and their transport to the North Sea. Here, as in many river basins across Europe, deficits in sediment quality are significant obstacles when achieving the goals of the WFD and the Marine Strategy Framework Directive (MSFD). Better sediment quality is therefore an important step towards good ecological and chemical water status or good status of the marine environment. As a result, integrated sediment management concepts were developed some ten years ago [1] [2], identifying coherent measures to achieve transregional management objectives. Nevertheless, not a single effective sediment remediation measure has been implemented through the WFD programme of measures to date. However, the environmental costs of inaction must somehow be set in relation to the costs of remediation measures.

According to the current legal situation in Germany, the federal states can decide which measures they want to implement in order to comply with the WFD. This leads to a prioritisation of locally effective measures in particular. The costs incurred are directly offset by a corresponding local benefit. On the other hand, remediation measures that would only have a positive effect in downstream water bodies and the sea are promptly classified as "disproportionate costs" by the responsible federal states. The situation is similar in international river basins, where downstream riparians depend on measures being implemented upstream to remediate pressures at source. This inevitably leads to displacement effects in the river basin.

But what if local costs were compared with the benefits in the entire river basin, as is actually intended by the EU in the sense of integrated river basin management according to the WFD? How would the proportionality test turn out then?

The aim of the project carried out was to develop and test an integral methodology that would allow a river basin-wide cost-benefit analysis and a river basin-wide consideration of the disproportionality of costs associated with pollutant/sediment management.

2. Cost-benefit analysis based on a fictitious measure

Within the framework of the project, the socio-economic test scheme [3] initially developed within the framework of the MSFD, which was later adapted to the requirements of the WFD under the title "Göttinger Prüfverfahren" [4], had to be modified so that it can also be applied to river basin-wide cost/benefit and cost disproportionality considerations.

The modification of the methodology and the proof of applicability are to be carried out using an example measure from the Elbe river basin. In order to avoid possible reservations and resistance to potential future measures, it was decided to exemplarily carry out the method development through the use of a fictitious measure. Assumptions had to be made to define the specifications of this fictitious measure. It was specified that the measure should contribute to a relevant reduction in the particulate-bound pollutant load of the Elbe and thus also the pollutant inputs into the North Sea. The fictitious measure should be planned realistically, and all resulting costs and benefits should be derived in as much detail as possible. The experts group decided to imply the construction of a fictitious weir with the area of the "Lower Middle Elbe" through which an artificial sedimentation basin would be able to accumulate potential upstream sediments allowing further treatment.
In order to keep the planning effort for the fictitious measure manageable, similar applicable planning documents were used. For the structure itself, it was possible to refer to a feasibility study [5] from the 1980s for the expansion of the reservoir of the Geesthacht weir (Fig. 1) for sediment trapping.

Fig. 1: *A weir with sedimentation basin serves as a fictitious measure for the socio-economic study. The structure could be similar to the weir and its sluices in Geesthacht, lock canal with double chamber on the left, weir with four weir gates and fish ladder on the right, here aerial photo (Bundesanstalt für Wasserbau)*

In the reservoir (sedimentation basin), the flow velocity is reduced to such an extent that suspended matter carried in the Elbe settles and can be removed from the reservoir in a second step for further treatment and disposal. The fictitious measure is designed in such a way that on average a long-term retention capacity of 68 % of all suspended matter is assumed, which corresponds to an average quantity of 240,000 t annually.
Retention of about 2/3 of the suspended sediment load transported in the Elbe would lead to a corresponding reduction in pollutant inputs to the Lower Middle Elbe, Tidal Elbe and North Sea areas on a long-term average.

In order to determine the positive and negative impacts that the implementation of the fictional measure could be expected to have on the uses and protected goods of the Elbe and the Sea/North Sea, five expert discussions were held in July 2020 with a total of 40 experts in four user groups focusing on "agriculture", "fisheries", "shipping" and "tourism" as well as for the protected good "environment/nature conservation". In addition, positive and negative economic impacts of the measure were identified as a basis for calculating the economic costs and benefits.

3. **Potential environmental benefits**

The following are some examples of costs and benefits to be considered in the context of a socio-economic study. Monetarisation of the measure and examples of costs to be taken into consideration (not fully comprehensive):

- Considerable human and material resources in the public administration are caused by the planning, construction and operation of the measure. In addition, investments must be made for e.g., land acquisition, planting, compensation payments.
- Costs also arise from the negative impacts on quality tourism, which is interested in a near-natural river landscape. Due to the massive intervention of the structure on the natural landscape, it is to be expected that the status of the UNESCO Biosphere Reserve could be at stake.
- Another issue is the restrictions on non-motorised water tourism. The annual monetary loss of tourism revenue is associated with a decline in gross value added which would affect sectors of private economic entities with their respective share in terms of lost daily expenditure [6], e.g., accommodation, catering, culture etc. However, there are also economic costs as the recreational value decreases due to the decline in rowing trips calculated with the travel cost method and benefit transfer (private economic entities).

4. Environmental Impacts of the measure

The negative impacts of the fictitious measure on other environmental goods and ecosystem services turned out to be serious, as the continuity for aquatic organisms is interrupted by the reservoir. With a backwater area of 50 km in length, there may be a reduced habitat provision for typical riverine floodplain animal and plant species, as well as a lack of hydromorphology and flowing water dynamics in this area. It is worth mentioning that these negative impacts would not have been included in the assessment in the case of real examples of measures. In reality, the construction of a weir as a sediment remediation measure is an extremely unrealistic measure. At the same time, it must be said, that the efficiency of the fictitious measures is very high and could only be realised in practice by combining measures.

A positive impact on other environmental goods and ecosystem services was clearly confirmed by the experts. However, these could not be quantified more closely/precisely for „pollutants in biota“, „birds“, „fish fauna“ and „marine environment“.

In this context, it should be emphasised that the state of research on the monetary valuation of environmental impacts varies greatly depending on the environmental sector. The monetary valuation of air pollutants, for example, is well established. For emissions of toxic substances into surface waters and sediments, on the other hand, there is little scientific knowledge, and a monetary valuation is not yet possible. Official cost rates exist for nitrogen and phosphorus emissions to surface and groundwater [7]. The development of environmental costs for the various protected goods has so far been pursued rather cautiously in Germany but is urgently needed.

In view of this lack of monetary valuation of water and sediment pollutants, a willingness-to-pay study [8] was used to calculate the economic benefits of increasing biodiversity in and around open waters.

The significantly reduced expenditure for water depth maintenance of the federal waterway due to the extended possibilities for action resulting from the improvement of the material sediment quality, are positive economic effects of the measure. In the long term, the use of pollutant-free sediments will become more important for coastal protection against the background of accelerated sea-level rise. For example, the sediment could be disposed of on land to raise the foreshore or the hinterland of the dyke. In addition, targeted small-scale reclamation areas could be created for dike construction. Another potential arises from the use of pollutant-free sediment for raising the tidal flats, for example to create an artificial sediment deposit on the coast, which is eroded by coastal dynamics and thus naturally distributed in the Wadden Sea.

5. Indications for the evaluation of future measured within the WSD implementation based on the implied methodology

The socio-economic approach exemplarily applied in this study is a valuable tool to identify an appropriate combination of measures to comply with WFD requirements. The given method delivers first results and clearly shows that remediation is worthwhile, in order to achieve a good condition of the waters and the marine environment. It further underlines the necessity to apply a holistic model to address the effects of measures at basin scale – which is key to understand cost-benefit assessments. However, a toxic-free environment by 2050, as envisaged in the EU Commission's ambitious zero pollution strategy, cannot be achieved in the Elbe river basin without remediation of sediments – probably not in other river basins either. Looking to the future, the investment is even more worthwhile – we will need clean sediments to protect coasts from sea level rise.

- **Discussion and future perspective**

However, how do you solve the problem that, according to the current legal situation, the regularly high costs of remediation measures have to be paid by just one party, even though everyone benefits? The answer: share the burden.

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Odborné příspěvky **Fachbeiträge**

Magdeburský seminář o ochraně vod 2023
Magdeburger Gewässerschutzseminar 2023
11.–12. 10. 2023

Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Rekultivace území po důlní činnosti
Rekultivierung von bergbaubeeinflussten Gebieten

HYDRIC RECLAMATION IN THE NORTH BOHEMIAN BROWN COAL BASIN

Ing. Petr Neumann, Ing. Jan Leníček, Ing. Miroslav Lopour

1. Initial motivation

The Government of the Czech Republic has been dealing with the overall concept of the transformation of the region of Ústí nad Labem affected by brown coal mining for many years. By its Resolution No. 421 dated as of 17 June 2019, this resolution ordered the preparation and submission of a proposal for the most technically efficient way of the future operation and management of flooded residual mining pits in the Ústí nad Labem Region to the Government by 30 June 2021. With respect to the view of the scope of the tasks assigned and the need for a longer period of time for the proper implementation of this task, a new Resolution No. 344 dated as of 6 April 2021 followed. This resolution instructed the individual ministries to complete the necessary tasks for the proper submission of concepts for all four sites of large open coal mines to the Government of the Czech Republic by 30 April 2023.

A working group was formed with the participation of representatives of the Ministry of Industry and Trade, Ministry of Agriculture and the Ministry of the Environment to fulfil the tasks assigned by the Government of the Czech Republic.

2. Initial conditions

The concept of the reclamation of the area affected by the surface brown coal mines: ČSA, Vršany, Bílina and Libouš (Nástup Tušimice) is closely connected with the water management possibilities of this region. For the purpose of balance calculations (defining possible sources and water requirements) for hydric reclamation, the working group adopted a dataset submitted by the state enterprise Povodí Ohře in the form of input hydrological quantities (time series of precipitation, temperature, specific water run-off from the basin and water infiltration to the groundwater level). The dataset included a calculation of the influence of the climate scenario on the hydrological quantities for the year 2050 and year 2100 time horizons. While precipitation is considered without climate change, temperature increases by +1.2 °C for 2050 and by **+3.1 °C for 2100** are considered relative to the reconstructed 1900-2018 temperature series. This temperature increase results in a 12% (2050) and 29% (2100) reduction in the magnitude of water run-off from the basin and an increase in evaporation from the water surface, respectively. It is the evaporation from the water surface that plays a key role in the balance of future lakes within the existing mines area. Due to the higher evaporation from the water surface than the precipitation in the mines area, this is an absolutely crucial balance quantity. The difference between precipitation and evaporation on/from the water surface is calculated to be 24 cm/year for the 1900-2018 time period, while for the 2050 horizon it is already 32 cm/year and **for the 2100 horizon it is 47cm/year**, i.e. almost double compared to the period 1900-2018. **For the conceptual designs of completed hydric reclamations, the 2100 climate scenario has been agreed as a guideline.**

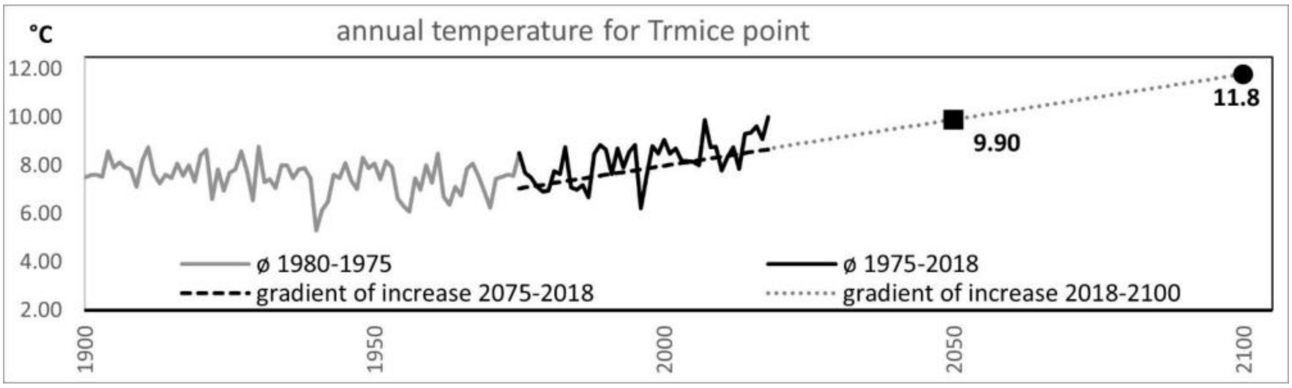

Fig. 1: *Temperature rise on the reconstructed temperature series in the Trmice point.*

3. Existing concept of completed hydric reclamation

The current concept for the reclamation of surface coal mines plans the creation of lakes with pre-defined levels (two flow-through lakes and two non-flow-through lakes) with a total water surface area of 30 km^2. For such a large, newly created water surface, the water loss from the water surface, under the above mentioned scenarios, amounts to a total of 14 million m^3/year, which is 0.45 m^3/s on average. This loss is partly compensated by inflows from the catchment area itself and a positive hydrogeological balance (groundwater inflow into the lake). Despite this, an external water inflow of **0.3 m^3/s** is required to maintain the defined levels. It is important to note that this is an average, and therefore in the summer months, when evaporation from the water level is at the highest level and the external water supply requirement for the lakes will be higher (for the months of June, July and August, up to twice the annual average).

Currently, inflows from the mines catchment area (115 km^2 in total) and pumped groundwater are discharged into adjacent watercourses. In total, for all four mines, this is an average of **0.4 m^3/s,** which will stop to improve the flow in the watercourses once mining activities are ended. In the future, these waters will largely become part of the water regime of the lakes themselves.

From the above mentioned conclusions of the water management studies, it can be stated that the end of brown coal mining will be associated with an impact on the water run-off conditions in the watercourse basins and in the case of maintaining the current concept in force the flows in the watercourses will be reduced by **0.7 m^3/s** on average. From the point of view of the backbone watercourse Bílina, which in the modelled solution for year 2100 climate, has a long-term average flow of **3.1 m^3/s** in the closure profile below the area of the big coal mines (below the confluence with the Bouřlivec), this is not negligible impact on the water regime. In terms of the impact on the Elbe River, the impact is already significantly lower.

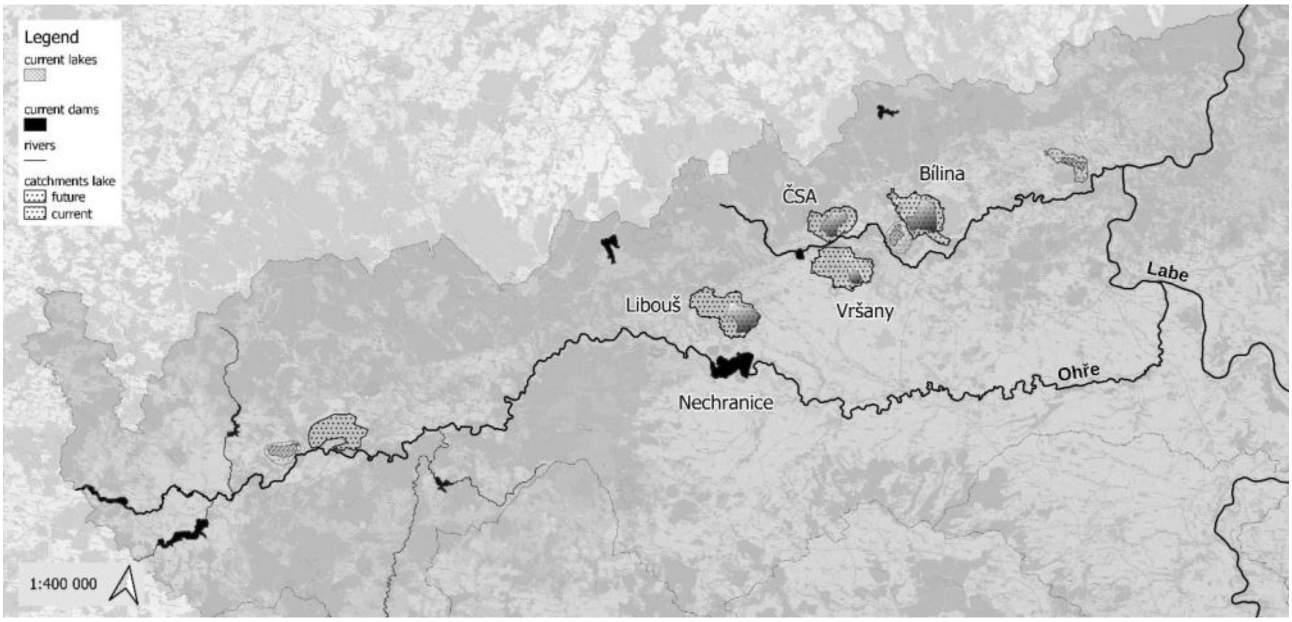

Fig. 2: *Situation with marked mines*

4. Proposed concept of completed hydric reclamation

The aim of the works assigned by the Government of the Czech Republic was to propose the most suitable (optimal) method of reclamation of the area. From the water management perspective, the search was undertaken for a method that would have the least negative impact on the existing water run-off conditions (in the considered horizon of year 2100 climate change) and at the same time could potentially bring benefits in the form of water management. The creation of an interconnected water management system in the form of flow-through lakes connected to watercourses, the possibility of creating storage areas on the future lakes, connecting with existing waterworks, or leaving the lake levels to their natural evolution were examined. At the same time, in addition to the water management criteria, the possibilities of using the newly reclaimed areas for the benefit of nature and landscape protection and the possibilities of energy use of the assessed sites, were examined. As a result, multi-criteria analyses were carried out for the individual mine sites, recommending the direction in which the reclamation of the area should be performed.

For the sites of ČSA and Vršany brown coal open mines, a synergy between water management, nature conservation and energy use was identified, which allows the formation of lakes in a natural way without defining the final water level. This concept also allows for the planned implementation of energy projects in the form of land-based and floating photovoltaics or the possible construction of a pumped storage hydroelectric power plant on the ČSA site. This water management concept will not be associated with the need to provide external water (outside the lake basin) to maintain a specific water level. Naturally sustainable levels on future lakes can be considered to be significantly lower than those proposed in the current concept and will only be supported by inflows from the catchment area, surface rainfalls and hydrogeological inflows, depending on the development of climate conditions. The impact on the water run-off conditions in the catchment area will therefore only be associated with the end of the discharge of pumped water from these two large open coal mines with an average size of **0.16 m^3/s**.

The current concept of the hydric reclamation of the Bílina open coal mine considers a flow-through lake, which, due to its size (11 km^2), reduces the water flows by **4 %** (unevenly throughout the year, more in the summer months) for the assessed 2100 climate scenario. Therefore, the possibility of creating a lake with a lower level and leaving it to develop spontaneously without the need for external water inflow from watercourses is addressed. It is currently assessed what the final shape of the open coal mine needs to be in order to allow for this concept in terms of stability of the slopes of the residual pit. If such a solution is not found and it will be necessary to flood the mine to a higher level, possibly up to the level of the flow-through lake, it is proposed to allocate a storage area of 22 million m^3 on the lake itself, with a level control up to 2 m high, which can redistribute the outflow from the lake during the year and improve the outflow from the lake during the dry months. The impact on the outflow conditions in the case of a non-flowing-through lake will only be associated with the end of the discharge of pumped water from the open coal mine with an average size of **0.18 m^3/s**. In the case of a flow-through lake, the water level will decrease by a further **0.11 m^3/s**.

For the site of the future Libouš Lake, it has been verified that there is not enough water for a flow-through lake from the watercourses that flowed through the area before the mining activities started. Therefore, it is possible to leave the formation of the future lake to natural development without the need for external surface water from watercourses. In such a case, the impact on the water runoff conditions would only be associated with the end of the discharge of water from the open coal mine of **0.05 m^3/s** on average.
The mining pit is located close to the existing Nechranice reservoir, which is one of the largest reservoirs in the Czech Republic in terms of storage volume which serves both storage and flood protection functions. The possibility of connecting this waterworks with the residual pit of the coal mine is being investigated, whereby the storage and retention volume of the waterworks will almost double. This interconnection would result in an increase in the water surface area (by 10 km^2) associated with a loss of water from the water surface (**0.14 m^3/s**). Considering the water capacity of the Ohře River (Qa = 31 m^3/s) and the function that this connection would provide, this loss is in fact quite negligible. Increasing the storage capacity of the reservoir will allow the Ohře River to be improved in dry periods by **single-digit cubic meters per second** depending on the size of the connection (an increase in storage capacity of 54 million m^3 will result in an improvement of **2.4 m^3/s**). The maximum theoretical potential for increasing the storage capacity is up to three times the amount (155 million m^3).

5. Conclusion

The proposed concept of hydric reclamation brings a significantly milder and lower impact on the runoff conditions in the Lower Elbe basin compared to the original concept. Instead of the original load on the hydric system of a total long-term average of **0.7 m^3/s**, it considers lakes independent of water sources outside their own catchment area. This approach results in a loss of water only in the catchment area of the residual pits, which for the current conditions amounts to an average of **0.4 m^3/s** (water from the catchment area and hydrogeological inflows). In the case of the connection of the Libouš residual pit with the Nechranice reservoir, the total average water loss will be increased by the water loss from the Libouš Lake of **0.5 m^3/s**. However, the connection will result in a significant improvement of the water flow in dry periods in the **single-digit cubic meters per second range**. This water management effect will fully compensate for the impact of the hydric reclamation on the water runoff conditions in the Elbe basin, which will not only be linked to the future hydric reclamation of the four open brown coal mines in the Most basin, but also to the already implemented or future planned reclamation in the entire Lower Elbe basin with a possible positive impact beyond the borders of the Czech Republic.

Tab. 2: *Monitored quantities for individual open coal mines*

Coal mine/future lake	Catchment area	Area of lakes according to the existing concept	Loss of water from the surface of lakes (2100)	Existing discharges of pumped water from coal mines
	km^2	km^2	mil.m^3/year	m^3/s
ČSA	20.5	6.5	2.8	0.09
Vršany	30.4	2.5	1.2	0.07
Bílina	30.3	11	4.8	0.18
Libouš	33.6	10.4	5.2	0.05
Total	115	30	14.1	0.39

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Green floating islands, a suitable alternative to improve ecological conditions in a wide range of artificial reservoirs, including flooded surface coal mines.

RNDr. Milan Hladík, Ph.D.

1. Introduction

In the territory of the Czech Republic, we can find only a few natural lakes (mainly glacial or peat lakes in mountains or blind arms and pools along rivers), but thousands of man-made reservoirs of different purpose and size have been built. They are for example small reservoirs located in towns or villages for accumulation of fire water, ponds used for fish farming (in size from 0.5 to 648.0 hectares), water supply reservoirs (the biggest reservoir Švihov has an area of 1,600 ha) and some of the largest reservoirs in Europe (the area of Lipno Reservoir is 4,870 ha) which are among other purposes mainly used for protection against floods and water accumulation for power generation. Recently, large new reservoirs have been created by flooding former surface mines. According to the Water Framework Directive, all of these reservoirs reach low ecological potential mainly because of the absence of littoral habitats, which is mainly due to frequent water level fluctuations, high nutrient content in the water, steep banks and inappropriate fish stock.

However, the absence of the littoral habitats could be partially solved by installing floating islands that would allow the growth of wetland and littoral plants and offer suitable conditions for large scale of water and wetland organisms. The design of the islands must be sufficiently durable to climatic influences such as wind, waves and ice, it must enable growth of a wide range of plants, and at the same time cannot be expensive. The construction should have a long life to require little maintenance and therefore cheaper operating costs. To achieve a satisfactory effect, it can be assumed that it will be necessary to build relatively large areas of the floating islands.

The development if this type of floating islands has been the goal of two scientific projects and interim results promise the possibility of wide application in practice, including reservoirs created by flooding former surface mines. Moreover, according to the results of ongoing projects, floating islands can create a unique environment for nesting and resting of a wide variety of water birds.

2. Different conditions in different types of reservoirs require different properties for the construction of floating islands

In general, floating islands must be very durable to resist variable climatic conditions, especially on larger water areas. Islands must provide conditions for the prosperity of plants whose roots will create suitable conditions for other aquatic organisms. Islands should have a modular structure to make their construction and maintenance more simplified.

Different reservoirs have different construction and purpose and thus we can describe the different requirements for floating islands. For example, fire reservoirs are small, often have concrete banks and a low quality of water, and they are often located in the inner city of the municipalities. Floating islands do not have to be very durable but should have an aesthetic function in addition to ecological functions.

The fish farming ponds are often very shallow, where we can find a high layer of sediment on the bottom. They are also regularly completely drained in the annual cycle, the littoral zone is missing mainly due to the low transparency of the water, regular draining, and disturbance by carp. Floating islands should mainly create here habitats for wetland plants and birds nesting.

In large reservoirs, the water level usually fluctuates in an annual cycle, the littoral habitat is completely missing due to regular drying and erosion, and the floating islands must withstand severe climatic conditions, mainly

waves, wind and freezing ice. Apart from all of the ecological functions listed above, creating of a suitable spawning habitat for phytophile fish species also has importance in these reservoirs.
In flooded coal mines, except similar climatic conditions found in large reservoirs, we encounter greater depth and steep banks, which significantly complicate the anchoring of the islands.

3. Project “Floating green islands, a perspective alternative for improvement of ecological potential and support of littoral habitats in water reservoirs"

The basic design solution of floating islands was developed and tested during a research project co-financed by the National Agency for Science and Engineering entitled "Floating green islands, a perspective alternative for the improvement of ecological potential and support of littoral habitats in water reservoirs". Over the four years, the trial islands were richly populated with a wide range of organisms, from wetland and aquatic plants to benthos and microorganisms. More than 70 species of plants from mosses to trees (*Salix, Alnus*) were found on the islands after 4 years from initial installation, rich underwater root systems created conditions for the development of the benthos community. The islands were used by fish as spawning grounds, as there were eggs discovered from different cyprinid fish and pike. Large scholas of fish fry found shelter under the islands and in the immediate vicinity of the islands themselves [1]. Moreover, nesting waterfowls, such as wild duck (*Anas platyrhynchos*) and the protected Common Tern (*Sterna hirundo*), were also recorded. During the project lifecycle, it was possible to successfully test the construction of floating island which was provided by Biomatrix Water, Scotland, and alternative construction designs which were also developed. The most advantageous construction is based on steel gabion nets, which are supplemented with durable plastic floats, and the rooting of the plants is supported by coconut mats. Light steel construction ensures durability, anti-corrosion protection which ensures a long life. The connecting system created by steel spirals ensures strength and flexibility, as well as a large space allowing for any requested design solution. The advantage of a simple design is easy installation and a cost effective price. The climatic conditions in the large reservoir located in high attitude proved that there is no possibility for long term anchoring of the islands in an open water area of the reservoir. In the open water, the strong wind a high waves are not proving to be limiting, as the durable and elastic construction can absorb the pressures, but serious damage to the islands repeatedly occurred when the islands froze. When large floes were created during the melting of the ice, these drifted due to the wind and carried away the islands, the anchor ropes were broken and the structure of the islands were damaged. Therefore, it was necessary to find sheltered bays for long term localisation of the islands.

4. Project “Implementation of floating green islands to improve nesting conditions for waterfowls and strengthen the biodiversity of pond ecosystems"

The development of modifications to the technical solution of the floating islands continues within the framework of the project called "Implementation of floating green islands to improve nesting conditions for waterfowls and strengthen the biodiversity of pond ecosystems", co-financed from EEA and the Norway Grants 2014-2021 – CZ-ENVIRONMENT program. The aim of the projects is primarily to develop a design solution suitable for the nesting of various groups of waterfowls (*laridae, anatidae*). They have different requirements for their nesting sites and use these islands for nesting, especially for protection against predators. A total of 16 islands in pond systems in South Bohemia and 4 islands in flooded surface coal mines in the Most area have been installed. The islands are composed by parts that include wetland vegetation, which are suitable for the nesting of different species of ducks, and elevated parts covered by two layers of coconut mat, which are preferred by seagull and tern. During the first season of the project, islands proved successful for the nesting of tufted duck (*Aythya fuligula*), mallard (*Anas platyrhynchos*), greylag goose (*Anser anser*), great crested grebe (*Podiceps cristatus*) eurasian tern (*Sterna hirundo)* and black-headed gull (*Chroicocephalus ridibundus).* A large number of birds used the floating islands for resting throughout the season, including birds resting during long migrations.

5. Project "Floating islands - support of biodiversity and water quality"

Project "Floating islands - support of biodiversity and water quality" which is also co-financed from EEA and Norway Grants 2014-2021 – CZ-ENVIRONMENT program is aimed on the construction of large concrete floating islands for the nesting of Eurasian tern (*Sterna hirundo*) in 8 reservoirs within the South Moravian region, and smaller green floating islands which will be attached to the concrete constructions to improve conditions for adolescent baby birds. The project began in 2023 and the first results will be known after the deadline of this contribution and will therefore be published during a later presentation.

6. Conclusion

According to the experience gained from more than 30 sites in the Czech Republic, floating islands offer a highly effective technical solution that can multiple ecological functions on a variety of man-made reservoirs including flooded surface coal mines. Floating islands mainly enable support of the wetland vegetation and the nesting conditions for different groups of waterfowls. Floating islands can be installed either independently or as part of, for example, floating photovoltaic power plants. For example, in the operation of floating photovoltaic power plants, it turns out to be a problem when birds sit on the panels and pollute them with their droppings. Floating islands can provide waterfowls more comfortable and carefree alternatives for their resting and possible nesting. Detailed technical solutions must be further developed in order to guarantee durability, the long life and acceptable maintenance of the islands as well as an agreeable price. The ability to utilize nutrients and suppress the development of aquatic blooms has not been sufficiently described and quantified which could probably be achieved after the building of large areas of islands. Since the reservoirs created by the flooding of the former coal mines are also gradually becoming popular tourist destinations, it is also necessary to take into account the aesthetic effect of the blooming wetland vegetation on the islands.

More info about the ongoing project can be found on webpage https://ragoostrovy.fzp.czu.cz/en

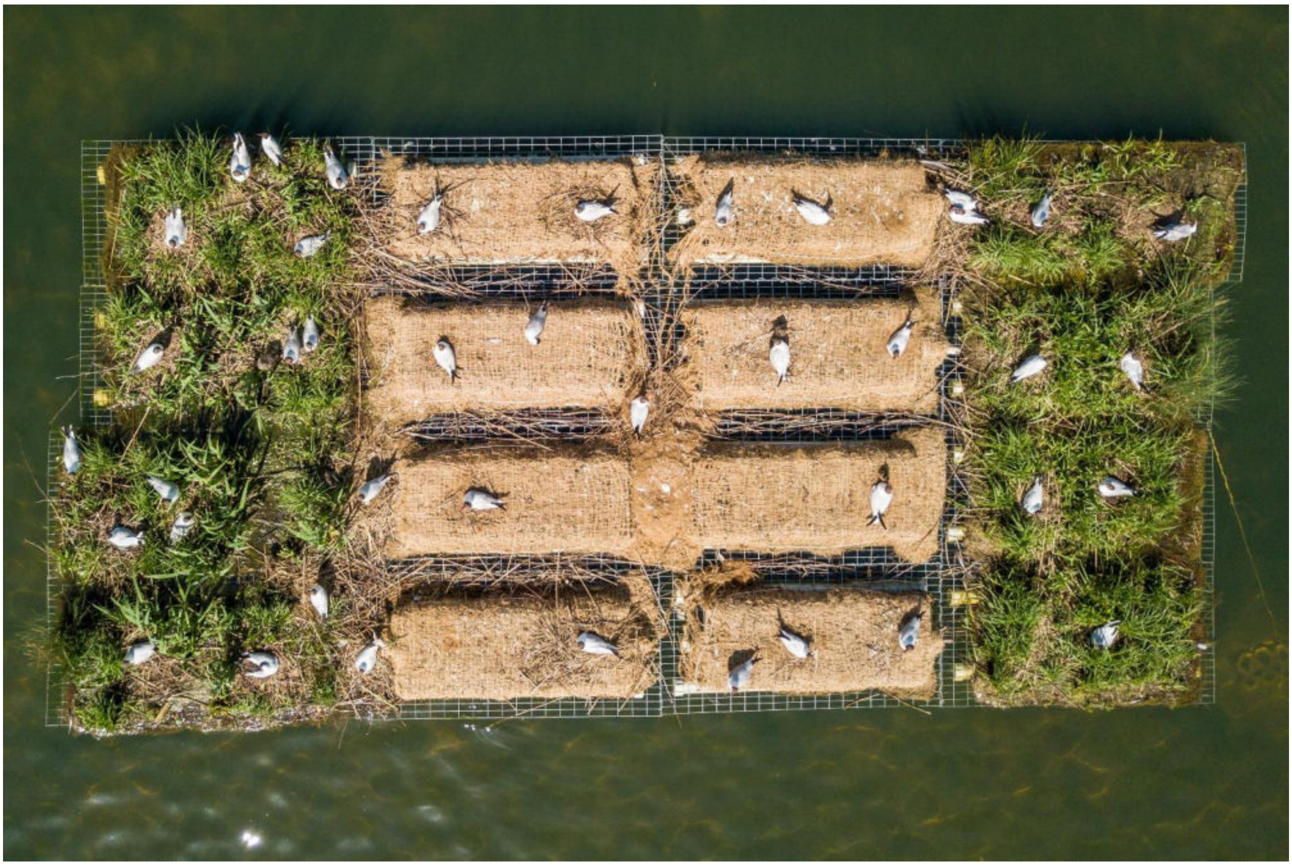

Fig. 1: *Nesting black headed gull on the artificial island, Vrbenské rybníky, May 2023*

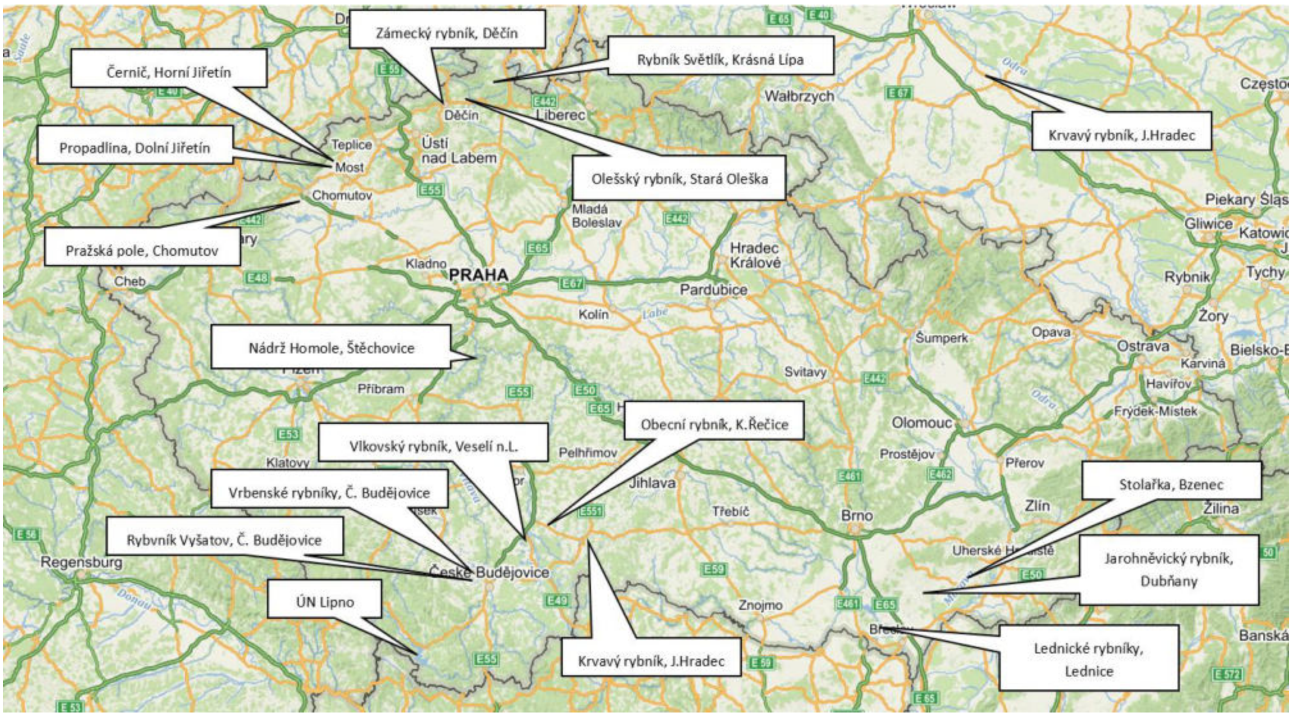

Fig. 1: *Map of localisation of already installed artificial floating islands in the Czech Republic*

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[1] Artificial floating islands: a promising tool to support juvenile fish in lacustrine systems, Journal Hydrobiologia, DOI 10.1007/s10750-023-05204-8

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Flooding of lignite mines in northwestern Bohemia – evaluation of the sustainability of the assessed solution options

Svejkovský Václav

In the Ústí Region, the mining of brown coal will be discontinued in the near future in four open-pit lignite mines. These locations are ČSA, Vršany, Libouš, and Bílina – Fig. 1. According to the current comprehensive plans for reclamation and recultivation, a process called hydraulic recultivation will be carried out. This involves flooding the deepest parts of the remaining pits of these mines. Due to previous experiences, especially with the creation of Lake Most in the area of a former lignite mine, and considering the projected impact of climate change on the reduction of water resources, it was necessary to verify whether the assumptions for ensuring

Based on the initial water management studies conducted between 2019 and 2021, the Government of the Czech Republic issued Resolution No. 344 on April 6, 2021 [1], which assigned tasks to the Ministers of Agriculture, Industry and Trade, and the Environment. The state enterprise Povodí Ohře was tasked with ensuring the water management balance of the remaining pits and assessing the feasibility of the water management system for the flooded pits.

The following water management studie were carried out as part of the government tasks:

- Verifivation of water management solutions for residual pits at ČSA and Vršany sites - searching for a sustainable water level option without the need for water pumping for the operation of flooded residual pits, including the possibility of spontaneous succession application.
- Evaluation of the impact on the Bílina River by water intake for filling and operation of residual pits - addressing the issue of wastewater disposal in the entire Bílina basin, including proposed measures to improve water quality, assessment of water quality in future lakes, taking into account the water source for filling and operation, proposal of ecological flow in the Bílina River considering the condition of water bodies.
- Technical-economic study on connecting Lake Libouš with the Nechranice water facility, including lake bypass.

These water management studies aimed to refine the proposed water levels in future lakes, taking into account the long-term significant water intakes from the Bílina River while considering climate change and water needs for other users. They also aimed to examine the possibility of connecting the future Lake Libouš with the Nechranice water facility on the Ohře River.

Based on the aforementioned tasks, the study "**Water Management Solution for Residual Pits at ČSA and Vršany Sites in Relation to Other Residual Pits**" (CTU, 1/2022) [4] was conducted. The study aimed to verify the water management solution for the water management system in the Bílina basin and find the final water levels for the future lakes Libouš, ČSA, Vršany, and Bílina using a simulation model that considers all current and prospective water demands. The water management solution verified the operational regimes of individual lakes for the current climate and climate projections for the time horizons of 2050 and 2100. It utilized data from previous studies, especially hydrological inputs and the water demands of current and future users. The assessment was carried out for two options for ensuring ecological flow downstream. The first approach adopts ecological flow values determined in accordance with the methodological instruction of the Department of Water Protection of the Ministry of the Environment for setting ecological flow values in watercourses ref. no. ZP16/98, 1998. The second approach introduces an ecological flow regime, considering not only a single value but also the requirements of the Framework Directive on Water No. 2000/60/EC of the European Parliament and the Council for ensuring good surface water status.

The study reached the following conclusions:

Lake Libouš - in the case of connecting Lake Libouš with the Nechranice reservoir, the water balance of the lake is resolved. The water level will fluctuate together with the level in the Nechranice reservoir, i.e., in the existing storage and retention space of the Nechranice reservoir. However, if Lake Libouš is not connected to the Nechranice reservoir, a long-term sustainable water level at which the future Lake Libouš could be operated cannot be found.

Lake ČSA - for the 2020 and 2050 climate scenarios, the lake can be operated at an operational level of 180.00 meters above sea level in accordance with the comprehensive plan for remediation and reclamation. However, for the 2100 climate scenario and the ecological flow regime according to [5], the sustainable water level at the specified elevation is only 172.00 meters above sea level, requiring an annual water subsidy of approximately 1.4 million cubic meters. Lake ČSA will not have any water management benefits. If there is a need to maintain a specific operational level for reasons other than water management (e.g., energy), it would be necessary to include the water replenishment from Bílina to stabilize the operational level in the economic evaluation of these plans. Another option is to consider the operational regime of Lake ČSA based on natural fluctuation of the water level according to climate trends. In this variant, the lake can be left to its own development, including the initial filling phase with water only from its own catchment. Alternatively, the lake can be filled with current transfers from Bílina and Ohře to a level corresponding to a sustainable water level using water only from its own catchment for the 2050 or 2100 climate scenarios, and then allow it to follow its natural development.

Lake Vršany - for the 2050 climate scenario, the lake can be operated at an elevation of 206 meters above sea level. However, for the 2100 climate scenario, it can only be operated at an elevation of 187 meters above sea level. The option of allowing the site to follow its own development was also examined. The lake level would be strongly influenced by the climate change scenario, and for each time horizon, the stable operational level differs by approximately 30 meters. Another possible variant is to fill the lake to a level of 182.66 meters above sea level (the stable level for the 2100 time horizon) by pumping water from Ohře through the Nechranice Industrial Water Pipeline.

Lake Bílina - the lake can be operated at an operational level of 200 meters above sea level in all time horizons. The advantage of this solution is the possibility of subsidizing the deficit Lake Most at an operational level of 199 meters above sea level and the ability to allocate storage space on Lake Bílina. The size of this storage space is 21.88 million cubic meters. This volume could improve the flow rates in the Bílina river, resulting in an increase of up to 1.51 m^3/s for the current climate, 1.17 m^3/s for the 2050 climate, and 1.02 m^3/s for the 2100 climate.

The study "**Impact of Water Flow in the Bílina River: Withdrawal for Filling and Operation of Residual Pits, Wastewater Treatment in the Entire Bílina Basin, Water Quality in Future Lakes Including Consideration of the Water Source for Filling and Operation with Emphasis on Diverting Wastewater Outside the Future Lake Basins, Measures to Improve Water Quality**" (VÚV T.G.M., 1/2022) [5] was conducted as a task assigned [1]. It evaluated the potential impact of water withdrawals for filling residual pits of surface mines on the condition of water bodies in the Bílina River. In order to ensure suitable hydrological conditions that do not negatively affect the biological components of water bodies during water withdrawals, the study [5] proposed an alternative approach instead of using a single value for the ecological flow rates in watercourses according to the methodological instruction of the Ministry of the Environment, identified as ZP16/98. This approach aims to preserve a certain natural flow regime of the watercourse not only during low flows but throughout the range of exceedance.

Another part of the study [5] examined the impact of water withdrawal on water quality in the Bílina River, the future lakes, and proposed possible measures for wastewater treatment in the Bílina basin. Currently, all water bodies in the Bílina basin are assessed as being in worse than good ecological or chemical condition.

At the location of the proposed filling of the future Lake ČSA from the Bílina River, the current water quality is unfavorable, with phosphorus concentrations exceeding the target value for the water body by 108%. Similarly, at the location of the proposed filling of the future Lake Bílina from the Bílina River at the Želenice profile, the current water quality is also unfavorable, with phosphorus concentrations exceeding the target value for the water body by 332%. The major contributors to the pollution in the profiles are point sources, primarily municipal wastewater, but also industrial and mining water, particularly at the Želenice profile. Simulations of the concentration development in the profiles for filling the future lakes by 2050 revealed that the assessed indicators would deteriorate by approximately 20%. According to the evaluation of proposed measures for point sources, the optimal alternative appears to be a moderate level of measures, involving increased phosphorus removal or intensification of purification for other indicators directly at the sources (wastewater treatment plants) in the Bílina basin. Implementing these measures could lead to an improvement in the water withdrawal profile for the ČSA location at the Jiřetín weir close to the target values for a good ecological state. In the water withdrawal profile for the Bílina location in Želenice, the condition would improve, but the exceedance of the target value would still be high due to the large number of pollution sources upstream of the profile. Therefore, even with the implementation of a comprehensive set of measures, achieving a good water state would not be possible.

The quality of water in the future lakes would be negatively affected only during the filling phase. After the stabilization of lake levels at operational levels, there would be a significant improvement in water quality and gradual lake oligotrophication. The exception would be Lake Bílina in the variant with a storage space and water outflow, which would remain permanently eutrophic given the current and future phosphorus concentrations in Bílina.

The connection of the future lake Libouš with the Nechranice Reservoir was examined in the study "**Connection of the Libouš residual pit with the Nechranice Reservoir, technical-economic study**" (VD-TBD, 1/2022) [6]. It sought the technically and economically optimal connection option while ensuring the ecological flow in the Hutná stream, where the current flow is maintained by the operation of the Libouš mine's wastewater treatment plant. The connection options of the lake with the Nechranice Reservoir through an open channel, underground adit, and a combination of these solutions were evaluated. Considering certain uncertainties, the technical solution was proposed with a focus on safety. Under these assumptions, the study demonstrated that all variants are feasible under the given conditions. The study showed that the combination of an open channel and adit had practically no effect, and this option was excluded from further consideration. It was verified that the connection of Lake Libouš with the Nechranice Reservoir through a channel or adit would have a significant storage effect. It would improve the Nechranice Reservoir's outflows by approximately 24% under current conditions, and the connection would allow compensating for the impacts of climate change until the time horizon of 2100. Such improvement would have a positive impact on agriculture, the environment, electricity production in the Nechranice hydropower plant, as well as in small hydropower plants on the lower Ohře River, costs related to the implementation of erosion control measures on the Nechranice Reservoir, recreation, and more. The open channel connection would further enhance flood protection for municipalities along the lower Ohře River. It would increase the level of protection from a flood that occurs approximately once every twenty years to a flood that occurs approximately once every fifty years. In the case of an adit, the increase in flood protection would be minimal. From this perspective, considering easier operation, including technical inspections, an open channel is more advantageous from a water management perspective. In any case, any connection has a significant water management effect, including the creation of a new lake with a sustainable water level.

In addition to water management studies, other materials evaluating the reclamation of residual pits, the impact of reclamation methods on the environment, or other potential uses of reclaimed areas have been processed. Based on all these documents, a multi-criteria assessment of reclamation options for these four residual pits was conducted. The possible approaches were evaluated from the perspectives of water management, economics, energy, the environment, and social aspects.

In June 2023, the materials for deciding on the CSA site, where mining will be terminated in 2024, will be submitted to the Government of the Czech Republic. Subsequently, materials regarding the other three sites will be presented to the government. Then, the comprehensive plans for the remediation and reclamation of individual residual pits will be updated. After mining cessation, reclamation will be carried out in each location according to these updated plans. From a water management perspective, this will lead to the creation of a sustainable state in the area, considering the impact of climate change.

Literature

[1] Government Resolution No. 344 dated April 6, 2021.

[2] Study on the comprehensive water management balance of flooding residual pits after complete cessation of brown coal mining in the Ústí Region - Stage Report No. 1 (CTU, 6/2020).

[3] Study on the comprehensive water management balance of flooding residual pits after complete cessation of brown coal mining in the Ústí Region - Stage Report No. 2 (CTU, 11/2020).

[4] Water management solutions for the CSA and Vršany residual pit sites in relation to other residual pits (CTU, 1/2022).

[5] Study on the impact on the Bílina watercourse due to water intake for filling and operation of residual pits, wastewater treatment in the entire Bílina basin, water quality in future lakes including consideration of water sources for filling and operation with an emphasis on diverting wastewater outside the future lake basins, measures to improve water quality (WRI T.G.M., 1/2022).

[6] Connection of the Libouš residual pit with the Nechranice Reservoir, technical-economic study (VD-TBD, 1/2022).

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Reducing water quality impacts from abandoned mines on streams and rivers in Saxony – Challenges and benefits for the River Elbe Basin

C. Stevens, M. Martin, E. Janneck, A. Greif

1. Impacts from abandoned mines on the River Elbe catchment

Pollution with Arsenic, Copper, Zinc, Cadmium or Nickel from abandoned ore mines currently prevents 16% of the 558 Saxon waterbodies from reaching the aims of the European Water Framework Directive. Thus, pressures from mining have been declared one of the five significant water management issues in the transboundary River Elbe Basin.

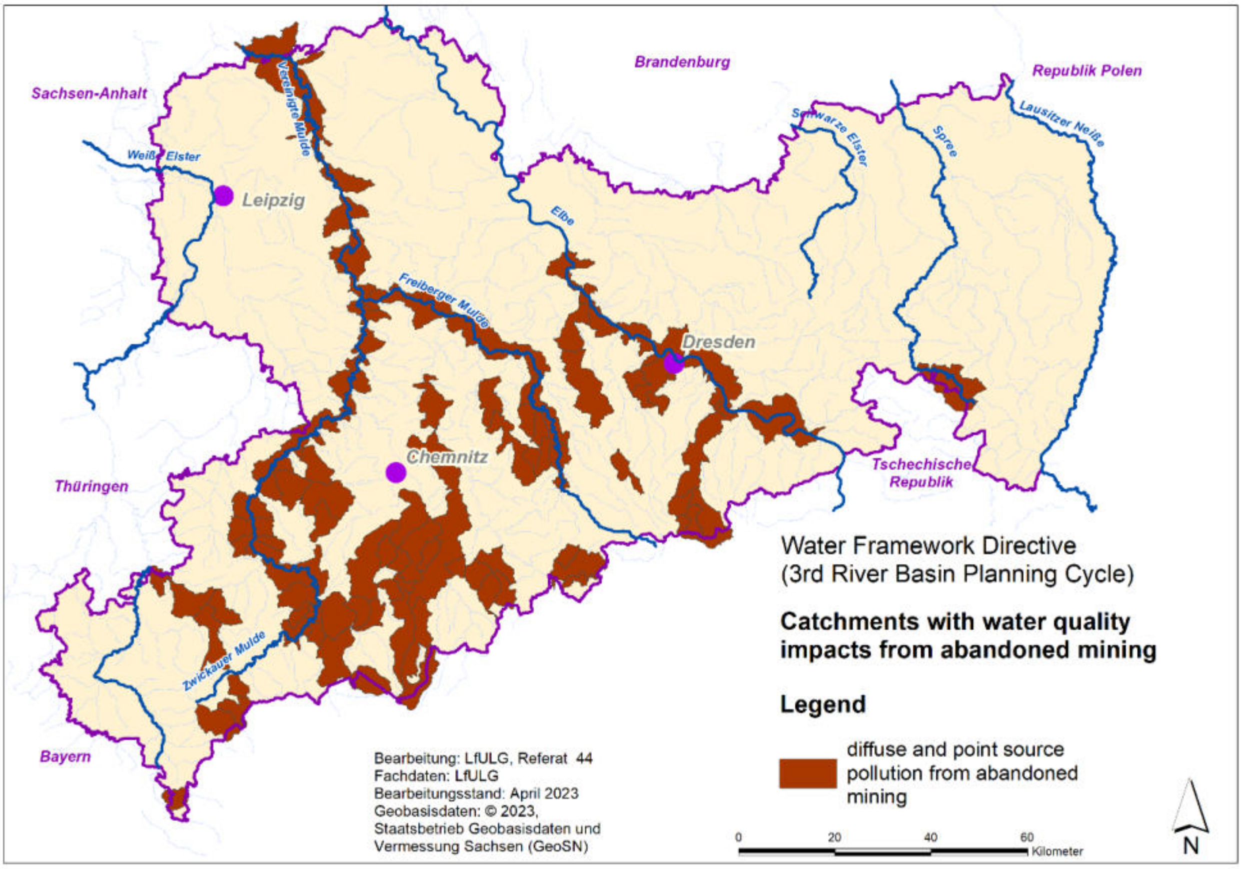

Fig. 1: *Water quality impacts from abandoned mines on surface water bodies in Saxony*

In Saxony, emissions from abandoned ore mines and their associated spoil heaps and tailings are responsible for the pollution of more than 1300 km of river. Fig. 1 illustrates the catchments with impacts from abandoned mining in Saxony. A number of hotspots for these contaminations are well-documented. However, for the majority of waterbodies the specific sources of pollution and their respective impacts on the river system remain unknown.

2. Applying the DPSIR approach on a catchment scale

Investigations in accordance with the Driver-Pressure-State-Impact-Response (DPSIR) approach are currently being carried out on a catchment basis by the Saxon State Office for Environment, Agriculture and Geology.

Work aims to (1) identify specific point and diffuse sources of pollution as well as to (2) apportion the contribution from each source in comparison to the total pollution load for each waterbody.

New monitoring results from over 1300 water samples from the Zwickauer Mulde catchment have been visualized using river flow diagrams. This approach has enabled fruitful discussions in catchment area related stakeholder workshops. The spatially detailed monitoring data collected from streams and rivers during 2021-2022 in three sampling campaigns show a good degree of source apportionment.

Investigations in 30 water bodies found > 40 point sources and > 160 diffuse sources linked to the prevalent arsenic and heavy metal contaminations in these respective catchments. Fact sheets with detailed information for mining pressures and the apportionment of specific pollutant sources have been produced for each water body investigated. In summary, 6 waterbodies (20%) receive all of their exceeding pollutants from the adjacent upstream waterbody. For 3 waterbodies (10%) exceedances are caused purely by geogenic sources. In 7 cases (23%), pollution is entirely of diffuse character, whilst in further 2 waterbodies (7%) point sources are to blame. For the remainder of waterbodies (40%) a combination of pollution sources apply.

Results from the source apportionment of the identified pollution sources allow for the interpretation of pollution loads on both a waterbody-level (Fig. 2) as well as a regional catchment-level, which takes into account downstream impacts. Thereby benefits from the remediation of individual pollution sources can now be evaluated for the River Elbe sub-basin Zwickauer Mulde.

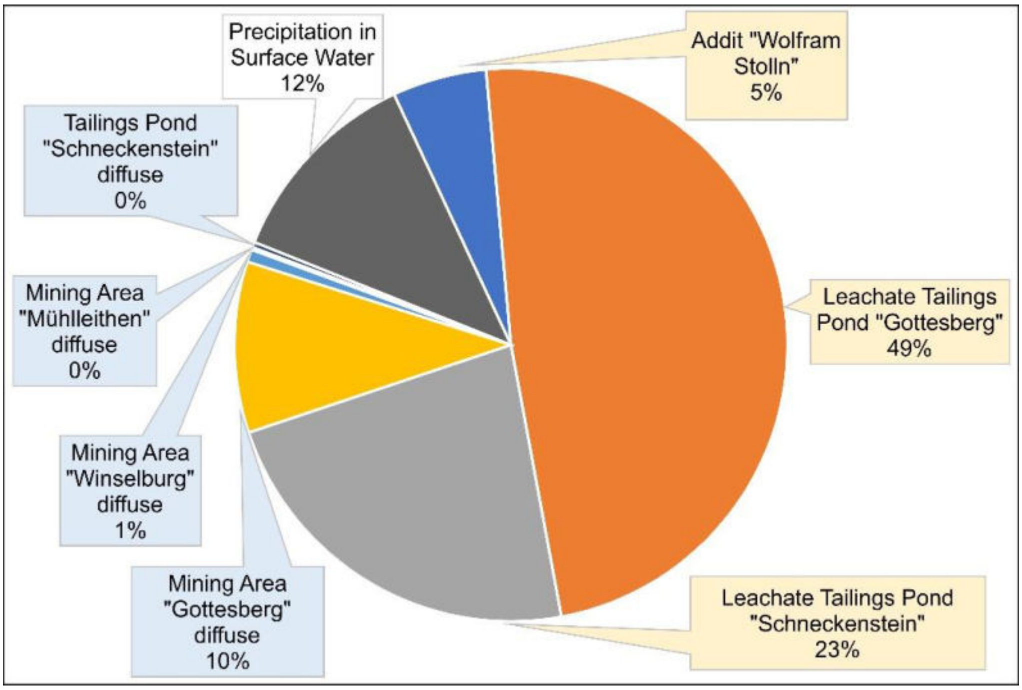

Fig. 2: *Example for source apportionment for arsenic loads in the waterbody Kleine Pyra*

3. The bigger picture – River Basin Management Planning – allocating measures to achieve the highest ecological and chemical status possible

Investigation results allow for a detailed breakdown of the overall pollution load to specific sub-sources. The importance of these sources with regard to their load contributions, the length of waterbody affected, the level of exceedance (distance-to-target) as well as the presence of multiple pollutants together with an assessment of remediation options and costs will form the foundation for decision making for sustainable River Basin Management under the European Water Framework Directive.

Fig. 3 illustrates the importance of differentiating between different severities of pollution through the application of the distance-to-target approach as well as the relevance of impacts from upstream sources through consideration of the length of watercourse affected.

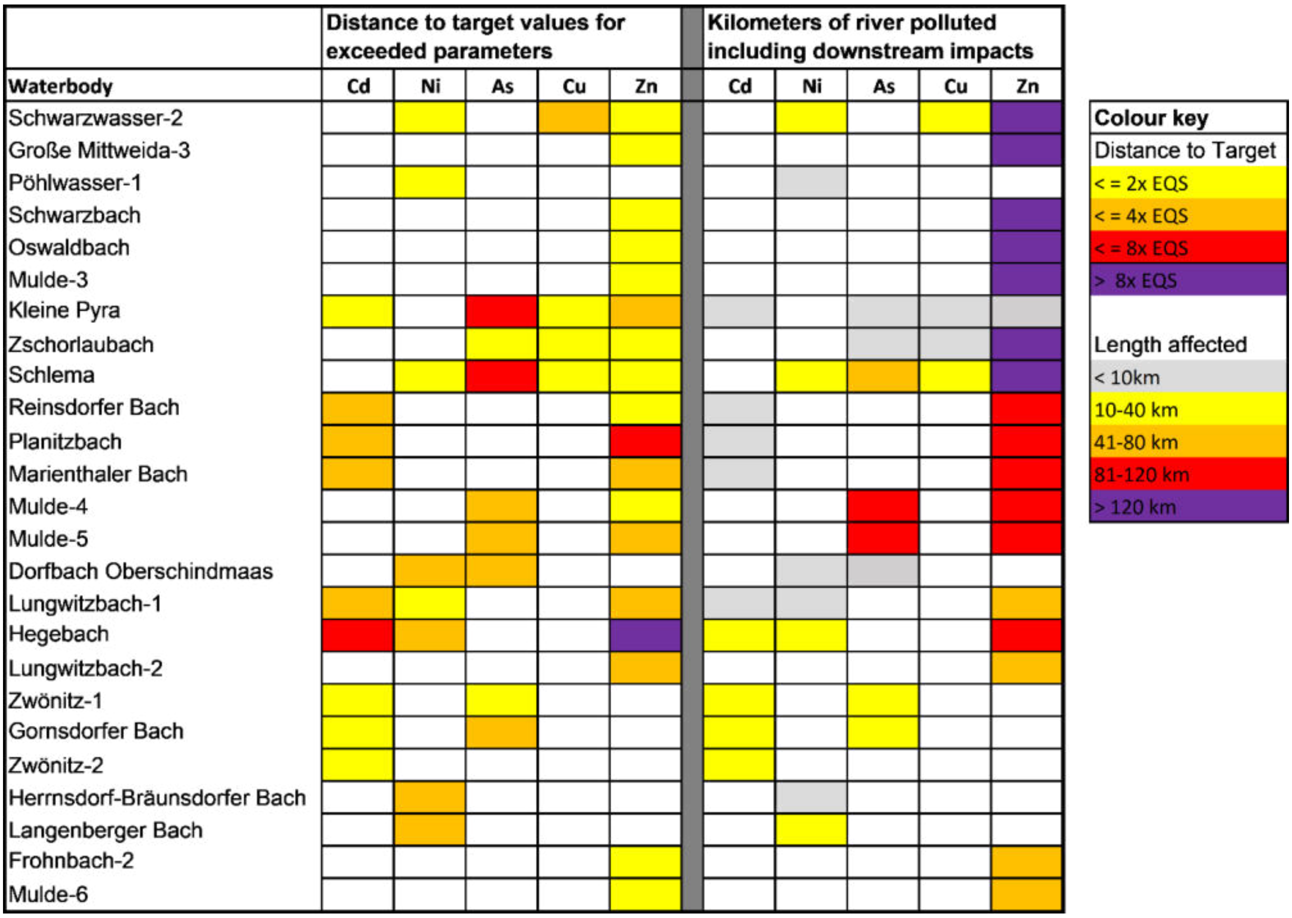

Fig. 3: *Considering distance-to-target values based on levels of exceedance of Environmental Quality Standards (EQS) and downstream impacts based on river length affected by pollutants*

Action to be taken in the various waterbodies for the next river basin management plan range from "desk-based" actions such as the application of revised geogenic background concentrations or the application of less stringent environmental objectives in cases of solely diffuse sources (where technical measures are not feasible) to the derivation of mine-water-remediation measures on a site-by-site basis. The feasibility of practical measures will depend on their associated costs, affordability, land availability and most importantly the permittability and commitment to publicly fund measures for dealing with the legacies of abandoned mining.

4. Nature based solutions as affordable measures for the highest ecological and chemical status possible

Some of the point sources identified in this work are predestined for treatment using natural attenuation (passive) technologies. A pilot study for the treatment of Zinc- and Cadmium-rich mine waters at the St. Christoph Adit in the Saxon Ore Mountains has shown promising results with removal rates of 95% for both Zinc (Fig. 4) and Cadmium. In this case, a Reductive Vertical Flow Reactor was trialled both under laboratory and field conditions. Much Know-How has been developed through the application of a wide range of natural attenuation technologies world-wide since the 1990ies. Today these technologies offer an affordable alternative to expensive active water treatment, whilst minimising the long-term requirements for energy supply, chemical reactive agents and maintenance.

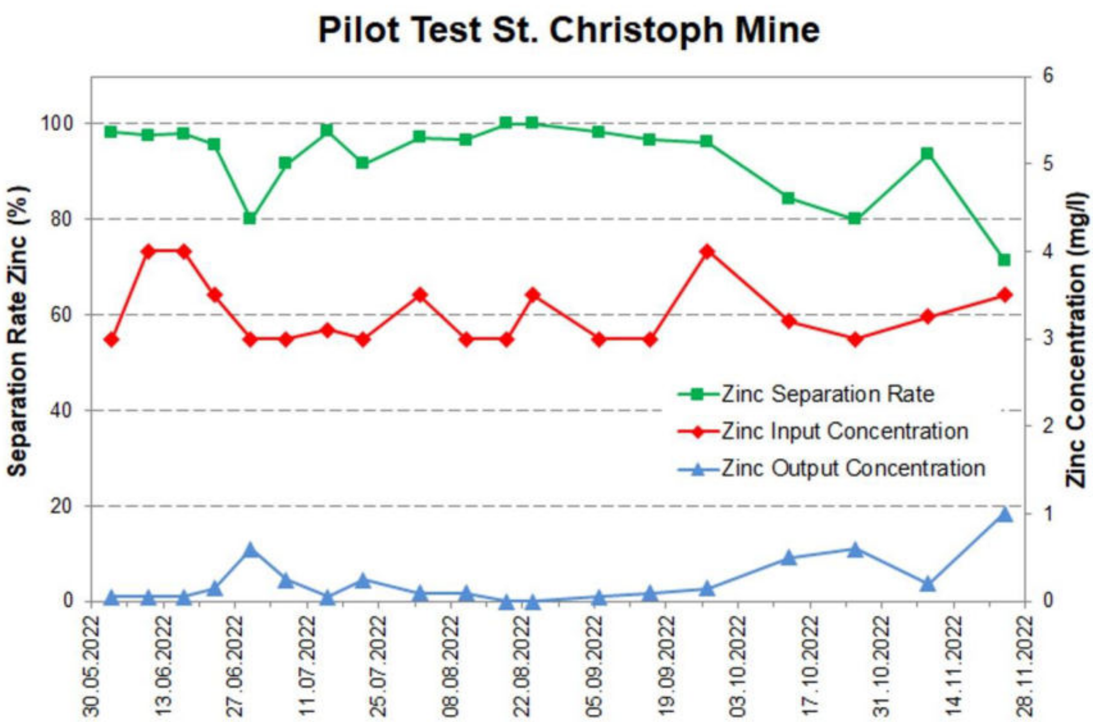

Fig. 4: *Inflow and outflow concentration and removal rates for zinc during the pilot test at St. Christoph Mine*

Literature:

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Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Water quality above and below pollution sources under low flow situations

Libuše Barešová, Vít Kodeš, Petr Tušil

1. Study area and methods

The identification of river profiles suitable for assessing the effect of drought on water quality includes the entire Czech Republic, however, 46 sources of mainly municipal pollution within the Elbe basin were selected for this contribution. For selected discharge sources, there are situated water quality monitoring sites above and below the wastewater discharge. The distance of the monitoring sites from the point of discharge is usually up to 5 km. An important selection criterion was the absence of a significant tributary with possible other sources of discharge between the monitoring sites. The flow above and below the discharge source can thus be considered comparable. The size of the discharge sources included a large range from approx. 400 connected inhabitants to 130 000 connected residents. For the resulting set of water quality monitoring sites, the average flows and flows in the dry period were traced (flow Q_{355d} was considered as the limit of hydrological drought) and the share of the amount of wastewater in the flow in the recipient in the dry period was determined. Furthermore, the behaviour of selected water quality parameters was studied depending on the location of the monitoring site (above and below the pollution source) and the year of monitoring.

All spatial analyses were performed in the ArcGIS environment. Data from the ČHMÚ ARROW information system were used to analyse the results of water quality measurements.

2. Results

The share of wastewater discharged from individual selected sources in the flow of watercourses (recipients of wastewater) ranged in the dry period between 1 and 83%. In accordance with [1], no significant dependence between the size of the discharge source (expressed by both the number of connected inhabitants and the amount of discharged wastewater) and the share of wastewater in the flows in the streams was found. The exception was the largest assessed source, which also had the highest share of discharged wastewater in the stream. This relationship is significantly influenced by the size of the stream into which the wastewater is discharged.

To illustrate the water quality situation above and below the discharge sources, the total phosphorus parameter was chosen as the average of the values measured in the summer months (Fig. 1). The time period was chosen from 1990, since no measurements are available above discharge sources before that year. Several insights emerge from the graph. Up to about 2004, the concentration ranges are larger than in the later period, but in the later period the occurrence of outliers increased (these situations are often associated with rainfall-runoff events). The situation below the discharge sources is almost always significantly worse than above the sources, although it is not optimal even there (these profiles can be located below other discharge sources). For comparison – the limit for permissible surface water pollution for total phosphorus in Government Regulation No. 401/2015 Coll. is 0.15 mg/l (annual average), and a concentration between 0.03 and 0.07 mg/l (median) is determined for good ecological status of water bodies [2]. For the period from 2006, it is shown that even though the median concentration of total phosphorus above the discharge sources varies in similar values, the situation below the discharge sources differs significantly in individual years. The situation is significantly worse in years 2007 and 2008, 2015, 2017 and 2018, 2022 (median of concentrations above 0.25 mg/l).

3. Conclusion

Detailed analyses were also carried out for other water quality parameters (water temperature, BOD_5, conductivity, $N\text{-}NH_4$, chlorides, dissolved oxygen, AOX). Work on a sub-task within the PERUN Competence Centre (www.perun-klima.cz) will continue with further analyses of time series, with a focus on flows in dry periods, the size of recipients, the distance of monitoring sites from the discharge source and the type of sewage system (unified vs. compartmental – influences the impact of rainfall-runoff events on water quality in watercourses).

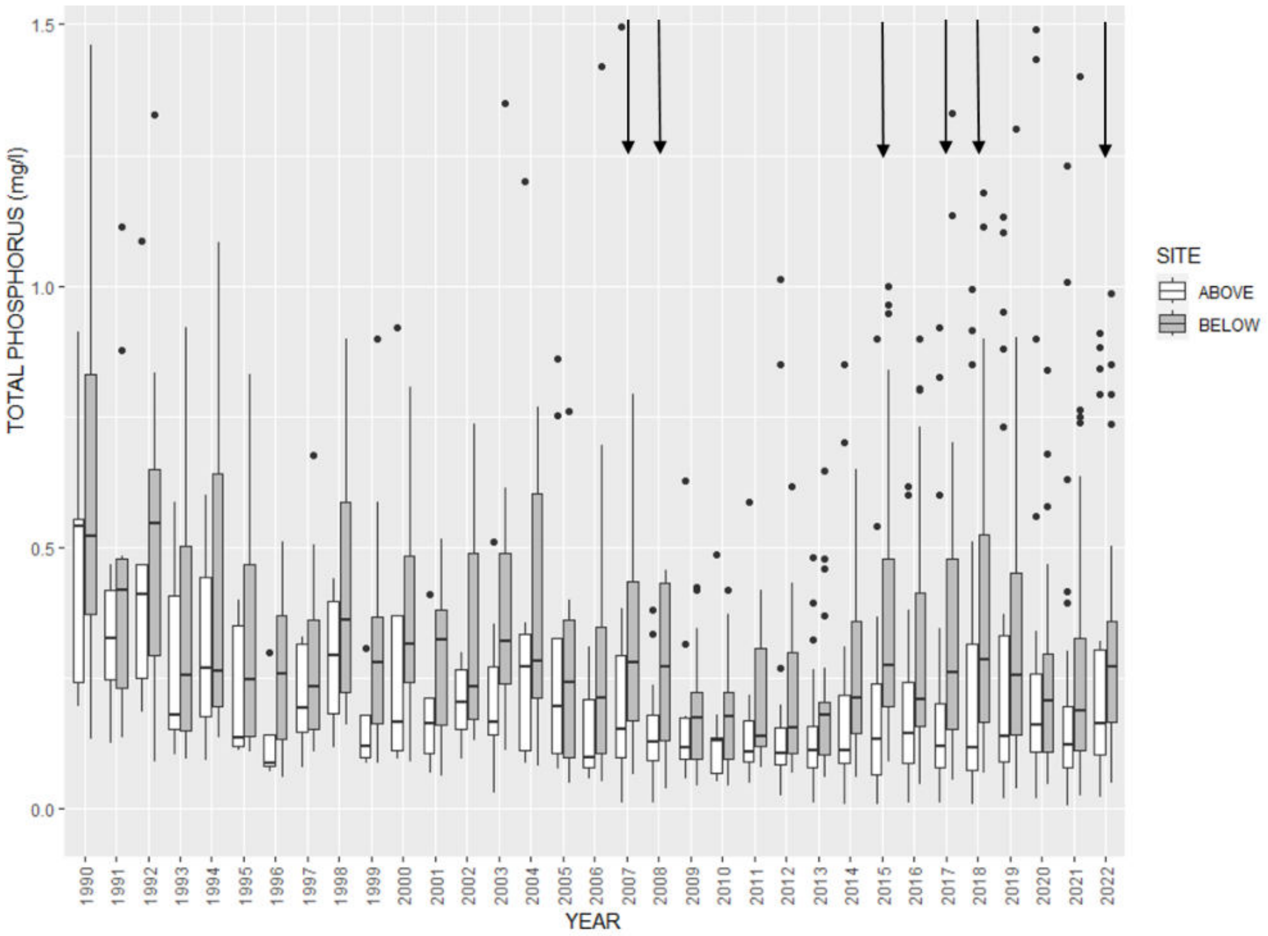

Fig. 1: *Average concentrations of total phosphorus in the summer months on selected water quality monitoring sites above and below discharge sources (the upper and lower limits of the box correspond to the 1st and 3rd quartiles, the horizontal line inside the box indicates the second quartile – the median, black points represent outliers values)*

Acknowledgement

This research was supported by the PERUN Competence Centre (TAČR project SS02030040 Prediction, Evaluation and Research for Understanding National sensitivity and impacts of drought and climate change for Czechia).

The water quality data comes from the operational monitoring of the state enterprises Povodí.

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Hydrological drought in the context of climate change: Case study of the Blšanka and Loděnice basins

Mgr. Alois Burian, prof. RNDr. Bohumír Janský, CSc.

1. Introduction

Submitted paper summarizes the basic principles used to estimate climate change on the water resources with emphasis on the occurrence of hydrological drought. At the same time, individual components and processes of hydrological modelling conditioning the formation of affected time series in the near (2020–2050) and far future (2070–2100) are described. A total of sixteen simulations created from the seven global climate models (GCM) of the CMIP5 project and three climate scenarios (RCP; Representative Concentration Pathways) were used. The time series of precipitation and air temperature, which have been influenced by the climate change, were derived by an advanced delta method that counts also with the change of variability. The conceptual hydrological model BILAN is used to simulate changes. The parameters of the BILAN model were calibrated based on the observed time series of both selected river basins. Afterwards, the values of the parameters were used to create scenario series affected by climate change. The results of the research suggest that the created projections assume to influence the air temperature and precipitation. The differences in runoff process and hydrological balance were caused by the mentioned changes. Based on the created simulations, changes in the range and seasonal monthly runoff are identified. At the same time, an increasing frequency of occurrence and the size of deficit volumes can be expected in scenario periods.

2. Area of interest

These are the Blšanka and Loděnice basins. Both selected areas are characterized by similar meteorological characteristics, a comparable hydrological regime and similar runoff conditions. These are areas that have been affected by drought in recent years, especially in the summer months. One of the causes of deepening dry periods is the partial precipitation shadow of the Ore Mountains. This effect is more significant in the case of the Blšanka basin, but even in the Loděnice area, the precipitation deficit is often manifested.

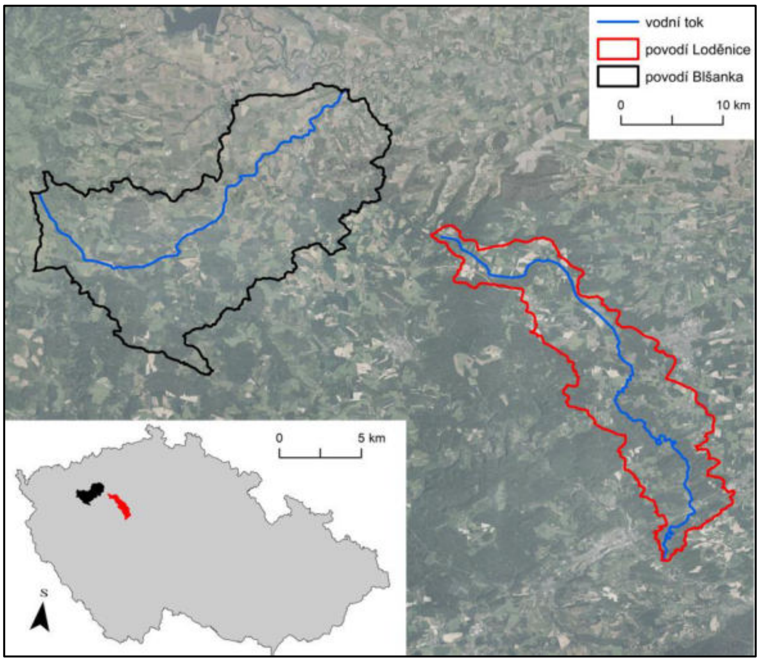

Fig. 1: *Comprehensive map of selected basins – Blšanka and Loděnice river.*

3. Data and methods

Individual time series were processed into a set of hydrometeorological variables, which served to calibrate the BILAN model. Outputs from global climate models from the CMIP5 project (Coupled Model Intercomparison Project – Phase 5) were used for research purposes. Based on these outputs, scenario series affected by climate change were created using the so-called advanced incremental method [2]. Input data to the BILAN model in the form of observed time series of precipitation and air temperatures were corrected for individual simulations by the incremental factor delta [1].

4. Results

For the purposes of the work, the BILAN hydrological model was chosen, with the help of which estimates of climate change impacts in the Blšanka and Loděnice basins were simulated. Outputs from sixteen simulations created from seven global climate models and three climate scenarios were used. Conditions affected by climate change were used to create future scenario.

Tab. 2: *Overview of calculated percentage changes in precipitation totals according to the projections used.*

	Blšanka basin		Loděnice basin	
projection	**2020–2050**	**2070–2100**	**2020–2050**	**2070–2100**
CanESM2_rcp45	+ 7 %	+ 9 %	+ 7 %	+ 9 %
CanESM2_rcp85	+ 10 %	+ 8 %	+ 11 %	+ 9 %
GFDL-CM3_rcp26	+ 15 %	+ 14 %	+ 14 %	+ 13 %
GFDL-CM3_rcp45	+ 10 %	+ 17 %	+ 10 %	+ 17 %
GFDL-CM3_rcp85	+ 14 %	+ 17 %	+ 14 %	+ 16 %
GISS-E2-H_rcp45	+ 10 %	+ 7 %	+ 10 %	+ 8 %
HadGEM2-ES_rcp26	+ 4 %	+ 3 %	+ 2 %	+ 4 %
HadGEM2-ES_rcp45	+ 10 %	+ 11 %	+ 7 %	+ 11 %
HadGEM2-ES_rcp85	+ 10 %	+ 13 %	+ 10 %	+ 10 %
MPI-ESM-LR_rcp26	+ 11 %	+ 6 %	+ 10 %	+ 5 %
MPI-ESM-LR_rcp45	+ 12 %	+ 12 %	+ 10 %	+ 11 %
MPI-ESM-LR_rcp85	+ 9 %	+ 15 %	+ 7 %	+ 13 %
MRI-ESM1_rcp85	– 1 %	+ 10 %	– 1 %	+ 10 %
NorESM1-M_rcp26	+ 9 %	+ 9 %	+ 7 %	+ 9 %
NorESM1-M_rcp45	+ 6 %	+ 9 %	+ 5 %	+ 10 %
NorESM1-M_rcp85	+ 8 %	+ 19 %	+ 8 %	+ 15 %

Tab. 3: *Overview of calculated changes in air temperature according to the projections used.*

	Blšanka basin		Loděnice basin	
projection	**2020–2050**	**2070–2100**	**2020–2050**	**2070–2100**
CanESM2_rcp45	+ 1,69 °C	+ 2,64 °C	+ 1,76 °C	+ 2,69 °C
CanESM2_rcp85	+ 1,74 °C	+ 5,08 °C	+ 1,77 °C	+ 5,16 °C
GFDL-CM3_rcp26	+ 2,21 °C	+ 2,72 °C	+ 2,21 °C	+ 2,72 °C
GFDL-CM3_rcp45	+ 2,61 °C	+ 3,80 °C	+ 2,61 °C	+ 3,80 °C
GFDL-CM3_rcp85	+ 2,76 °C	+ 6,28 °C	+ 2,76 °C	+ 6,30 °C
GISS-E2-H_rcp45	+ 2,24 °C	+ 3,18 °C	+ 2,23 °C	+ 3,17 °C
HadGEM2-ES_rcp26	+ 2,24 °C	+ 2,27 °C	+ 2,32 °C	+ 2,33 °C
HadGEM2-ES_rcp45	+ 2,38 °C	+ 3,45 °C	+ 2,46 °C	+ 3,52 °C
HadGEM2-ES_rcp85	+ 2,62 °C	+ 6,35 °C	+ 2,69 °C	+ 6,42 °C
MPI-ESM-LR_rcp26	+ 0,86 °C	+ 0,73 °C	+ 0,86 °C	+ 0,74 °C
MPI-ESM-LR_rcp45	+ 0,81 °C	+ 1,54 °C	+ 0,83 °C	+ 1,53 °C
MPI-ESM-LR_rcp85	+ 0,83 °C	+ 3,49 °C	+ 0,85 °C	+ 3,53 °C
MRI-ESM1_rcp85	+ 0,77 °C	+ 3,03 °C	+ 0,85 °C	+ 3,09 °C
NorESM1-M_rcp26	+ 1,30 °C	+ 1,72 °C	+ 1,58 °C	+ 1,93 °C
NorESM1-M_rcp45	+ 1,51 °C	+ 2,37 °C	+ 1,95 °C	+ 2,85 °C
NorESM1-M_rcp85	+ 1,46 °C	+ 3,72 °C	+ 1,57 °C	+ 3,90 °C

5. Conclusion

For the purposes of the work, the BILAN hydrological model was chosen, with the help of which estimates of climate change impacts in two chosen basins were simulated. Outputs from sixteen simulations created from seven global climate models and three climate scenarios were used. Conditions affected by climate change were used to create future scenario series for the near (2020–2050) and far (2070–2100) futures. Thanks to the series created in this way, changes in the distribution and seasonality of outflows and changes in the hydrological balance were identified. In conclusion, the hydrological drought was evaluated with the help of insufficient volumes and the analysis of annual minimum outflows. The results of the final thesis clearly indicate that in the Blšanka and Loděnice basins, a decrease in outflows can be expected, especially in the summer, a higher frequency of occurrence and size of insufficient volumes and lower values of annual minimum outflows.

Based on these results, a more frequent occurrence of hydrological drought can be expected in the Blšanka and Loděnice basins.

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Optimizing the design of the system of flood- and erosion-protection measures

Martin Caletka, Pavla Štěpánková, Karel Drbal, Kamila Osičková

1. Introduction

The resilience of the landscape in Czechia to the effect of climate change – drought on the one hand and intense rainfall events on the other – is limited. Major factors include large land blocks and inappropriate agricultural practices. In an effort to improve this situation, land consolidation projects are realized, within which boundaries of plots are re-delineated and systems of flood- and erosion-protection measures are proposed. Their implementation is financially demanding. Therefore, it is always necessary to evaluate their effect on the reduction of surface runoff and associated negative consequences.

The aim of this contribution is to provide information about the ideological concept of the optimization task. The ultimate goal, however, is to propose a methodological procedure (a universal system) enabling a similar method of evaluation applicable in various conditions, always taking into account the limits of a specific site.

2. Methodology

The properties of various flood- and erosion-protection measures can be parametrized. For this purpose, the HEC-HMS software is used, in which watershed models of selected pilot sites in Czechia are compiled. The arrangement of the measures proposed is then modified and the effect of on surface runoff and erosion on the one hand and implementation and operation cost on the other is assessed, always taking into consideration the geographical limitations of a specific site.

At the same time, the basic version of a tool for assessment is developed. It is based on a combined criterial function, which minimizes the initial costs on measures and maximizes the effect of protection. This procedure is performed in the MATLAB and SIMULINK environment. It should lead into optimization of complex flood protection system.

3. Current status of development

As the first step the model of small reservoir was proposed for optimisation (Fig. 1). The sub-optimum was sought through the comparison of the maximal flood wave transformation achieved and the lowest initial costs needed (Fig. 2).

Currently, a similar procedure is being developed for various measures such as ditches, swales or infiltration belts. In addition to the runoff, also the effect on erosion and protection of built-up areas from concentrated surface runoff is taken into account.

The ultimate goal is to create a tool for assessment of various water retention and flood protection measures. This tool should will possibly be used for assessment during the planning process according to Flood directive and the preparation of flood risk management plants.

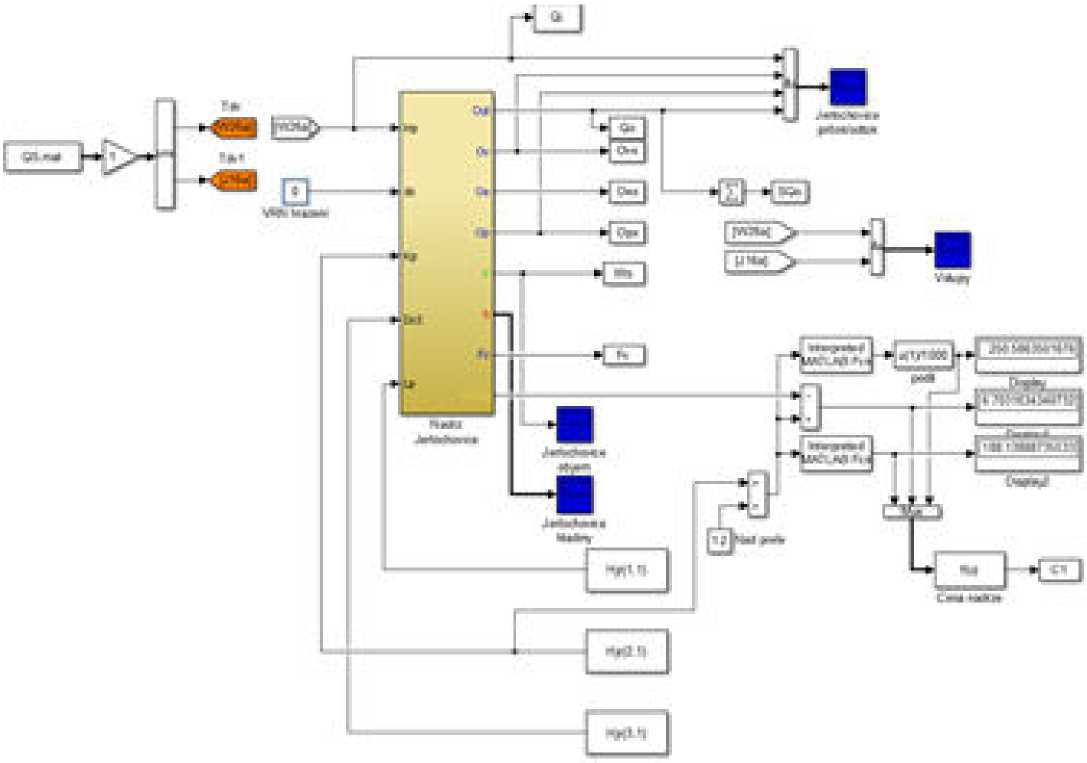

Fig. 1: *Model of the small reservoir with optimisation of bottom outlets and initial costs*

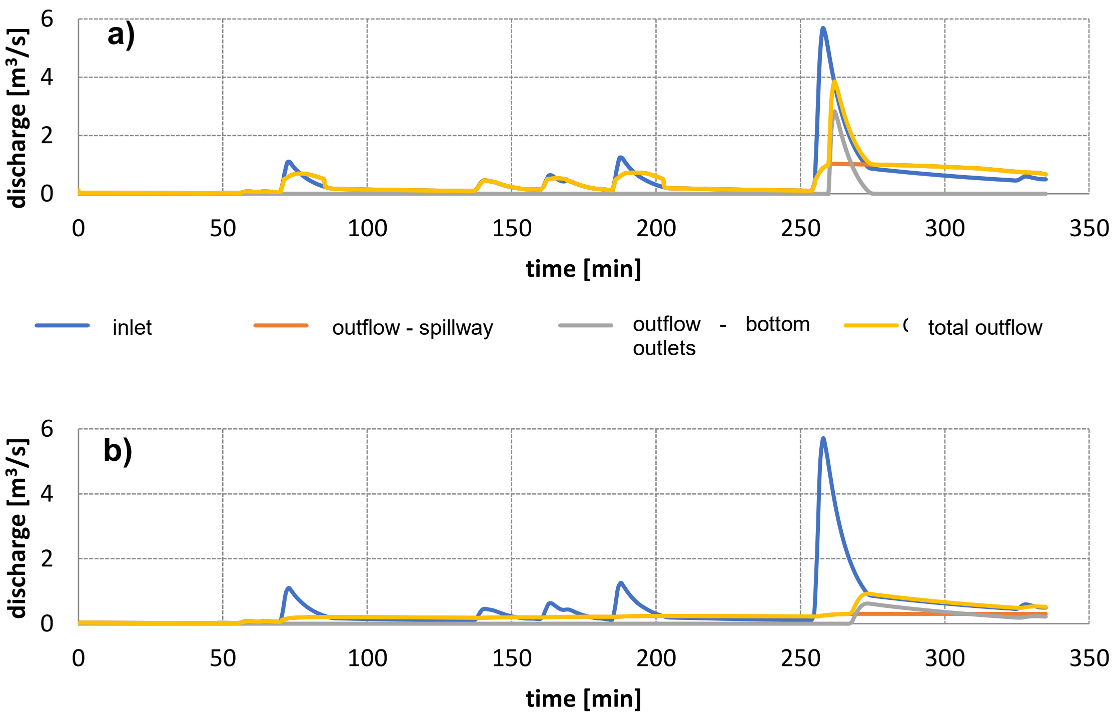

Fig. 2: *Transformation – a) start of optimisation, b) reaching of suboptimum*

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Simulation of pollutants transport at the Švihov drinking water reservoir and Želivka river basin

Eva Ingeduldová, Petr Jiřinec, Pavel Tachecí and Evžen Zeman

1. Introduction

The Švihov water reservoir is the largest drinking water reservoir in the Czech Republic. Detailed knowledge of flow characteristics and pollution transport within the whole reservoir is important for trouble-free water supply of more than millions of inhabitants. 3D simulation model of flow and concentration dynamics is described. A simple water balance and nutrient mass balance model was established for the Želivka river basin (1190 km^2), drained to Švihov water reservoir. This model may serve inputs for 3D model of reservoir.

2. 3D numerical model of flow and pollution transport in the Švihov reservoir

The 3D numerical model (MIKE 3 FM, ca. 1.3 million unstructured space elements) has been created based on detailed DEM of the reservoir and is schematizing flow and pollutant transport in 39 km long reservoir including tributaries affected by backwater. The numerical model was successfully calibrated and validated using measured and observed data (velocity profiles, discharges, wind directions and velocities, air and water temperatures and selected pollutants concentrations – BOD, total phosphorus, N-NO_3) – example of calculated temperature stratification is described in Fig. 1.

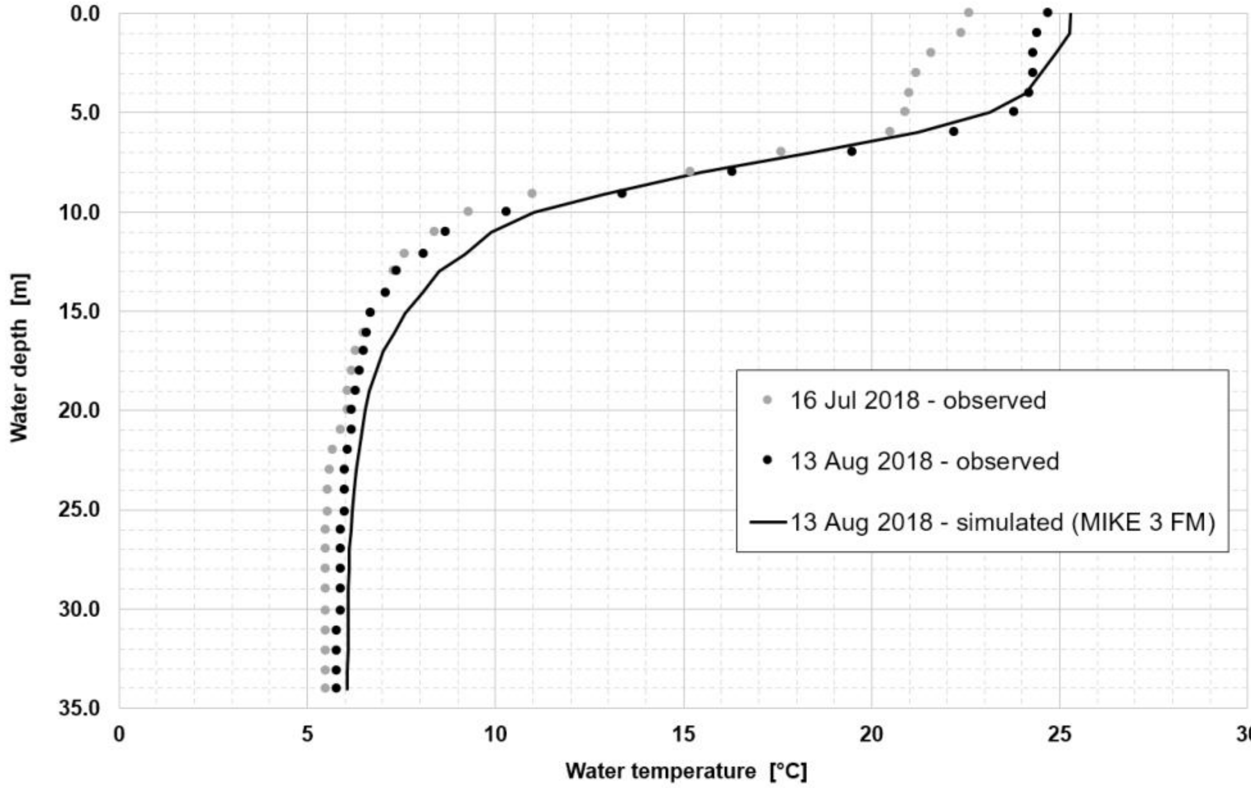

Fig. 1: Temperature stratification in the Švihov reservoir – at the Dolní Kralovice vertical profile

The aim of the study was to describe flow characteristics and potential pollutants spreading in the reservoir under various hydrological and temperature conditions and different pollutant concentrations and scenarios. This model (with modified schematization) has been also proposed for short-term forecast of concentration and propagation of pollutants in time from any point in the reservoir area (e.g., in case of unexpected ecological disaster) to inlet structure for water potable treatment plant. The optimal operation with inlet structure (selection of most convenient intake stage) can be done according to forecast simulation results.

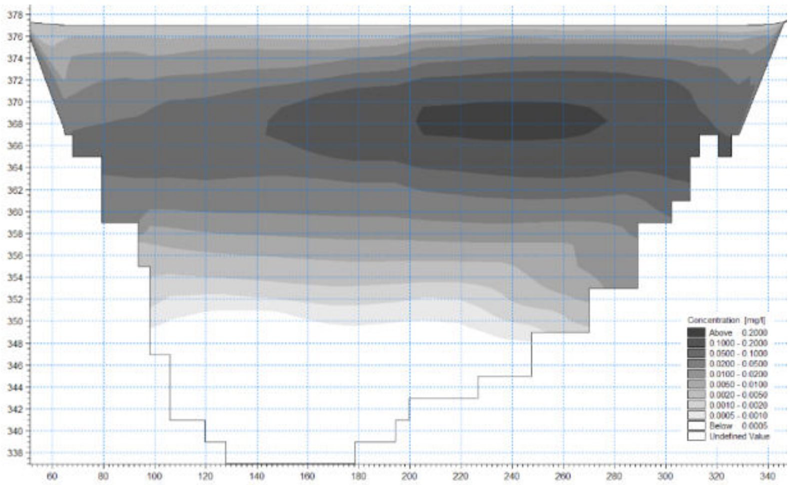

Fig. 2: *Pollutant concentration (vertical profile) in the Sedlický potok bay 3 days after simulated an ecological disaster.*

3. Nutrients mass balance model for Želivka river basin

MIKE BASIN (DHI Software) was used for model establishing. Concentration changes along river reaches are approximated by simplified 1st order decay equation. Model set-up consists of 476 km of river reaches, 159 subcatchments, 116point sources and water users. Water balance was calculated using 12 monthly median discharge values in 21 flow gauging stations (records of CHMI and Povodí Vltavy s.p.) and reported data of main water users. Total phosphorus, BOD, COD, $N\text{-}NO_3$ and $N\text{-}NH_4$ concentrations in 27 points of CHMI and Povodí Vltavy s.p. observation network were used for model calibration. Based on matter flux / discharge correlation relationships, 12 typical values of nutrient concentrations per year were calculated. Concentrations of nutrients from non-point sources were approximated from literature review, based on land-use categories. Nutrient concentrations change along main river reaches at the river Želivka basin were simulated. Average amount of nutrients entering the water reservoirs (in 2015-21 years period) under common flow conditions was assessed. Results of this MIKE BASIN model also serve an input for some of scenarios simulated by abovementioned 3D numerical model of Švihov reservoir.

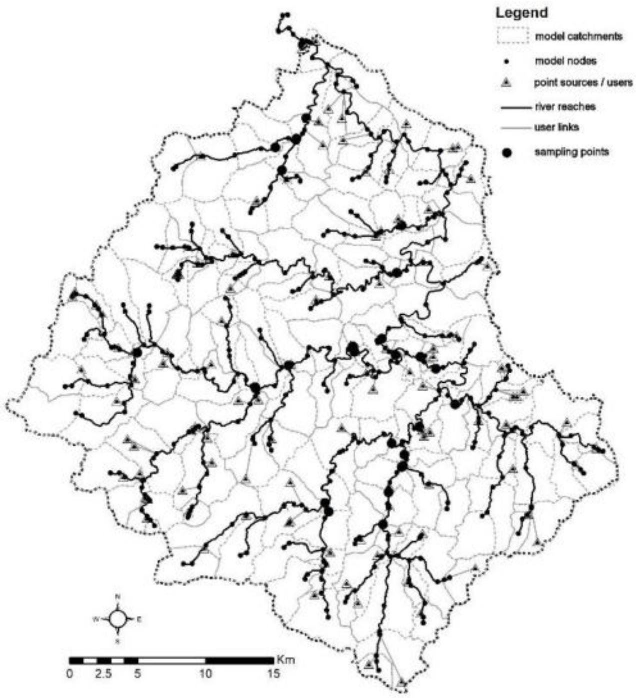

Fig.3: *MIKE BASIN model schematization of Želivka river basin*

Based on data analysis and modelling results, can be expected, that in range of non-extreme discharge values, total flux of phosphorus to the Švihov water reservoir reaches about 5.9 tons annually, total flux of nitrate-nitrogen (N-NO_3) is about 720 tons. Majority of this flux (about 80%) passes though Poříčí station (the River Želivka), while about 15% originates from Martinický creek catchment.

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Emerging Organic Micropollutants (perfluorinated alkyl substances, pharmaceuticals, pesticides and their metabolites) in surface waters of the Czech Part of the Elbe River Basin

Ferenčík Martin, Koutník Milan, Schovánková Jana, Vohralík Gregor

1. Introduction

Organic micropollutants, namely polar organic micropollutants (e.g. Polar pesticides and their degradation products, human and veterinary pharmaceuticals, polyfluorinated alkyl compounds - PFCs and others) are among the important synthetic organic pollutants (xenobiotics) that often exhibit undesirable toxicological and ecotoxicological properties (persistence, bioaccumulation, toxicity, carcinogenicity, mutagenicity, reproductive effects, estrogenic effects). Substances with these properties are on the list of priority substances in European legislation (Directive 2000/60/EC of the European Parliament and of the Council of 20 October 2000 establishing a framework for Community action in the field of water policy; Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy). Due to insufficient information from real surface water monitoring, Watch Lists have been established for selected potential priority substances since 2015 by means of Commission (EU) Implementing Decisions.

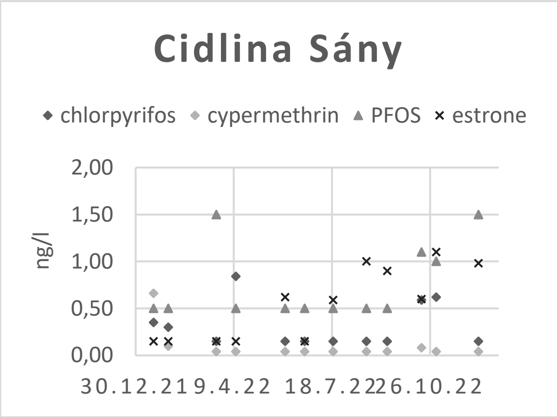
The individual Watch Lists included for example hormones, antibiotics, neonicotinoid insecticides, azole pesticides and pharmaceuticals, UV filters. A combination of liquid chromatography and tandem mass spectrometry is often used for their determination. High-resolution mass spectrometry is used to confirm and identify new xenobiotics. Most of these substances have already been implemented by the laboratory, but have not been able to reach all the required limits [1, 2]. In order to achieve the required very low limits of determination (sometimes tens to thousands of ng/l), the most sensitive analytical instrumentation is needed. Grant funding will be used for its acquisition: Ålesund Call-3A from the Norway Grants 2014-2021 programme "Environment, Ecosystems and Climate Change", mediated and co-financed by the State Environmental Fund of the Czech Republic.

2. Methods

For the sensitive determination of organic micropollutants are preferentially used standardised analytical methods where available, for example [3], but these methods must be adopted for laboratory condition and instrumentation. Up-to date modern instrumentation, for example high-performance liquid chromatograph connected to tandem mass spectrometry (HPLC-MS/MS) or gas chromatograph connected to single quadrupole or better triple quadrupole (GC-MS or GC-MS/MS) are standards for today’s analytics of trace and ultra-trace organic micropollutants. For ultra-trace determination (sub ng/l) of substances with highest effects (hormones, pyrethroid insecticides, tributyltin, etc.) are still necessary very laborious extraction and cleaning steps prior to chromatographic determination.

3. Results and discussion

Following Graphs in pictures 1 and 2 represent real concentrations of selected micropollutants in small river Cidlina, which has very intensive agricultural character with small towns and villages in its basin. Figure 1 illustrates need for very low limits of quantitation (LOQ), because of low Environment Quality Standards (EQS). Chlorpyrifos (LOQ= 0,3 ng/l), cypermethrin (LOQ= EQS= 0,08 ng/l), PFOS (LOQ=1 ng/l, EQS=0,6 ng/l), estrone (LOQ=0,3 ng/l, EQS= 0,4 ng/l), venlafaxine and venlafaxine-O-desmethyl (LOQ= 10 ng/l, EQS= 6 ng/l). For clarity reasons values below LOQ are set to the half of LOQ.



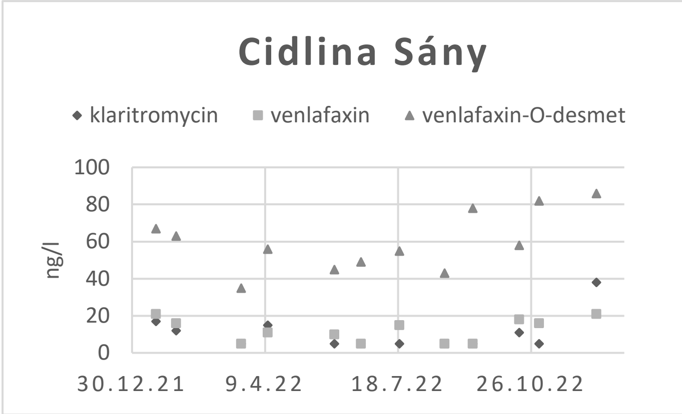


Fig. 1 and 2 *Concentrations in ng/l of selected pollutants at Cidlina Sány in 2022*

4. Coclusions

Current hydroanalytical techniques allow us to determine a wide range of organic micropollutants at very low concentrations. Nevertheless, some of the substances with the highest negative effects are still a challenge for analysts. In addition, we should also be concerned with the analysis of related substances (analogues, substitutes, new groups of substances), which often have even greater adverse effects on ecosystems and, consequently, on humans. For this purpose, high-resolution mass spectrometry using libraries, databases and internet resources is a powerful tool.

Norway grants

Working together for a green Europe

STATE ENVIRONMENTAL FUND OF THE CZECH REPUBLIC

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[3] ČSN EN ISO 21676:2018 **Water quality** — Determination of the dissolved fraction of selected active pharmaceutical ingredients, transformation products and other organic substances in water and treated waste water — Method using high performance liquid chromatography and mass spectrometric detection (HPLC-MS/MS or -HRMS) after direct injection.

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Water quality trends and concentration-discharge changes during different rainfall-runoff conditions in headwaters – Blanice River case study

Fraindová Kateřina, Matoušková Milada, Kliment Zdeněk

1. Introduction

Headwater ecosystems are extremely sensitive to any natural or anthropogenic influences, such as climate change, land cover and land use or changes in the precipitation chemistry [1]. They are, though, an indispensable part of the ecosystem and important drinking water sources, both actual and potential. Knowledge of their status and dynamics is therefore crucial. Blanice River headwaters is a good example of temperate mountain headwater areas, which is partially under nature land protection with implemented measures improving water quality. This ecosystem is also unique because of the most abundant population of the critically endangered freshwater pearl mussel (*Margaritifera margaritifera*) in Central Europe [2].

2. Long-term changes of water biogeochemistry in the catchment

With focus on changes in physical-chemical concentrations in outlet profile Blanický mlýn, a significant decreasing trend was observed for N-NO_3^- during most of the months and also in the annual data series since 2003 according to data from Povodí Vltavy, State Enterprise [3]. Mean annual N-NO_3^- concentration decreased from 1,175 µg.l⁻1 in 2004 to 587 µg.l⁻1 in 2018. The other nitrogen and phosphorous compounds also showed some significant decreasing trends during the year. In small forested tributary catchment was detected slightly different results according to the comparison of data from CGS [4] in 1994–2006 and our data in 2018–2019. Values of pH increased, which corresponds with the overall trend and recovery from acidification in Central Europe. Together with this change, decreases in SO_4^{2-} concentrations were detected. However, some of the metals (Fe, Al, Mg) and N-NO_3^- concentrations increased.

3. Wastewater treatment plant

Analyses of conductivity changes during Wastewater treatment plant (WWTP) Zbytiny construction in 2009 shows strong decrease of mean EC under the WWTP (Fig.1). While above Zbytiny village was EC values before and after WWTP construction almost the same (around 70 µS.cm^{-1}), under the Zbytiny village and also under WWTP EC values have changed from 175 µS.cm^{-1} before WWTP construction to 71 µS.cm^{-1} after WWTP construction.

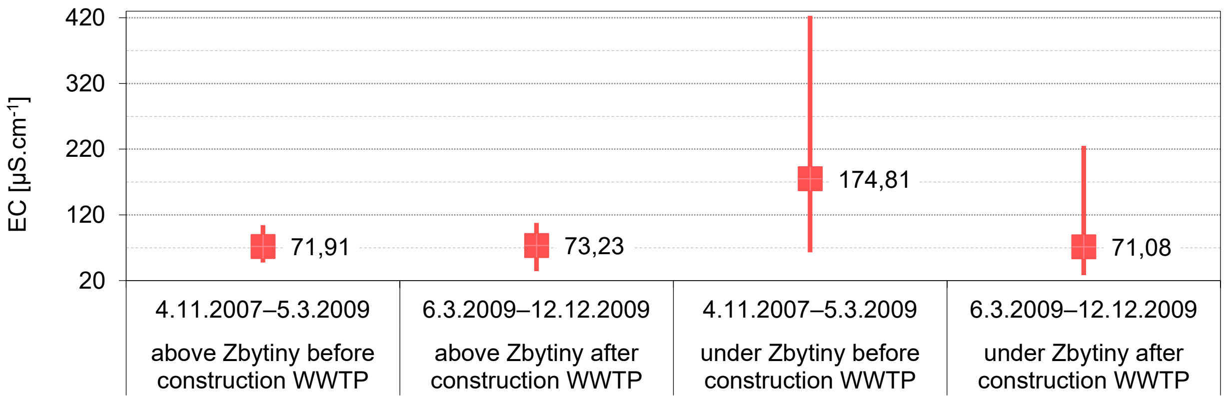

Fig. 1: *Electric conductivity (EC) concentrations before and after Wastewater treatment plant (WWTP) Zbytiny construction in 2009. Points refer to mean concentrations, tails indicate maximum and minimum measured values.*

4. Influence of extreme rainfall-runoff conditions

With regard to runoff conditions, there was an obvious increase in Al, COD_{Mn}, DOC and TP in all studied sites during a rainfall-runoff event (Table 1). The largest increases were registered for Al concentrations, where the Al concentrations were more than three times higher during the rainfall-runoff event than under normal conditions in all sites.

In four sites the Al concentrations were more than five times higher and in two sites were ten times higher than under normal conditions. The concentrations of Al reached almost 1000 $\mu g.l^{-1}$ during the increased discharge in these two catchments, which could affect freshwater pearl mussel population negatively [5]. Apart from one site, the concentrations of COD_{Mn} were more than three times higher in all sites. Higher concentrations were also observed for DOC, but this parameter was measured only at four sites. A significant increase in TP concentrations was also registered. The highest increase more than five times higher was detected in one site, and in four sites was more than three times higher.

Tab. 1: *Elevated concentrations of selected water quality parameters during a rainfall-runoff event, bold black > 10 times higher than median, italics black > 5 times higher than median, black > 3 times higher than median, NM = Not Measured.*

Site number	Site name	Al [$\mu g.l^{-1}$]		COD_{Mn} [$mg.l^{-1}$]		DOC [$mg.l^{-1}$]		TP [$\mu g.l^{-1}$]	
		Median	Event conc.	Median	Event conc.	Median	Event conc.	Median	Event conc.
1	ARN	191	**940**	12.2	38.1	14.3	25.2	40	90
2	PER	85	*440*	5.4	25	NM	NM	15	30
3	TET	82.5	**940**	6.9	31.2	7.5	26.1	15	*80*
4	SPA	149	*750*	7.2	32.6	8.3	23.2	15	50
6	ZBY	127	*950*	6.2	27.2	NM	NM	33	130
7	SVI	250	**840**	4.2	17	NM	NM	33.5	80
8	CER	82	**900**	4.9	12.3	NM	NM	25	100
9	BLM	139	*1130*	8.2	35.8	9.7	27.5	35.5	110

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Options and limits of pollutant load balancing in mining impacted catchment areas (case study Wismut GmbH)

Annia Greif; Mirko Martin; Christine Stevens

1. Introduction

Legacies of the Erzgebirge silver, lead, zinc, tin and uranium mining and processing significantly release heavy metals and arsenic into the environment. In combination with geogenic influences this is a major reason why many water bodies in Saxony fail to achieve the good status required by the EU WFD. With regard to mining-related sources, Wismut GmbH supported a study by the LfULG [1] with expertise from its remediation activities, which have been taking place since 1991. While many mining objects, especially the waste rock dumps (WRD), have been remediated and are now being maintained, this goal will be achieved for the industrial tailings ponds in the next few years. In contrast, the mines will remain subject to controlled flooding and water treatment for a long time.

2. Study area

In the present study, pollutant loads are balanced for the remediation areas of Schlema-Alberoda (Schlema, Mulde-4) and Crossen (Mulde-5) in the period 2016 to 2022. The Schlema-Alberoda remediation site (Fig.1) is characterized by its distinctive WRD landscape. In addition to emissions from the mine and the water treatment plant (WPT) Schlema-Alberoda, emissions from the Schneeberg mine (old mining) via the Markus-Semmler-Adit (MSS) and streams must also be taken into account.

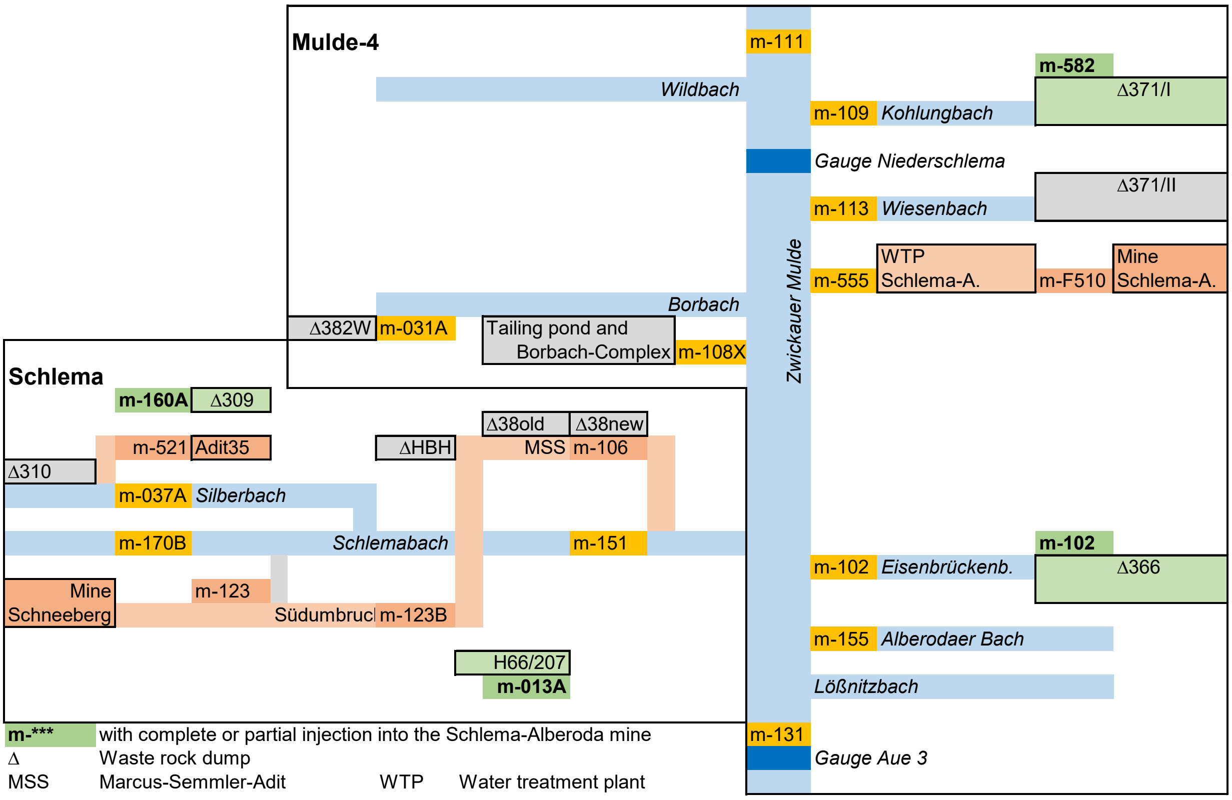


Fig. 1: *River flow diagram of remediation site Schlema-Alberoda within the water body Schlema and Mulde-4*

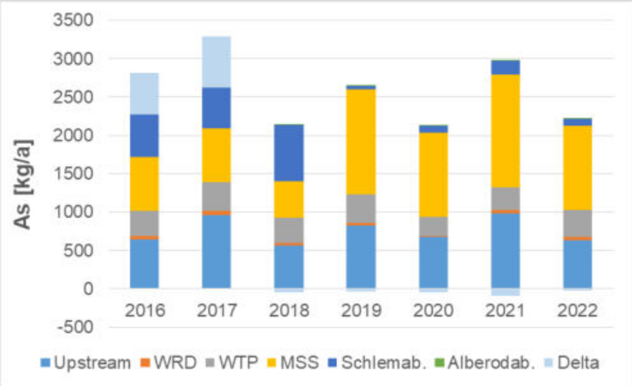
At the Crossen site, the tailings pond Helmsdorf/Dänkritz 1 dominates. Its seepage and some groundwater undergo treatment in the Helmsdorf water treatment plants. The bankside areas of the former Crossen processing plant and the former waste dump have been remediated and are now primarily used for flood protection.

3. Results of load balancing

Regarding the emissions of concern for the receiving water bodies, annual loads were calculated for selected parameters. Methodical challenges lie in the site hydrology (discharge conditions, influence of the Eibenstock reservoir, uncertainties in gauging data), and above all in the site hydrochemistry (preload from upper reaches, water treatment regimes, microbiological processes). These uncertainties complicate the interpretation of the processes between the water phase and the freshly sedimented particulate matter. Loads are significantly influenced by discharges. The review period from 2016 to 2022 was characterized by below-average hydrologic conditions, with 2018 and 2020 having particularly low flows.

For the element arsenic at the Schlema-Alberoda site, significant loads are recorded in the Zwickauer Mulde (Mulde-4). The MSS causes the biggest increase in the arsenic load in the Zwickauer Mulde. After final completion of the "Südumbruch" adit bypass in 2019, almost all mine waters from the Schneeberg mine have been draining via the MSS and no longer enter the Schlemabach. In total the arsenic load from Schneeberg mine is even higher than the arsenic load from the upstream. Another, but significantly lower, load portion is attributable to the treated waters from the Schlema-Alberoda WTP. The load difference of unknown origin in 2016/17 originates mainly from uncertainties in the volume balance.

For the element uranium at the Schlema-Alberoda site, the highest load contribution in the Zwickauer Mulde results from the large volume of treated water from the WBA Schlema-Aberoda, followed by the sum of the inputs from the WRD (seepage water) (Fig. 2). A subordinate portion of the load can also be attributed to the Schneeberg mine (via) MSS. In several years a slightly negative balance for uranium suggests a transition from the water phase into the sediment, which was underpinned by suspended matter investigations.



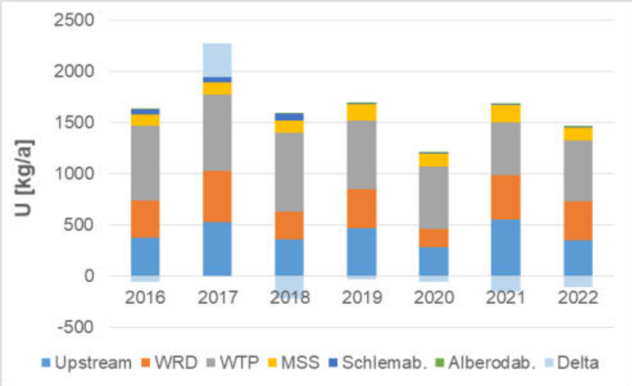


Fig. 2: *Load distribution of arsenic and uranium within the Zwickauer Mulde river (related to m-111)*

The retention of both elements at the Schlema-Alberoda WTP amounts to a multiple of the load at point m-111. At the Crossen site, due to the high treatment performance of the WTP, the residual contamination discharged has hardly any influence on the Zwickauer Mulde (Mulde-5). Here, a load difference remains that cannot be explained by the point sources of Wismut GmbH.

Literature:

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Special monitoring of the Elbe water quality during extreme low flows - results from Czechia and Germany

Gerd Hübner, Jiří Medek, Daniel Schwandt

1. Introduction

During the extraordinary low flow events of the River Elbe in 2018 and 2019 Special Monitoring Programs (SMPs) on water quality in Czechia (Povodí Labe, státní podnik) and Germany (River Basin Community Elbe [1][2]) were run. The sampling dates of the national SMPs in 2018 were largely and in 2019 completely synchronised and shortened the regular sampling interval from a month (International Measuring Program of the IKSE) to a fortnight. In consideration of the sampling dates, the low flow periods were defined from 16 July until 10 December 2018 and from 15 July until 30 September 2019. Sampling sites ranged from the upper Elbe near Valy (CZ) to the lower section of the middle Elbe near Schnackenburg (DE), involving almost 700 river km (Tab. 1). Measuring results were compared between the two low flow events and with those from the selected hydrological reference year 2012. Here we focus on inorganic parameters. Results about organic trace substances in the Elbe during the low flow in 2019 are given in [3].

Tab. 1: *Sampling sites for Elbe water quality of the SMPs in Czechia (CZ) and Germany (DE) in 2018 and 2019*

Sampling site	initial	Elbe km		river side	responsible operator
		CZ	DE		
Valy	VL	947.8		right	CZ: Povodí Labe, státní podnik
Lysá nad Labem	LS	878.8		left	
Obříství	OB	842.1		right	
Děčín	DC	748.2		left	
Hřensko / Schmilka	HR / SM	726.1	3.9	right	CZ: Povodí Labe, státní podnik / DE: Saxony (LfULG)
Wittenberg	WB	516.2	213.8	middle	DE: Saxony-Anhalt (LHW)
Magdeburg	MD	411.9	318.1	left	DE: Saxony-Anhalt (LHW)
Cumlosen	CU	260.0	470.0	right	DE: Brandenburg (LfU)
Schnackenburg	SN	255.5	474.5	left	DE: Lower Saxony (NLWKN)

2. Results

At all sampling sites the maximum water temperature of the Elbe during the low flow in 2018 was higher than in 2019. The highest water temperatures were measured at the upper Elbe. With one exception the maximum values of the electric conductivity of the Elbe water at each site were also always the highest in 2018. The measured oxygen contents did not point to ecological critical levels. In Czechia the Elbe showed relatively high concentrations of NH4-N in 2018 (Fig. 1), which occurred towards the end of the low flow period.

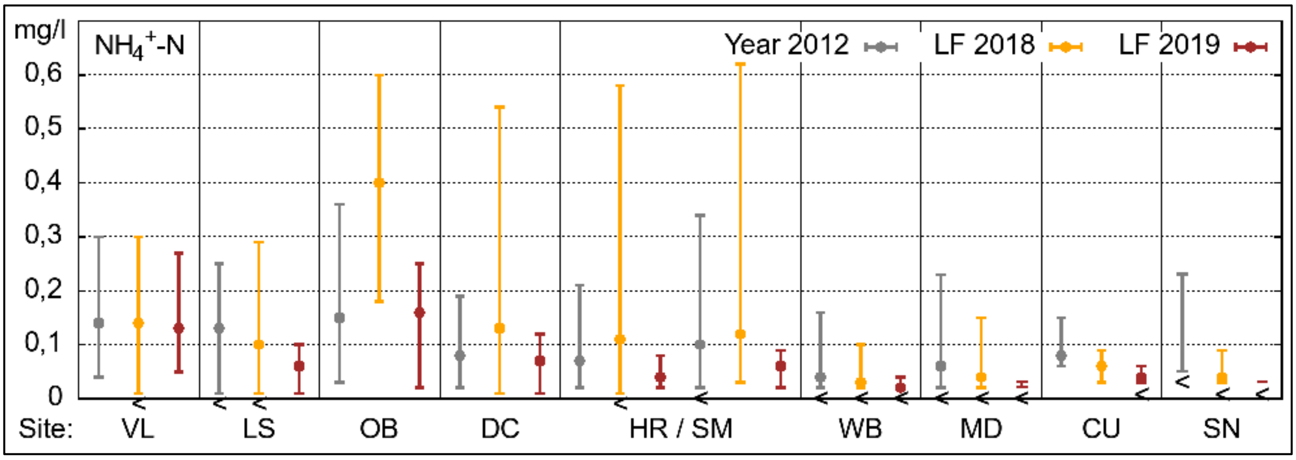

Fig. 1: *Concentration of ammonium nitrogen (range and mean) in the River Elbe in the reference year 2012 and during low flow (LF) in 2018 and 2019; „<“: at least one measurement below the limit of quantification*

Due to a stronger growth of phytoplankton in summer 2019 (indicated by the chlorophyll a concentration), there was a higher concentration of total suspended solids in the Elbe during the low flow 2019. The concentrations of total P and ortho-P were similar in both low flow periods. Only in single cases they exceeded the maximum concentration of the reference year.

In 2018 and 2019 concentrations of chloride, sodium, potassium and calcium achieved long-time maximum values at single sites in the German part of the Elbe.

Most of the measured heavy metals and arsenic reached elevated concentrations at single or more sampling sites. In the Czech part of the Elbe heavy metal concentrations in 2018 were often higher than in 2019. For example, measuring results for copper and arsenic are given in Figure 2.

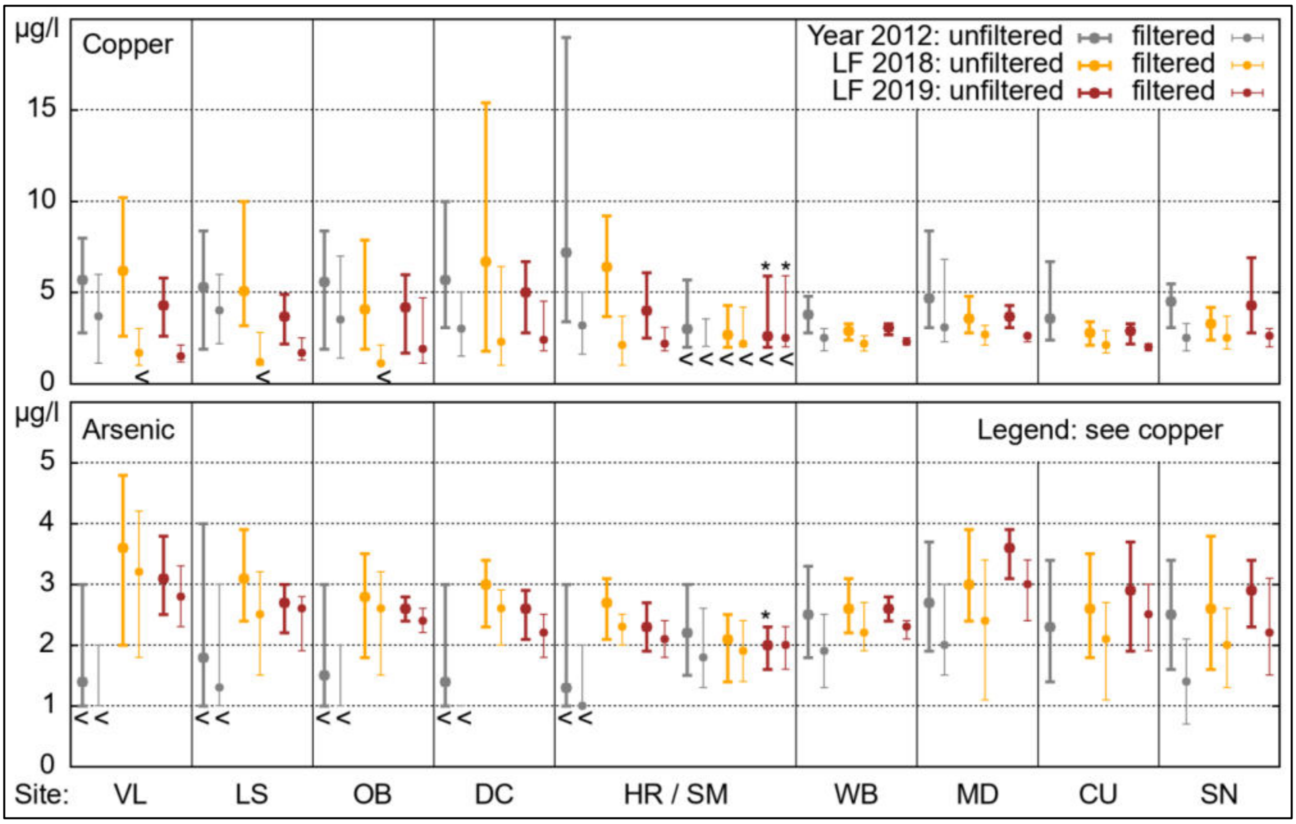

Fig. 2: *Concentration of copper and arsenic (range and mean) in the River Elbe in the reference year 2012 and during low flow (LF) in 2018 and 2019; „<": at least one measurement below the limit of quantification; * without statistical outliers*

Literature:

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A comprehensive approach to the protection of drinking water sources - risk analysis of the catchment areas

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1. Introduction

Access to good quality and safe drinking water is one of the basic requirements of modern society. Already in 2004, the World Health Organization published a new concept based on comprehensive risk assessment and management, covering the entire supply system from the raw water source to the consumer's tap. Only in 2020 was the new EU Directive 2020/2184 on the quality of water intended for human consumption [1] published. This Directive emphasises the comprehensive protection of water resources and introduces the obligation to prepare not only a risk assessment and risk management of the water supply system, but also risk assessment and risk management of the catchment areas for abstraction points of water intended for human consumption.

Within the project "Tools for risk assessment of catchment areas for abstraction points of water intended for human consumption" (supported by the Technology Agency of the Czech Republic) we develop the methodology for risk assessment and management of catchment areas. For this purpose, it should be based on the knowledge gained and measures taken according to Directive 2000/60/EC of the European Parliament and of the Council [2] and it should take better account of the aspects of climate change impacts on water resources. The approach should also aim at reducing the degrees of treatment necessary for the production of water for human consumption by identifying problems in the catchment areas and proposing remedial measures to improve the quality of the water abstracted. This comprehensive procedure will ensure a constant exchange of information between the relevant risk assessors, water suppliers and the competent authorities.

2. Solution progress

In the first year of the project, an inventory of related available data was carried out, which is essential for processing the methodology for risk assessment and management of the catchment areas, and their usability was assessed. On a national scale, the categorization was done according to the types of abstraction points. Categorization is essential for the selection of pilot abstraction points and the verification of procedures for processing the first draft of the methodology.

The largest number of abstraction points for drinking purposes in the Czech Republic are groundwater abstraction points. We focused the most on them when we did the categorization. We classified groundwater abstraction points according to two criteria. The first criterion is the significance of the abstraction based on the amount of abstracted water. For larger sources that are of strategic importance, more information and input data are usually available, therefore a more detailed risk analysis of the catchment area and, of course, the water supply system should be prepared. The second criterion for categorizing groundwater abstraction points is natural characteristics. With them, we focused on hydrogeological structures characterized by their time-space regime, which depends on the morphology of the terrain, the permeability of the rock group and the slope of the groundwater level. Based on this criterion, we divided groundwater sampling into four basic groups: sampling from the subsurface zone, sampling from the fluvial quaternary, sampling from deeper structures and sampling from the karst. We are now selecting pilot abstraction points for individual categories, for which we will evaluate the potential risk and propose procedures for processing the risk analysis of the catchment areas.

3. Conclusion

By the end of 2024, the main output of the project will be a methodology (NmetS) describing the procedure for identifying and assessing risks of the catchment areas with abstraction points of water intended for human consumption, including a proposal for the effective use of nationally available data. For more information, visit the project website (pitnavoda.vuv.cz).

4. Acknowledgements

This contribution was supported by the Technology Agency of the Czech Republic grant SS05010210 "Tools for assessing the risks of parts of watersheds related to water abstraction points intended for human consumption".

Literature:

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Analýza málovodného období 2014–2020 v povodí Labe – Podzemní vody

Pavel Knotek

Počínaje rokem 2014 nastalo v povodí Labe období s převážně podnormálními srážkami a nadnormální teplotou vzduchu. To se odrazilo jak na povrchových, tak i podzemních vodách. Po hydrologických vyhodnoceních sucha v povodí Labe v roce 2015 [1] a v roce 2018 [2] bylo nyní zpracováno vyhodnocení celého suchého období v letech 2014–2020 [3], které obsahuje hodnocení povrchových i podzemních vod.

Hodnocení podzemních vod bylo provedeno zvlášť za českou a německou část povodí Labe, a to u mělkých vrtů (v české i německé části) na základě referenčního období 1981–2010 a u hlubokých vrtů (pouze v české části) na základě referenčního období 1991–2010. Pro jednotlivé monitorovací objekty byly z měsíčních průměrů referenčního období stanoveny měsíční statistické charakteristiky zahrnující minimum, maximum a hodnoty percentilů 5 %, 15 %, 25 %, 75 %, 85 %, 95 %. K těmto charakteristikám byly následně vztaženy hodnoty měsíčních průměrů v hodnoceném období 1/2014 – 12/2020 a byly rozděleny do sedmi kategorií od mimořádně nízkého stavu hladiny (≤ 5 %) po mimořádně vysoký stav hladiny (> 95 %).

Na základě stavů hladin podzemní vody v mělkých vrtech byl v komentáři hodnocen vývoj v jednotlivých koordinačních oblastech mezinárodní oblasti povodí Labe. V české části byly na základě stavů podzemní vody v hlubokých vrtech ještě zvlášť hodnoceny 3 vybrané vodohospodářsky významné hydrogeologické oblasti: Jihočeské pánve, Severočeská křída a Východočeská křída.

Slovní hodnocení je doplněno grafy s chodem hladiny podzemní vody v hodnoceném období ve vybraných monitorovacích objektech. Chod hladiny je přitom znázorněn na pozadí charakteristik referenčního období. Kromě komentáře a grafů pro vybrané objekty byly u mělkých vrtů pro každou koordinační oblast také zpracovány tabulky s procentuálním podílem monitorovacích objektů, ve kterých bylo v jednotlivých měsících hodnoceného období dosaženo výrazně nízkého a mimořádně nízkého stavu hladiny podzemní vody. Pro oblasti s hlubokými vrty v české části povodí je oproti tomu v tabulkách pro jednotlivé měsíce a roky hodnoceného období znázorněna celková klasifikace oblasti pomocí hodnot percentilů a stanovených kategorií stavu hladiny podzemní vody.

Literatura:

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Analyse der Niedrigwasserperiode 2014 – 2020 im Einzugsgebiet der Elbe – Grundwasser

Pavel Knotek

Im Jahr 2014 begann im Einzugsgebiet der Elbe eine Periode mit überwiegend unterdurchschnittlichen Niederschlägen und überdurchschnittlichen Lufttemperaturen. Das wirkte sich sowohl auf die Oberflächengewässer als auch auf das Grundwasser aus. Nach den hydrologischen Auswertungen der Niedrigwassersituation im Einzugsgebiet der Elbe im Jahr 2015 [1] und im Jahr 2018 [2] wurde nun die Auswertung der gesamten Niedrigwasserperiode 2014 – 2020 erarbeitet [3], die die Bewertung der Oberflächengewässer sowie des Grundwassers enthält.

Die Bewertung des Grundwassers erfolgte separat für den tschechischen und den deutschen Teil des Elbeeinzugsgebiets, und zwar bei den Flachbohrungen (im deutschen und tschechischen Teil) auf Grundlage des Referenzzeitraums 1981 – 2010 und bei den Tiefbohrungen (nur im tschechischen Teil) auf Grundlage des Referenzzeitraums 1991 – 2010. Für die einzelnen Messstellen wurden aus den Monatsmittelwerten des Referenzzeitraums monatliche statistische Merkmale unter Einbeziehung der Werte Minimum, Maximum und Perzentilwerte 5 %, 15 %, 25 %, 75 %, 85 %, 95 % festgelegt. Diesen Merkmalen wurden anschließend die Monatsmittelwerte aus dem bewerteten Zeitraum 01/2014 – 12/2020 zugeordnet und in sieben Kategorien von extremem Niedrigwasser (≤ 5 %) bis zu extremem Hochwasser (> 95 %) eingestuft:

Auf Grundlage der Grundwasserstände in den Flachbohrungen wurde in einem Kommentar die Entwicklung in den einzelnen Koordinierungsräumen der internationalen Flussgebietseinheit Elbe bewertet. Im tschechischen Teil fand noch eine gesonderte Bewertung der Grundwasserstände in den Tiefbohrungen von drei ausgewählten wasserwirtschaftlich bedeutenden hydrogeologischen Gebieten statt: der Südböhmischen Becken, der Nordböhmischen Kreide und der Ostböhmischen Kreide.

Die verbale Bewertung ergänzen Diagramme mit Ganglinien des Grundwasserstands in ausgewählten Messstellen. Die Ganglinien werden dabei vor dem Hintergrund der Merkmale des Referenzzeitraums dargestellt. Neben dem Kommentar und den Diagrammen für ausgewählte Messstellen gibt es bei den Flachbohrungen für jeden Koordinierungsraum auch Tabellen mit dem prozentualen Anteil der Messstellen, in denen in den einzelnen Monaten des bewerteten Zeitraums im Grundwasser starkes oder extremes Niedrigwasser erreicht wurde. Für die Gebiete mit Tiefbohrungen im tschechischen Teil des Einzugsgebiets sind in den Tabellen hingegen für die einzelnen Monate und Jahre des bewerteten Zeitraums die Gesamtklassifizierung anhand der Perzentilwerte und der festgelegten Kategorien des Grundwasserstands dargestellt.

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First results of the persistent mobile organic compounds (PMOCs) monitoring in surface water and groundwater in the Czech Republic

Vít Kodeš, Ganna Fedorova, Roman Grabic, Larisa Zajecova

1. Introduction

PMOCs due to their environmental properties may pose serious threat to water resources used for drinking water supply, since they can easily pass through sorption barriers and thus through the water treatment systems. Their occurrence in surface and groundwater was recently confirmed by Schulze et al. [1].

2. Methods

PMOCs (Tab.1) were monitored at 20 surface water profiles (11 from the Elbe river basin) in 2020 utilising composite samples from automatic samplers. Based on the results from 2020, monitored profiles were reduced to 8 (6 from the Elbe river basin) in 2021. In total 80 composite samples were analysed for 20 PMOCs in 2021. The same PMOCs were also monitored in groundwater in 2021, when 125 samples from 125 sites (67 sites and samples from the Elbe river basin) were taken. The QExactive™ mass spectrometer (Thermo Fisher Scientific) was used for the detection of target compounds. HESI-II ionization interface and targeted MS/MS analysis (HRMS/MS) was performed. Accela 1250 LC pump (Thermo Fisher Scientific) coupled with Accela 600 LC pump (Thermo Fisher Scientific) and a HTS XT-CTC autosampler (CTC Analytics AG) were used. Two chromatography columns were used for the separation of target compounds: Hypercarb (50 × 2.1 mm i.d.; 3 µm particles; Thermo Fisher Scientific) and Arion® Polar C18 (50 × 2.1 mm i.d.; 5 µm particles; Chromservis).

Tab. 1: *Monitored substances*

Substance	CAS
(3-(Methacryloylamino)propyl)trimethylammonium chloride	51410-72-1
1-Adamantylamine	768-94-5
1-ethyl-3-methylimidazolium	65039-03-4
1-Naphthalenesulfonic acid	85-47-2
2-Acrylamido-2-methyl-1-propanesulfonic acid	5165-97-9
3,5-Di-tert-butylsalicylic acid	19715-19-8
3-Allyloxy-2-hydroxy-1-propanesulfonic acid sodium salt	52556-42-0
4,4-Diaminodiphenylmethane	101-77-9
4-Aminoazobenzene-4-sulfonic acid	104-23-4
6-Methyl-1,3,5-triazine-2,4-diamine	542-02-9
Benzyltrimethylammonium chloride	56-93-9
Dimethyl 5-sulfoisophthalate sodium salt	138-25-0
Dimethylamino propyl methacrylamide	5205-93-6
HEPES	7365-45-9
N,N-Dimethylbenzylamine	103-83-3
p-Toluenesulfonic acid monohydrate	6192-52-5
p-Xylene-2sulfonic acid hydrate	609-54-1
Sodium 2-Methyl-2-propene-1-sulfonate	1561-92-8
Sodium Methyl Sulfate	512-42-5
Vinylsulfonic acid sodium salt	3039-83-6

3. **Results**

Positive findings were confirmed for the following 9 substances: sodium methyl sulphate, 3,5-di-tert-butylsalicylic acid, p-toluenesulfonic acid, 1-naphtalenesulfonic acid, 1-adamantylamine, p-xylene-2-sulfonic acid, 1 -ethyl-3-methylimidazolium, 4,4-diaminodiphenylmethane, dimethylamino propyl methacrylamide and benzyltrimethylammonium chloride. The most frequently found substances in surface water samples were sodium methyl sulphate, 3,5-di-tert-butylsalicylic acid, p-toluenesulfonic acid, 1-naphtalenesulfonic acid, 1-adamantylamine, p-xylene-2-sulfonic acid and 1-ethyl-3-methylimidazolium. These substances occurred in all monitored profiles in most of the samples taken, with the exception of the substance 1-ethyl-3-methylimidazolium (Fig.1).

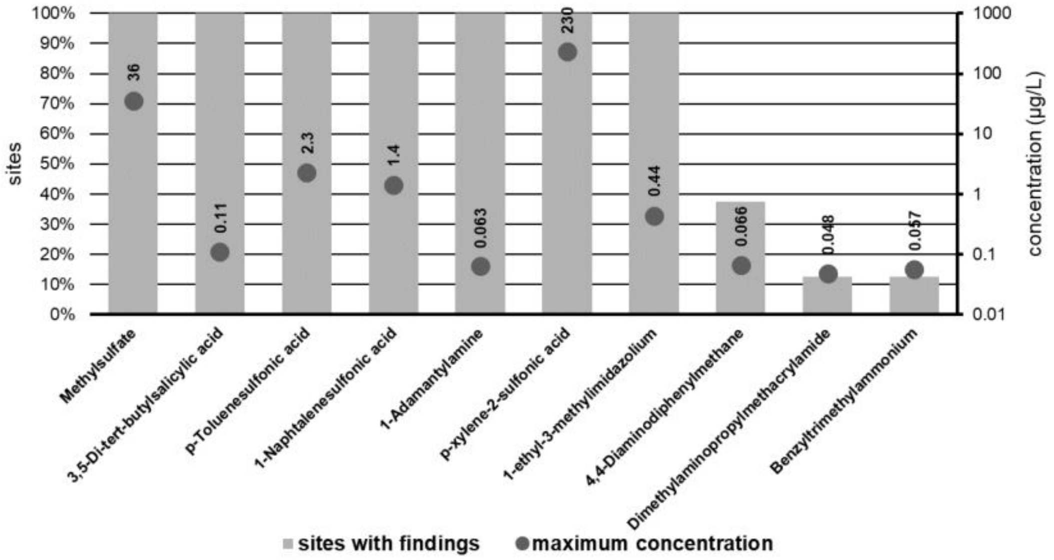

Fig. 1: *Findings and maximum concentrations in surface water in 2021*

9 PMOCs occurred in groundwater samples: p-toluenesulfonic acid, 3,5-di-tert-butylsalicylic acid, sodium methyl sulfate, 2,4-xylenesulfonic acid, 1-ethyl-3-methylimidazolium ethyl sulfate, naphthalene-1-sulfonate, 1-adamantylamine, 4,4′-diaminodiphenylmethane and benzyltrimethylammonium chloride. Maximum concentrations of individual substances ranged between 44 ng L-1 (benzyltrimethylammonium chloride) and 8700 ng L-1 (p-toluenesulfonic acid), see Fig.2. The other 11 substances were not found in groundwater.

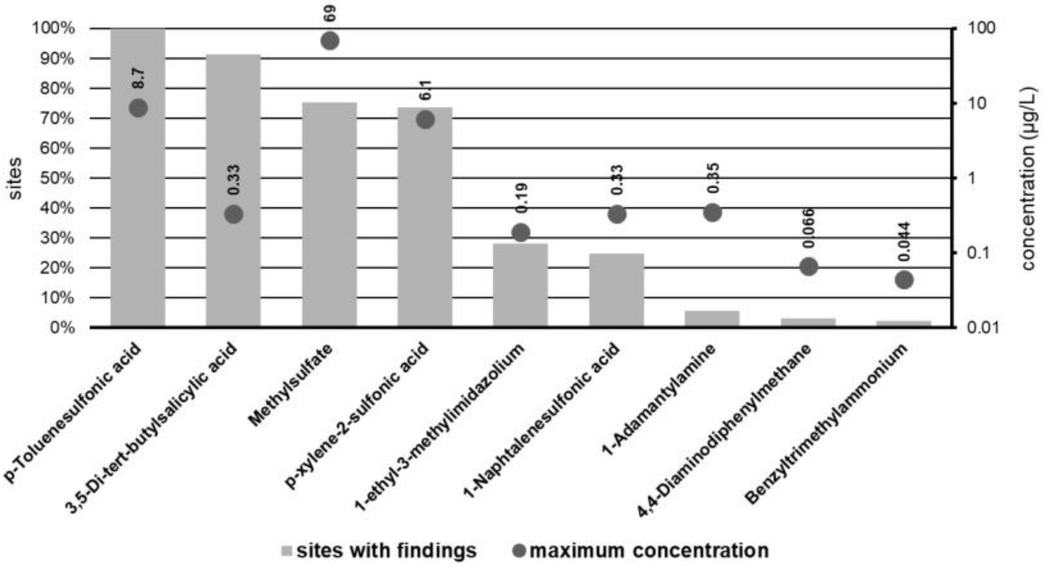

Fig. 2: *Findings and maximum concentrations in groundwater in 2021*

4. Conclusions

The results proved the occurrence of persistent mobile organic compounds in surface and groundwaters in the Czech Republic. These substances thus expanded the already quite extensive list of xenobiotics that we normally find in waters. They may pose potential threat to the water resources used to supply the population with drinking water and ultimately for human health.

Acknowledgement: The work was supported by the Ministry of Agriculture of the Czech Republic, project no. QK21020080, and by the Technology Agency of the Czech Republic project No. SS02030027.

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[1] Schulze et al. (2019) Occurrence of Emerging Persistent and Mobile Organic Contaminants in European Water Samples, Water Research, 153, 80-90

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Leaching of Micropollutants from Soils Irrigated with Treated Wastewater or Enriched with Biosolids, and their Uptake by Plants

Radka Kodešová, Helena Švecová, Aleš Klement, Ganna Fedorova, Miroslav Fér, Antonín Nikodem, Martin Kočárek, Roman Grabic

1. Introduction

Various micropollutants (including pharmaceuticals, cosmetics, cleansers, etc.) are increasingly being detected in the environment because of their incomplete removal from wastewater in wastewater treatment plants (WWTPs). These compounds contaminate water recipients, into which treated wastewater (effluent) is discharged. They can leach towards the groundwater or be taken up by plants if the effluent is used for irrigation or if biosolids from WWTPs are used for soil enrichment. Studies focused on the contaminant uptake by plants are usually carried out under greenhouse conditions [1], [2], [3]. Field studies usually focus on pharmaceuticals and other micropollutants analyses in irrigation water, plants, and soils [4]. However, there is usually no information about the transport of these compounds through the soil environment. Therefore, this study aimed to assess the fate of selected micropollutants more comprehensively.

2. Methods

To study the dynamic behaviour of selected compounds in the soil-water-plant environment, we conducted experiments directly in WWTP for České Budějovice, where nine raised beds with two different soils (sandy loam and sand) were installed. Either maize or a mixture of different vegetables (lettuce, carrot, and onion) was grown in these beds. Of the seven beds with the sandy loam soil, one containing either maize or vegetables was irrigated with tap water, and the other beds (maize or vegetables) were irrigated with WWTP effluent. In other pairs of beds, sludge or composted sludge was added. Only vegetables were grown in the beds with sandy soil irrigated with either tap water or effluent. Selected compounds' concentrations were measured in biosolids, effluent, and solution drained from the beds (every week, April-October), soils, and plant tissues.

3. Results

Of the seventy-five analysed substances (mainly pharmaceuticals), fifty-four were quantified in WWTP effluent. Different plants (vegetables or maize) did not considerably affect the behaviour (i.e., leaching from the beds and accumulation in soils) of the compounds in the beds irrigated with the effluent. Twelve compounds (e.g., gabapentin, tramadol, sertraline, carbamazepine and its metabolites, and benzotriazoles) were found in solution leached from beds with sandy loam soil, and nine substances from beds with sandy soil. However, much higher concentrations (and discharged percentages) were measured in water drained from the bed with sandy soil than those for the sandy loam beds. A gradual increase in the content of six substances (telmisartan, venlafaxine and its metabolite, carbamazepine, citalopram, and tramadol) was recorded in all beds irrigated with the effluent.

Thirty-three substances were quantified in the sludge, and twenty-seven were detected in the composted sludge. The compounds' loads from sludge and compost in beds were similar because of a much large dose of compost compared to the sludge dose. Only four compounds (sertraline and three benzotriazoles) were determined in the solution leached from the beds enriched with both biosolids. Concentrations of stable compounds from biosolids (telmisartan, venlafaxine, sertraline, and its metabolite, and citalopram and its metabolite) did not considerably change in time. A slightly decreeing trend was observed for sertraline, but this was likely mainly due to its leaching from beds. The mobility of sertraline and leaching from all beds were higher than expected, assuming its strong sorption in soils and sludge [5] [6].

Uptake of some chemicals (e.g., gabapentin, tramadol, carbamazepine and its metabolite, and venlafaxine and its metabolite) and their accumulation in plant tissues was observed mainly in vegetables grown on beds irrigated with effluent. Higher concentrations of compounds were found in tissues of plants planted in the sandy soil bed than in those from the sandy loam bed. Negligible concentrations were obtained for plants planted in the bed with sandy loam and composted sludge. Concentrations of compounds in the maize tissues were predominantly below LOQs. Low concentrations of carbamazepine and telmisartan were found only in the roots of maize planted in beds with sewage sludge. The detected concentrations cannot directly threaten human health based on the daily consumption dose [1]. However, the results of this study were highly affected by intensive rainfalls that diluted compounds concentrations, increased their leaching from the beds, and likely reduced plant uptake.

4. Conclusions

The results show the risk of contamination of water recipients and possible risks associated with using treated wastewater or biosolids in agriculture, i.e., compounds leaching towards groundwater and accumulation in soils and plants. Further studies are needed to investigate the behaviour of micropollutants under limited rainfall, during long-term irrigation with reclaimed wastewater, and after repeated application of biosolids.

Acknowledgement: The work was supported by the Ministry of Agriculture of the Czech Republic, project no. QK21020080, and by the European Structural and Investment Funds, project no. CZ.02.1.01/0.0/0.0/16_019/0000845. The authors also thank the ČEVAK, p.l.c. and the city of České Budějovice for the possibility to conduct the experiment in the WWTP area and our colleagues for their help.

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Monitoring of micropollutants in the Uhlava river

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Introduction:

The River Uhlava is an important source of water for both human consumption and the surrounding ecosystem. However, due to the development of human activities, the water quality is increasingly influenced by micropollutants, including pesticides, pharmaceuticals and personal care products (PPCPs), comlexing agents (EDTA and NTA), hormones, and other chemical compounds. These pollutants originate from industrial activities, agriculture, households, or healthcare. The presence of micropollutants in waterways deteriorates water quality and carries potential risks for aquatic organisms and human health, even at very low concentrations. Micropollutants can have adverse effects on aquatic organisms and, due to their ability to bioaccumulate, on entire ecosystems. Furthermore, they can enter drinking water and thus cause a risk to human health.

A project focused on monitoring micropollutants in the River Uhlava has been organized for the eleventh consecutive year (since 2013) through collaboration between Povodí Vltavy, State Enterprise, and Pilsen Water Treatment Plant. The monitoring scheme is adjusted each year based on the obtained facts, and the framework of monitoring expands along with the development of analytical methods. The main goal was to obtain predictive knowledge about the contamination of an important water source, to identify the main sources, and to assess the transport balance of substances in different seasons and under different hydrological situations. Knowledge of the issue of micropollutants transport helped in solving a dangerous water management accident in October 2019, during which several hundred kilograms of fungicidal mixture leaked from a local private wood processing plant into Drnovy potok.

Materials and Methods:

The samples of raw sewage and the outflow in waste water treatment plant (WWTP) Klatovy were taken monthly as composite 24h samples. The end profile of the Uhlava river (Uhlava Doudlevce) was sampled as weekly continuous integral sample. PPCPs were separated and detected by LC-MS/MS methods based on the direct injection of sample into chromatograph. Complexing agents were analysed by GC-NPD method after esterification and liquid-liquid extraction. Data of discharge were obtained by Povodí Vltavy, State Enterprise and by Klatovy WWTP operator (Šumavské vodovody a kanalizace a.s.). A balance analysis was carried out from the achieved results [1].

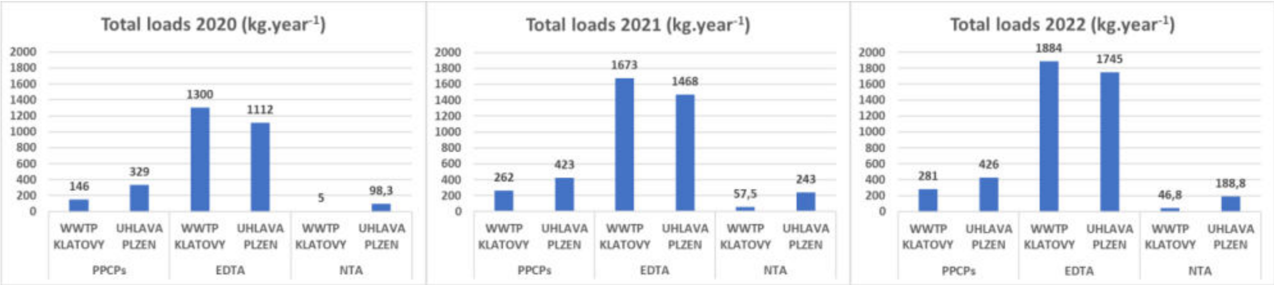
Results and discusion:

The results of long-term monitoring show that the main source of pollution in the Uhlava catchment area is Drnovy stream, which flows through the industrial town of Klatovy (22,000 inhabitants). The primary source is the municipal WWTP.

In 2020, PPCPs and complexing agents were monitored. The balance analysis showed similar EDTA load results between the Klatovy WWTP and the Uhlava Doudlevce end profile. In contrast, the input values of PPCPs from the Klatovy WWTP accounted for only 44% of the total amount of PPCPs found in Uhlava Doudlevce [2].

In 2021, the measurement of concentrations in untreated wastewater at the Klatovy WWTP was started. This makes it possible to determine what part of the contamination comes from capacity overflow and add it to the total load of the river. The results show that the input of pollution in this way is significant. Although only 9.5% of the total volume of water delivered to the WWTP was discharged to the capacity overflow of untreated wastewater, the total transport of substances from the WWTP increased by 65% for PPCPs, 12.8% for EDTA and 850% for NTA. In the case of NTA, the effect of short-term overloading of the WWTP is most evident, as NTA is almost removed from the water by WWTP technology. By including the WWTP overflow source, the sum of the total load of PPCPs from the Klatovy WWTP increased to 62% of the total load of the PPCPs found in the end profile of Uhlava Doudlevce [3].

Fig. 1-3 : Annual total loads of PPCPs and complexing agents.



In 2022, the monitoring scheme remained unchanged. The results confirmed a high proportion of transport of substances through the overflow of the wastewater treatment plant. The WWTP discharged 6.5% of the total volume of water supplied through its sewage overflow. This amount increased the total transport of PPCPs by 40.1%, EDTA by 7.5%, and NTA by 735%. For PPCPs, the sum of the total load from the Klatovy WWTP corresponds to 66% of the total load found in the end profile Uhlava Doudlevce [4].

Conclusion:

In 2020, without taking into account the effect of capacity overflow, the total load from WWTP Klatovy was estimated at 44% of the total load of PPCPs in the end profile of Uhlava river. In the years 2021 and 2022, after taking into account the effect of sewage overflow from the WWTP, the total load of PPCPs increased to 62%, respectively 66% of the total load of PPCPs in Uhlava Doudlevce. Over 30% of pollution is from other sources. NTA shows an extreme increase in total load during capacity overflow (up to 8 times). The goals of monitoring in the coming years are to find these sources. (i) It is necessary to start monitoring other sewage overflows in Klatovy. It can be assumed that during rainfall-runoff events, in addition to nutrients, an enormous amount of micropollutants also enters the Uhlava River. Therefore, it is necessary to include episodic events in the balance analysis. (ii) Another goal is to determine the total load of PPCPs and complexing agents at the Přeštice municipal WWTP (6,800 inhabitants; the second largest city in the catchment area). (iii) NTA shows an extreme increase in total load during capacity overflow (up to 8 times). Therefore, it is possible to think of NTA as a marker in case of overflow. (iv) An important part of the monitoring is the expansion to include new relevant micropollutants. A good focus of monitoring is the first step to preserve the quality of the given ecosystem and to protect human health.

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Analýza málovodného období 2014–2020 v povodí Labe – Povrchové vody

Petr Kuřík

Od roku 2014 na povodí Labe převažovala období s podnormálními srážkami a nadnormální teplotou vzduchu. To mělo za následek, že se v české i německé části povodí Labe až do roku 2020 opakovaně vyskytovaly i velmi dlouhé periody s minimálními průtoky s rozdílným prostorovým rozsahem a různou intenzitou, jejichž vyhodnocením pro celé povodí Labe se zabývala skupina expertů Hydrologie v rámci mezinárodní spolupráce pod záštitou Mezinárodní komise pro ochranu Labe (MKOL) a vypracovala společnou analýzu tohoto sedmiletého suchého období [1], která je k dispozici na internetových stránkách MKOL www.ikse-mkol.org. Analýza doplňuje již publikovaná podrobná vyhodnocení sucha v povodí Labe v letech 2015 [2] a 2018 [3].

Pro analýzu bylo vybráno 11 vodoměrných profilů v povodí Labe (4 na Labi a 7 na přítocích). Analyzovány byly charakteristiky teploty vzduchu, srážek a průtoku pro období 2014–2020, které byly porovnány s referenčním obdobím 1981–2010.

Hodnocené suché období 2014–2020 bylo natolik významné, že pouhé porovnání s charakteristikami za 30leté referenční období zdaleka nepostačovalo. Proto pro vodoměrné profily na Labi v Děčíně (od roku 1851) a Magdeburku (od roku 1727) bylo pro statistické zhodnocení tohoto suchého období využito jejich dlouhých řad pozorování. Na základě tohoto hodnocení lze konstatovat, že sedmileté období 2014–2020 patří k nejméně vodným za období pozorování těchto stanic.

V rámci vyhodnocení suchého období v roce 2018 byl proveden odhad „odovlivněných“ průměrných denních průtoků (bez vlivu nádrží) na Labi v Děčíně. Odvozený třicetidenní minimální průtok v roce 2018 na podkladě těchto dat vychází v Děčíně cca 41,0 $m^3.s^{-1}$, což by byla teoreticky nejmenší hodnota za období 1888–2020. Třicetidenní minimální průtok v roce 2018 (83,7 $m^3.s^{-1}$) byl nejnižší od roku 1964, tedy za období, kdy jsou malé průtoky nadlepšovány nádržemi. Vliv vodních děl na zvětšování minimálních průtoků je podrobněji popsán v publikacích MKOL k vyhodnocení sucha v letech 2015 [2] a 2018 [3].

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Analyse der Niedrigwasserperiode 2014 – 2020 im Einzugsgebiet der Elbe – Oberflächengewässer

Petr Kuřík

Seit 2014 war das Einzugsgebiet der Elbe durch unterdurchschnittliche Niederschläge und überdurchschnittliche Lufttemperaturen geprägt. Das hatte zur Folge, dass sich im tschechischen und im deutschen Teil des Elbeeinzugsgebiets bis zum Jahre 2020 wiederholt sehr lange Niedrigwassersituationen mit jeweils unterschiedlichem räumlichem Ausmaß und unterschiedlicher Intensität einstellten, mit deren Auswertung für das gesamte Elbeeinzugsgebiet sich die Expertengruppe „Hydrologie" im Rahmen der internationalen Zusammenarbeit unter dem Dach der Internationalen Kommission zum Schutz der Elbe (IKSE) befasste und eine gemeinsame Analyse dieses 7-jährigen Niedrigwasserzeitraums [1] erstellte, die auf den Internetseiten der IKSE www.ikse-mkol.org zur Verfügung steht. Diese ergänzt die bereits publizierten detaillierten Untersuchungen der Niedrigwasserjahre 2015 [2] und 2018 [3] im Einzugsgebiet der Elbe.

Für die Analyse wurden 11 Pegel aus dem Einzugsgebiet der Elbe (4 an der Elbe und 7 an den Nebenflüssen) ausgewählt. Betrachtet wurden Kenngrößen der Lufttemperatur, des Niederschlages und des Abflusses für den Zeitraum 2014 – 2020, die mit der Bezugsperiode 1981 – 2010 verglichen wurden.

Die bewertete Niedrigwasserperiode 2014 – 2020 war so bedeutsam, dass der reine Vergleich mit den Kenngrößen für den 30-jährigen Bezugszeitraum bei weitem nicht ausreichend ist. Deswegen wurde für die Pegel an der Elbe in Děčín (ab 1851) und in Magdeburg (ab 1727) für die statistische Einordnung dieses Niedrigwasserzeitraums auf lange Beobachtungsreihen zurückgegriffen. Die diesbezüglichen Auswertungen zeigen, dass der 7-jährige Zeitraum 2014 – 2020 zu den abflussärmsten seit Beobachtungsbeginn dieser Pegel gehört.

Im Rahmen der Auswertung der Niedrigwasserperiode im Jahr 2018 wurden die „bereinigten" mittleren Tagesabflüsse (ohne Talsperreneinfluss) an der Elbe in Děčín geschätzt. Der anhand dieser Daten abgeleitete 30-tägige Niedrigwasserabfluss für 2018 beläuft sich in Děčín auf ca. 41,0 m^3/s, was theoretisch der kleinste Wert für den Zeitraum 1888 – 2020 wäre. Der 30-tägige Niedrigwasserabfluss im Jahr 2018 (83,7 m^3/s) war der niedrigste seit Beginn der Niedrigwasseraufhöhung aus den Talsperren im Jahre 1964. Der Einfluss der Talsperren auf die Aufhöhung von Niedrigwasserabflüssen ist in den IKSE-Publikationen zur Auswertung der Niedrigwassersituation von 2015 [2] und 2018 [3] ausführlich beschrieben.

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Model examples of stream restoration proposals in the Ohře (Eger) River basin

Matoušková, M., Jonáš, M., Holík, J., Šobr, M. and Z. Kliment

1. Introduction

Stream revitalization has converted into one of the most essential tools in landscape planning and protection of water bodies. As a rule, we try to restore watercourses that have been improperly fortified and are in bad ecological condition. Our paper presents proposals for possible revitalization in urbanized and rural landscape in selected catchments of the Ohře (Eger) River. The first example is the revitalization of Bouřlivec Brook in the Lahošť urban area. The second example is renaturation and revitalization of the Klíšský Brook in the rural landscape. Main aims of the restoration in urban area were: i) to improve hydromorphological and ecological condition of the stream, ii) to increase flood protection measures and iii) to increase recreational usability in the riparian belt. Main aims of the restoration in rural area were: i) to accelerate renaturation processes in selected reaches, ii) partial removal of existing fortifications to stimulate natural fluvial-morphological processes to achieve a meandering channel course, iii) restoration of riparian belt and stimulation of succession vegetation processes. The actual restoration measures in both study areas should not endanger the occurrence and abundance of protected species.

2. Data and Applied Methods

The study area of the urban restoration projects was Bouřlivec Brook, between r. km 6.785-6.328 in the cadastral territory of the municipality of Lahošt'. From the discharge dataset provided by the Ohře (Eger) River Water Basin Authority, flood return periods were determined using the Gumbell distribution of extreme values [1,2] and the restoration concept was adjusted to match these thresholds. Longitudinal and cross-section profiles were geodetically measured and processed in AutoCAD. For cross-sections, the current and design maximum discharge capacity was calculated. In addition, granulometric analysis was performed in two upper and one lower adjacent reach. Average value of a mid-effective grain size then served as a basis for the riverbed stability calculations at four model cross-sections, which were processed using the Neill's equation. These assessed the stability at three different discharge limits (maximum discharge capacity, maximum discharge capacity of a cuvette and a discharge value, at which instability begins to occur). Finally, the assessment of the restoration effect regarding hydromorphology was determined using the HEM methodology [3]. The study area of the rural project was Klíšský Brook, between r. km 11.310-12.960 in the municipalities of Libouchec, Malé and Velké Chvojno. In some sections the riverbed and banks are fortified. The well-developed network of hydraulic drainage systems also heavily drains the adjacent floodplain. As in the urban project, the longitudinal and cross-section profiles were geodetically measured and current and design maximum discharge capacity was determined. The property rights along the stream, and historical stream route, were assessed based on cadastral maps and maps of the 2nd military mapping from the 19th century [4,5]. This information was then used to complete the delineation and scope of the restoration study.

3. Summary of results

The discharge return periods for selected years (2, 5, 10, 20, 50 and 100 years) correspond to the following values (3.35, 5.27, 6.53, 7.75, 9.32 and 10.50 $m^3.s^{-1}$) in Lahošť gauging station in the Bouřlivec catchment. Hydraulically, the discharge capacities of the cross-section do not interact much. This is due to the significant changes in the geometry of the flow area in the longitudinal profile. River substrate analysis showed a significant extent of silting by fine particles and the significant reduction of a mid-grained gravel fractions (d = 20-40 mm) in the already restored (r. km 6.328-5.794) adjacent reach. Stability calculations show a good level of hydrological connectivity of the proposed restoration design and, more importantly, its ability to withstand discharges >Q_2. Proposed restoration concept presents four variant solutions of a longitudinal and cross-section profiles, with respect to the slope of the riverbed and the manipulation area in close proximity to the stream (Fig. 1).

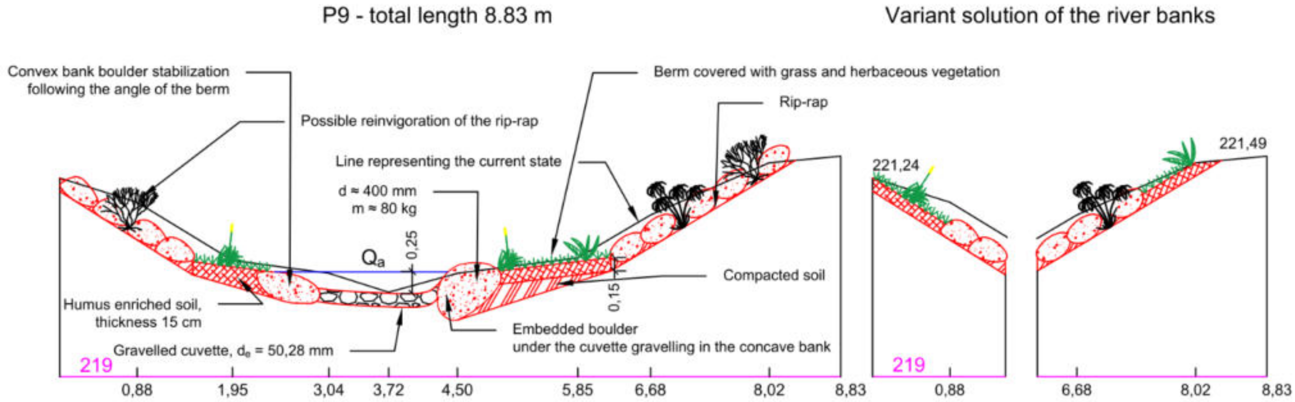

Fig. 1: *Example of cross-section profile from the urban area in Lahošť (Bouřlivec catchment)*

Regarding the rural project in the Klíšský Brook catchment the proposed measures can be divided into several stages of implementation. The first stage is the renaturation in sections (a) and (b). During this stage, it will be appropriate to carry out the monitoring of fluvial-morphological processes and the quality of surface and drainage water. The second stage is the revitalization in sections (c), (d) and (e). The third stage is the implementation of the revitalization measures in sections (g) and (f), where the stream can be returned to its original route (Fig. 2).

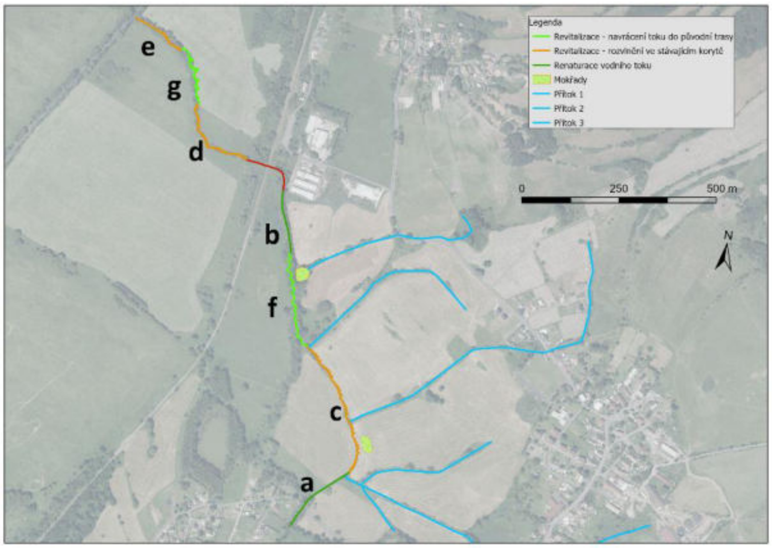

Fig. 2: *Proposal for a new channel route of the Klíšský Brook catchment*

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Dynamics of dissolved organic carbon in surface water during extreme rainfall-runoff events

Matoušková, M., Fraindová, K., Bejčková, M., Kliment, Z., Vlach, V., Vlček L.

1. Introduction

The release of a greater amount of natural organic matter (NOM) within climate change is registered in many catchments with peatbog areas. Increases in organic matter concentrations have been recorded in recent years in places such as Europe and North America (Lepistö et al. 2014; Ritson et al. 2014). Main reasons of increased levels of Dissolved organic carbon (DOC) in inland waters are connected to rising temperatures, changes of atmospheric depositions and the increased pH of surface water. Storms and snowmelt have great effect on releasing DOC into surface waters while more than 80 % of the annual DOC flux could be exported during these events (Raymond and Saiers 2010). Nevertheless, there is still a lack of understanding of the process of releasing DOC into the surface water during rainfall-runoff events. The aim of our research is to study the dynamics of releasing dissolved organic carbon (DOC) into surface water in headwater areas with peatbogs. DOC concentrations are analysed in relation to extreme rainfall-runoff (R-R) events and according to the hydroclimate preconditions of the catchment. These preconditions are described using selected hydroclimatic variables within 14 days period before the R-R event.

2. Applied methods and data sources

For the evaluation of relations and processes, the Principal Component Analysis (PCA), hysteresis loops or Pearson correlation coefficient was used. The lag time of DOCmax for Qmax, the dependence of DOCmax and groundwater levels were studied. The influence of flow rate on the decline and ascent phases of DOC concentrations by hysteresis loops and the influence of the number of partial flow maximums on the amount of transported DOC during the R-R event was analysed. Our first results show that great influence on the dynamic of DOC concentration in surface water has the change in groundwater-levels in the peatbog and the outflow amount during the R-R event. The hydroclimatic preconditions of the basin have also a significant influence on the DOC release. Changes in concentrations during R-R events also occurred for other compounds that were studied additionally. Particularly significant was the increase in metals (mainly Fe, Al, Mn) and base cation (K) and decrease in nitrate nitrogen.

Our study area is in the Vydra (Otter) River basin in the Šumava (Bohemian Forest) National Park. Our experimental catchment is the Rokytka Brook, the ROK1 site was selected for detailed analyses of DOC dynamics during different types of rainfall-runoff events according to highest representation of peat bogs and wetlands. The altitude ranges between 1100 and 1260 m a.s.l. The soil cover consists mainly of podzols and organic soils, while more than 60 % is covered by peat (Vlček et al. 2021). The source data comes from the automatic stations of the Faculty of Science, Charles University, and the Czech Hydrometeorological Institute. The differential method was performed using a Shimadzu TOC analyser (TOC-L CSH) at the Institute of Hydrodynamics of the CAS.

3. Summary of results

The greatest influence on the change in DOC concentrations in surface water have groundwater levels changes (HPV) Fig. 1 and variability of discharges (Q). The greater delay time of DOCmax for Qmax and the higher average DOC values during the episode occurred in previous conditions without a rain-runoff event. The dilution process (melting of snow cover, increased liquid precipitation totals) or thawing processes also has a significant influence on the amount and delay time of maximum DOC concentrations. The delay time also occurred in the presence of a rain-runoff event. The leaching of organic matter from individual layers of peat by increased HPV played a role here. The length of the delay time is reduced when during the previous period and during the episode the basin was saturated and groundwater levels reached high levels. During these conditions, most of the accumulated reserves of organic substances were depleted, with even the lower layers of the peat bog using HPV unable to mobilise other organic substances. In general, DOC concentrations increase with increasing runoff. However, this condition does not apply to all episodes studied. Preliminary conditions, hydroclimate conditions during the episode, the character of the basin and the number of flow waves play also important role.

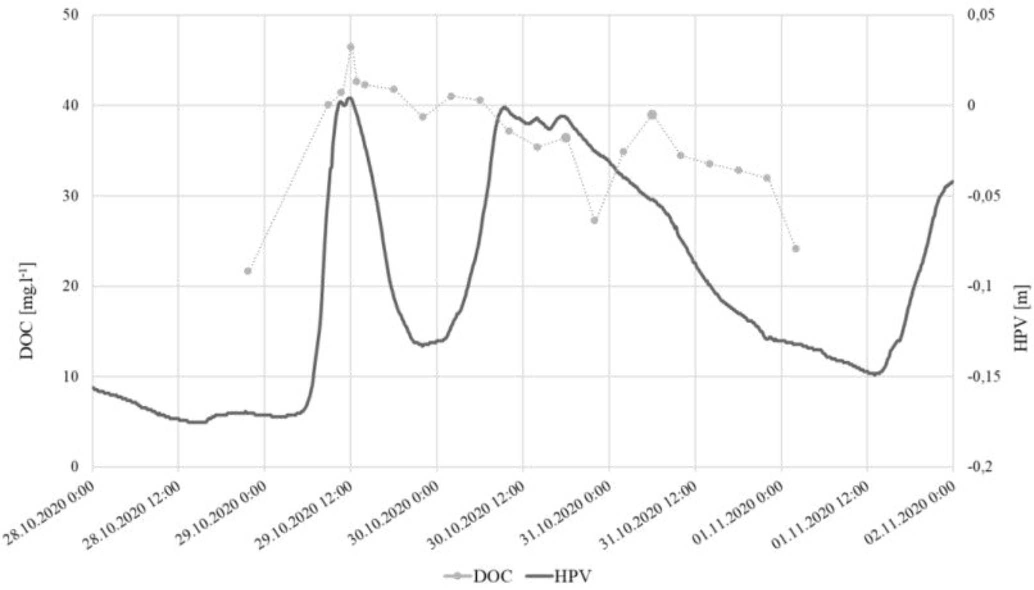

Fig. 1 *Changes of groundwater level (HPV) and concentration of DOC during rainfall-runoff event 28.10.-2. 11. 2020 in the Rokytka catchment*

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Mapping the quality and quantity of sediments in the weir reservoirs on the Czech Elbe River (project "MaSEL")

Jiří Medek, Pavel Hájek, Stanislav Král

1. Introduction

In the period 2021-2023, a study on the Mapping of quality and quantity of sediments in the weir reservoirs on the Czech Elbe River (project “MaSEL”) was prepared, which was financially supported by the Free and Hanseatic City of Hamburg within the ELSA programme (contract no. VV W1 580/21). The aim was to assess the quality of the Elbe sediments deposited in the individual weir reservoirs, which may contain old loads and pose potential risks to the quality of the Elbe ecosystem in the international Elbe River basin. The focus was on relevant pollutants from the ICPER Concept for Sediment Management [1] and in particular on organochlorine pollutants such as DDX and PCBs, elevated levels of which are occasionally found in the suspended matters of the Elbe River in the area of the Czech-German border.

2. Results

Within the framework of the project, an extensive research on the quality and quantity of sediments on the Czech Elbe was prepared. A significant achievement was the compilation of historical sediment monitoring data for the period 1999 - 2021 for the Elbe River profiles (13 profiles) and tributaries (15 profiles). From these data, tables of sediment quality indexes (SQI) were prepared according to the ICPER methodology [1]. These results, which refer to fresh sediment sampling twice a year, can be compared with the results of sediment sampled at the 32 weir reservoirs and weirs in the project to characterise the sediment quality at these sites. A longitudinal profile of sediment quality indexes was developed for the relevant ICPER pollutants (Fig. 1). Longitudinal profiles containing total "average" concentrations and maximum/minimum concentrations were further developed for these pollutants and for other relevant pollutants. Some atypical findings from the 2021 sampling campaign were verified by follow-up sampling in 2022. All data on concentrations of the analytes (about 130 parameters) are presented in rich tabular appendices. In addition to the relevant ICPER pollutants, the findings of some other pollutants (e.g. PBDE-209, toluene, para-cresol, AMPA) were interesting. For the polybrominated diphenylether PBDE-209, where high levels were found in the upper Czech Elbe, additional sediment sampling was carried out at other sites, so that a source site was located in the area of the city of Dvůr Králové nad Labem.

A separate part of the project was the experimental geophysical measurement of sediment thickness at four selected reservoirs (Smiřice, Předměřice nad Labem, Veletov, Obříství) by electrical resistivity tomography (ERT). The work was carried out by a team of authors from the Faculty of Science of Charles University and the Institute of Rock Structure and Mechanics of the Czech Academy of Sciences (Hartvich, Tábořík, Šobr, Janský et al.). The aim was to validate this method for possible use in determining the course of the current bed and the interface between aquifer sediments and free water on larger streams. Grain-size analyses were also performed in these reaches to characterize the physical properties of the river sediment.

Overall, the quality of sediments in the Czech Elbe is mostly very favourable and has improved significantly over the past 20 years. Increased findings can in some cases be explained by geogenic background (metals: Klejnárka - Starý Kolín). Nevertheless, several sites have been found which are problematic and may pose a risk to the international Elbe river basin. For DDX, these are the Obříství, Štětí and Lovosice weirs or the area between Pardubice and Týnec nad Labem. For PCBs, elevated levels were found in Lovosice, possibly in Hradec Kralove and Pardubice. There were also significant PCB detections in the Týnec nad Labem area, where the atypical congener ratio is related to a historical source in the chemical industry in Pardubice. There are elevated levels of metals, especially mercury, cadmium and lead, at a number of sites (almost in the entire section from Přelouč to Lovosice, with maximums at Velký Osek and Štětí). These are probably old historical loads, as the current situation is much more favourable when evaluating the monitoring data. Increased attention should be paid to the problematic sites or targeted removal of these contaminated sediments should be considered.

Longitudinal profile of the Elbe River — Sediment Quality Index — (according to the ICPER methodology, 2014)

Pollutant	Heřmanice	Hořenice	Jaroměř JUTA	Jaroměř I	Jaroměř II	Josefov	Smiřice	Předměřice n.L.	Hradec Králové
	2021/10		2021/10	2021/10		2021/10	2021/07	2021/07	2021/09
Hg	1,1		0,9	0,6		0,9	1,1	1,1	1,5
Cd	0,8		0,7	0,4		0,8	1,1	0,7	1,6
Pb	1,5		1,3	1,0		1,5	2,0	1,3	2,5
Zn	0,6		0,8	0,3		0,5	0,8	0,5	0,5
Cu	0,5		0,5	0,3		0,5	0,6	0,4	0,6
Ni	1,0		0,8	0,8		0,8	0,9	0,7	0,8
As	0,6		0,6	0,4		0,7	1,0	0,7	0,9
Cr	0,1		0,1	0,1		0,3	0,4	0,1	0,2
alfa-HCH	<0,7		<0,7	<0,7		<0,7	<0,7	<0,7	<0,7
beta-HCH	<0,2		<0,2	<0,2		<0,2	<0,2	<0,2	<0,2
gama-HCH	<0,7		<0,7	<0,7		<0,7	<0,7	<0,7	<0,7
p,p-DDT	<1		<1	<1		1,2	<1	1,3	<1
p,p-DDE	0,5		1,1	<0,4		0,6	0,6	0,5	<0,4
p,p-DDD	<0,9		2,5	<0,9		1,8	1,9	2,7	<0,9
PCB 28	<0,05		<0,05	<0,05		<0,05	<0,05	<0,05	<0,05
PCB 52	0,1		0,2	<0,05		0,2	<0,05	<0,05	<0,05
PCB 101	0,1		0,2	0,1		0,1	0,1	0,1	0,7
PCB 118	<0,05		0,1	<0,05		<0,05	<0,05	<0,05	0,1
PCB 138	0,1		0,3	0,1		0,3	0,2	0,1	1,5
PCB 153	0,2		0,5	0,2		0,3	0,2	0,2	2,2
PCB 180	0,2		0,4	0,2		0,3	0,2	0,1	2,3
Σ 7 PCB	0,1		0,2	0,1		0,2	0,1	0,1	1,0
pentaCB	<0,003		<0,003	<0,003		<0,003	<0,003	<0,003	<0,003
HCB	<0,06		<0,06	<0,06		0,1	<0,06	<0,06	<0,06
b(a)pyren	0,7		0,6	0,3		1,3	0,6	1,2	0,9
anthracen	0,6		0,5	0,3		0,8	0,6	1,4	0,8
fluoranthen	4,0		3,8	3,0		6,9	4,3	7,7	6,0
Σ 5 PAH	0,6		0,6	0,3		1,1	0,6	1,0	0,9

Pollutant	Opatovice n.L.	Pardubice	Srnojedy	Přelouč	Týnec n.L.	Veletov	Kolín	Klavary
	2021/09	2021/09	2021/09	2021/09	2021/10	2021/10	2021/10	2021/10
Hg	1,5	1,1	1,1	9,8	16,0	10,2	5,1	17,0
Cd	1,3	1,1	1,1	1,7	3,0	1,0	2,1	3,2
Pb	1,7	1,3	1,3	2,2	2,3	1,2	2,8	2,8
Zn	1,4	0,5	0,6	0,9	1,0	0,4	1,4	1,3
Cu	0,6	0,5	0,5	0,7	1,7	0,6	0,9	1,0
Ni	0,9	0,9	0,7	0,9	1,1	0,8	1,1	1,4
As	0,8	0,8	0,7	0,9	1,1	0,7	2,1	3,6
Cr	0,3	0,2	0,2	0,3	0,4	0,2	0,3	0,4
alfa-HCH	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7
beta-HCH	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
gama-HCH	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7
p,p-DDT	<1	7,0	<1	<1	<1	<1	<1	<1
p,p-DDE	<0,4	1,3	2,6	1,8	1,2	<0,4	<0,4	1,8
p,p-DDD	<0,9	1,8	3,0	2,3	1,5	<0,9	<0,9	1,6
PCB 28	<0,05	0,1	0,1	0,4	23,0	0,4	0,1	0,3
PCB 52	<0,05	0,4	0,3	0,8	8,5	0,2	0,4	0,7
PCB 101	<0,05	1,3	0,3	0,3	2,7	0,1	0,2	0,3
PCB 118	<0,05	0,3	0,1	0,1	1,7	<0,05	<0,05	0,1
PCB 138	0,1	3,0	0,4	0,4	1,9	0,1	0,2	0,3
PCB 153	0,1	3,4	0,6	0,5	2,6	0,1	0,2	0,5
PCB 180	0,1	3,5	0,4	0,4	1,8	0,1	0,2	0,4
Σ 7 PCB	<0,05	1,7	0,3	0,4	6,0	0,2	0,2	0,4
pentaCB	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
HCB	<0,06	<0,06	<0,06	0,1	0,1	<0,06	<0,06	0,1
b(a)pyren	0,3	0,6	1,0	0,7	0,7	<0,008	0,2	0,4
anthracen	0,3	0,2	0,8	3,1	5,1	0,1	0,3	1,1
fluoranthen	2,0	2,8	5,6	4,2	4,2	0,1	1,5	2,4
Σ 5 PAH	0,3	0,5	1,0	0,7	0,7	<0,01	0,2	0,4

Pollutant	Velký Osek	Poděbrady	Nymburk	Kostomlátky	Hradištko	Lysá n.L.	Čelákovice	Brandýs n.L.	Kostelec n.L.
	2021/10	2021/10	2021/10	2021/10	2021/10	2021/10	2021/10	2021/10	2021/10
Hg	19,8	17,9	1,3	13,2	4,0	14,5	0,4	11,1	9,6
Cd	3,8	3,2	0,5	2,5	1,0	2,4	0,3	2,8	1,8
Pb	4,1	2,0	1,0	3,3	2,7	3,1	0,3	3,1	2,3
Zn	1,6	0,9	0,6	1,4	0,8	0,9	0,1	1,3	0,9
Cu	1,1	1,3	0,3	1,0	0,6	1,1	0,2	1,1	0,9
Ni	1,0	1,1	0,8	1,1	0,8	1,3	0,6	1,2	1,1
As	2,9	1,2	0,8	2,3	2,6	1,4	0,8	2,3	1,0
Cr	0,3	0,3	0,1	0,3	0,2	0,3	0,1	0,3	0,2
alfa-HCH	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7
beta-HCH	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2
gama-HCH	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7
p,p-DDT	<1	<1	<1	<1	<1	<1	<1	<1	<1
p,p-DDE	<0,4	<0,4	<0,4	2,2	<0,4	1,2	<0,4	1,1	<0,4
p,p-DDD	<0,9	<0,9	<0,9	3,4	<0,9	1,4	<0,9	1,1	<0,9
PCB 28	<0,05	2,1	0,2	1,3	0,1	2,2	<0,05	1,0	0,9
PCB 52	<0,05	0,9	0,1	1,2	0,1	1,4	<0,05	0,4	0,6
PCB 101	<0,05	0,6	<0,05	0,7	0,1	0,6	<0,05	0,3	0,3
PCB 118	<0,05	0,2	<0,05	0,2	<0,05	0,2	<0,05	0,1	0,2
PCB 138	<0,05	0,7	<0,05	0,9	0,2	0,6	<0,05	0,3	0,4
PCB 153	<0,05	1,1	0,1	1,1	0,2	0,8	<0,05	0,4	0,6
PCB 180	<0,05	0,8	0,1	1,1	0,2	0,8	<0,05	0,3	0,5
Σ 7 PCB	<0,05	0,9	0,1	0,9	0,1	0,9	<0,05	0,4	0,5
pentaCB	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
HCB	<0,06	<0,06	<0,06	0,1	<0,06	<0,06	<0,06	<0,06	<0,06
b(a)pyren	0,02	0,1	0,1	0,6	0,1	0,5	<0,008	0,3	0,2
anthracen	0,1	1,6	0,1	1,4	0,2	1,6	0,02	0,6	0,5
fluoranthen	0,2	0,7	0,6	4,2	0,8	2,9	0,1	1,9	1,2
Σ 5 PAH	0,01	0,1	0,1	0,6	0,1	0,5	<0,01	0,3	0,2

Pollutant	Lobkovice	Obříství	Dolní Beřkovice	Štětí	Roudnice n.L.	České Kopisty	Lovosice	Střekov
	2021/10	2021/10	2021/11	2012/12	2021/12	2021/12	2021/12	2022/04
Hg	1,1	17,0	1,5	30,9	4,9	1,7	8,9	1,3
Cd	0,7	3,0	1,1	6,5	1,6	0,7	2,7	0,9
Pb	1,0	3,1	1,8	7,3	2,5	1,5	3,1	1,3
Zn	0,5	1,5	0,6	1,9	0,8	0,5	0,9	0,7
Cu	0,4	1,6	0,4	2,3	0,8	0,4	1,1	0,5
Ni	0,9	1,1	1,0	1,6	0,9	0,9	1,2	1,0
As	0,5	1,4	0,6	2,1	0,9	0,7	1,2	0,7
Cr	0,1	0,3	0,1	0,5	0,1	0,1	0,5	0,1
alfa-HCH	<0,7	1,6	<0,7	3,7	<0,7	<0,7	1,4	<0,7
beta-HCH	<0,2	<0,2	<0,2	0,4	<0,2	<0,2	<0,2	<0,2
gama-HCH	<0,7	0,8	<0,7	<0,7	<0,7	<0,7	<0,7	<0,7
p,p-DDT	<1	1,9	<1	4,7	<1	<1	14,7	<1
p,p-DDE	<0,4	1,9	<0,4	5,0	1,3	1,6	4,6	1,3
p,p-DDD	<0,9	10,0	<0,9	15,6	1,5	1,5	10,3	2,3
PCB 28	0,1	2,1	<0,05	0,1	0,3	0,2	1,3	0,3
PCB 52	0,1	1,3	<0,05	0,3	0,8	0,1	0,8	0,2
PCB 101	0,2	0,8	0,1	0,5	0,6	0,1	1,4	0,5
PCB 118	<0,05	0,4	<0,05	0,2	0,2	<0,05	0,4	0,2
PCB 138	0,3	1,0	0,1	0,9	1,0	0,1	2,8	0,9
PCB 153	0,5	1,2	0,1	1,1	1,3	0,2	3,8	1,1
PCB 180	0,5	1,0	0,1	1,1	1,2	0,1	3,7	1,0
Σ 7 PCB	0,2	1,1	0,1	0,6	0,8	0,1	2,0	0,6
pentaCB	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
HCB	<0,06	0,3	1,0	0,4	0,1	<0,06	0,3	0,1
b(a)pyren	0,04	0,3	0,1	1,0	0,5	0,4	0,8	0,1
anthracen	0,1	0,9	0,1	1,2	0,7	0,2	0,8	0,4
fluoranthen	0,7	2,1	0,4	5,6	2,7	1,6	4,5	3,7
Σ 5 PAH	0,1	0,3	0,1	0,9	0,4	0,4	0,8	0,4

SQI ≤1,0 · SQI ≤2,0 · SQI ≤4,0 · SQI ≤8,0 · SQI >8,0

Fig. 1: Longitudinal profile of the Elbe River – Sediment Quality Index – 2021-2022 (according to the ICPER methodology, 2014)

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Assessing the Impact of Debris Flow in Upper Savneti, Georgia: A Study of Triggering and Runout Mechanisms

Aida Mehrpajouh, Jens Engel

1. Introduction

Debris flow, a natural disaster that can cause devastation, is becoming a priority for authorities and researchers due to the expected increase in extreme weather events. Numerical modelling has emerged as a valuable tool in simulating the effects of debris flow and identifying areas at risk, helping authorities develop mitigation plans to protect residents and infrastructure [1]. One of the main goals of this study is to combine the experimental simulation using two models (TRIGRS and RAMMS) and monitoring of the in-situ condition of the wet season in Georgia when the landslide can lead to a debris flow in order to decrease the fatality risk and to check the warning zone.

2. Study Area and Methodology

Two study areas are located in Upper Svaneti, Georgia (43° 2'20.95"N, 42°42'4.38"E). The average annual precipitation is over 900 mm, and the maximum number of rainy days is observed from April to July with an average of 14 days. The digital elevation map (DEM) and slope are generated from 5 cm resolution drone photographs. Based on the detailed geology map, most part of the area of interest is located in Limestone, marl, sand, and slate [2]. Due to the remote mountainous area, landslide inventory is lacking. However, local news reported a debris flow in September 2021, meeting the criteria for rainfall intensity. To ensure the reliability of the results, field surveys including photogrammetry were conducted.

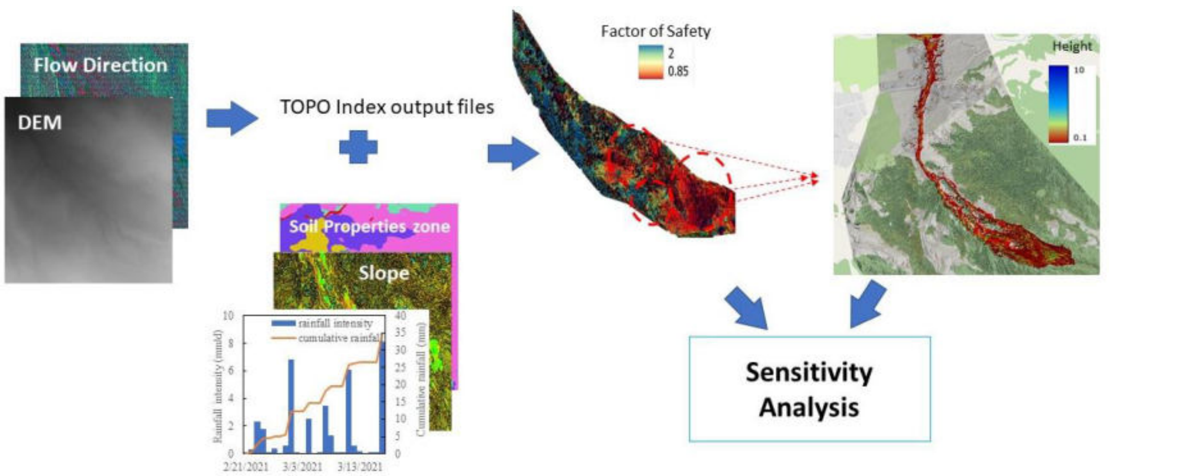

Fig. 1. Figurative summary of the research, TRIGRS and RAMMS output and sensitivity analysis

By incorporating an infiltration module in order to determine pore-pressure changes, and changes in factor of safety due to that, the TRIGRS model can simulate the timing and distribution of shallow landslides based on rainfall characteristics.

$$FS = \frac{\tan \phi'}{\tan \delta} + \frac{c' - \psi(z,t)\gamma_w \tan \phi'}{\gamma_s z \sin \delta \cos \delta}$$

It is worth mentioning that the unsaturated zone is considered in solving the Richard equation in the TRIGRS simulation [3] and the changes in pore pressure are taken into account in calculating the factor of safety. The soil properties for this purpose are measured based on boreholes downstream of the local catchment. Rapid mass movement simulation (RAMMS) was developed to capture the post-failure runout pattern using semi-empirical Voellmy-Salm rheology equation [4]. The numerical model's friction deceleration S is represented as follows[5]:

$$S = \mu\rho h g cos\theta + \frac{\rho g u^2}{\xi}$$

Calibration of the μ and ξ requires referencing documented historical events to determine optimal fitting parameters for subsequent analyses.

3. Results and discussion

To calibrate the parameters of the software used in the study, multiple simulations were conducted in order to understand their behaviour in the area of interest. The findings indicate that the thickness of the soil layer directly affects the safety factor in the TRIGRS models, with a thicker layer resulting in a lower safety factor. However, changes in the water table depth within the range of zero to 1 meter from the surface have a negligible impact on the presented topography. Decreasing the cohesion of the soil by 20% leads to a reduction in the minimum factor of safety from 0.67 to 0.45. Conversely, a lower permeability contributes to an increase in the factor of safety. These observations demonstrate that the models are more sensitive to variations in soil properties and pore pressure changes than to steady water table conditions.

In the RAMMS models, the locus of the critical factor of safety determined by TRIGRS was selected as the release block. The results also highlight the software's sensitivity to the Voellmy parameters. When μ exceeds 0.1, the material remains within the streambed, whereas reducing it to 0.02 can potentially impact downstream buildings. For a detachment of 30 cm of material from critical blocks, the material height reaching the residential area can increase by approximately 4 meters when μ is set to 0.02 and ξ to 800. However, houses near the river appear more susceptible to debris material, irrespective of their volume and viscosity.

Additionally, to validate the outcomes of the numerical models, the results were overlaid with the data obtained from two drone flights conducted between October 2021 and 2022 to assess annual deformation. The analysis reveals that most of the deformation occurred within the footprint of the previous landslide that took place in April 2021. Since no damage reports were recorded during the study year, it can be assumed that all released material followed the main channel. Consequently, the calibrated values for μ and ξ could be higher than 0.01 and lower than 800, respectively.

This study examined debris flow in Upper Savneti, Georgia, using TRIGRS and RAMMS models with in-situ monitoring. The findings emphasize model sensitivity to soil properties, pore pressure changes, and soil layer thickness. Calibrated parameters offer insights into factors of safety, material height, and downstream impacts. Drone flights validate model results, enhancing reliability. The findings highlight the significance of parameter calibration for reliable debris flow modelling.

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Ongoing projects to monitor large-scale hydrological extremes at the Elbe River

Silke Mechernich, Robert Weiß, Marcus Hatz and Jörg Uwe Belz

1. Introduction

The knowledge of the course of flooding or low water events is required for multiple stakeholders and tasks. Not least because the realization of guidelines of the European Community (flood risk management directive, Water Framework Directive) and national programs (e.g. German Strategy for Adaptation to Climate Change, National Flood Protection Programme, Bundesprogramm Blaues Band Deutschland, Gesamtkonzept Elbe,) requires court-proof data, monitoring and data-analysis for the planning and evaluation of measures of actions. In order to analyse the course of flooding or low water events, a wealth of data and comprehensive organizational preparations are required before, during and afterwards. Therefore, two ongoing projects are compiled by authorities at federal and state level on behalf of the German River Basin Community (FGG Elbe): The new digital terrain model of the water course (DGM-W) Elbe and the development of a concept for a "Hydrological Measurement Program for floods and low water events along the Elbe river".

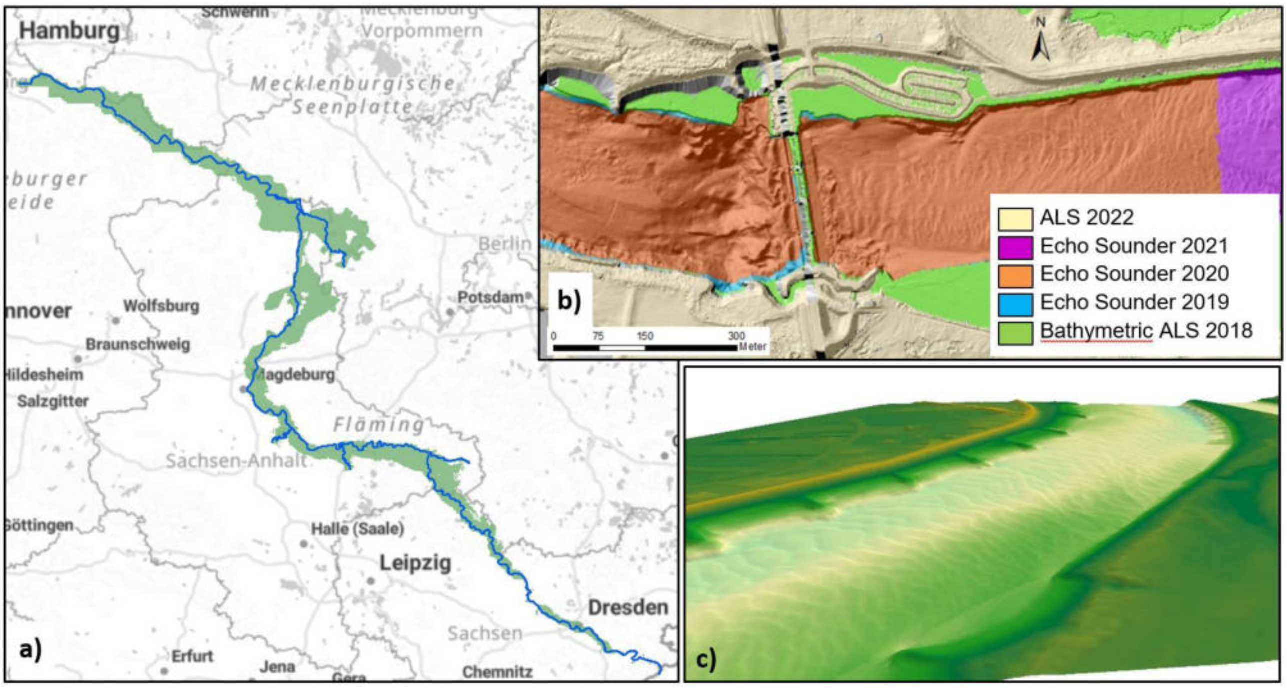

Fig. 1: *(a) Coverage area of the new DGM-W Elbe, (b) example of the data source map at Geesthacht, (c) example of the existing DGM-W Elbe near Geesthacht, with significant data interpolations in the zone of fluctuating water levels*

2. The new digital terrain model of the water course (DGM-W) Elbe

For precise planning and monitoring, it is required to use up-to-date and homogeneous geospatial data. In this context, a new digital terrain model of the Elbe waterway (DGM-W Elbe) is currently being processed. The study area covers the Elbe from the Czech border to Hamburg, plus the Lower Havel River from Rathenow downstream (**Fig. 1a**). The data for the DGM-W mainly derives from Airborne Laserscanning (ALS) flights in winter 2021/2022, as well as recent echo soundings (2021) and bathymetric ALS data of the low water survey in 2018 (**Fig. 1b**). The project will be completed end of 2024, with the core products being the DGM-W (**Fig. 1c**), classified laser point cloud and a digital surface model (DOM).

3. Ongoing work for a Measurement Program for hydrological extreme events along the Elbe river

The objective of the “Hydrological Measurement Program for floods and low water events along the Elbe river" (MEE) is to reconcile an exact chain of actions in the event of an incident. Currently, the concerted actions for the three topics 1) discharge measurements, 2) longitudinal water level measurements and 3) situation maps and water-land-boundary detection are prepared for the river sections shown in **figure 2a**. For each topic, the requirements need to be reconciled. This covers especially:

- warning and triggering levels,
- responsibilities for measuring data and processing products,
- a clear technical description of the required measurements and products (e.g. for tender actions),
- possibilities for financing.

The focus of this presentation is the preparation of maps and water-land boundaries, which should be obtained by image flights during the flooding peak and the lowest water level, respectively. Additionally, in the case of flood events, satellite data analysis by the Copernicus Emergency Mapping Service (CEMS) are planned to be used. A detailed plan about the required actions of all institutions is in progress and will be presented on the poster. The main planned product for the water-land-boundary detection is shown in **figure 2d**.

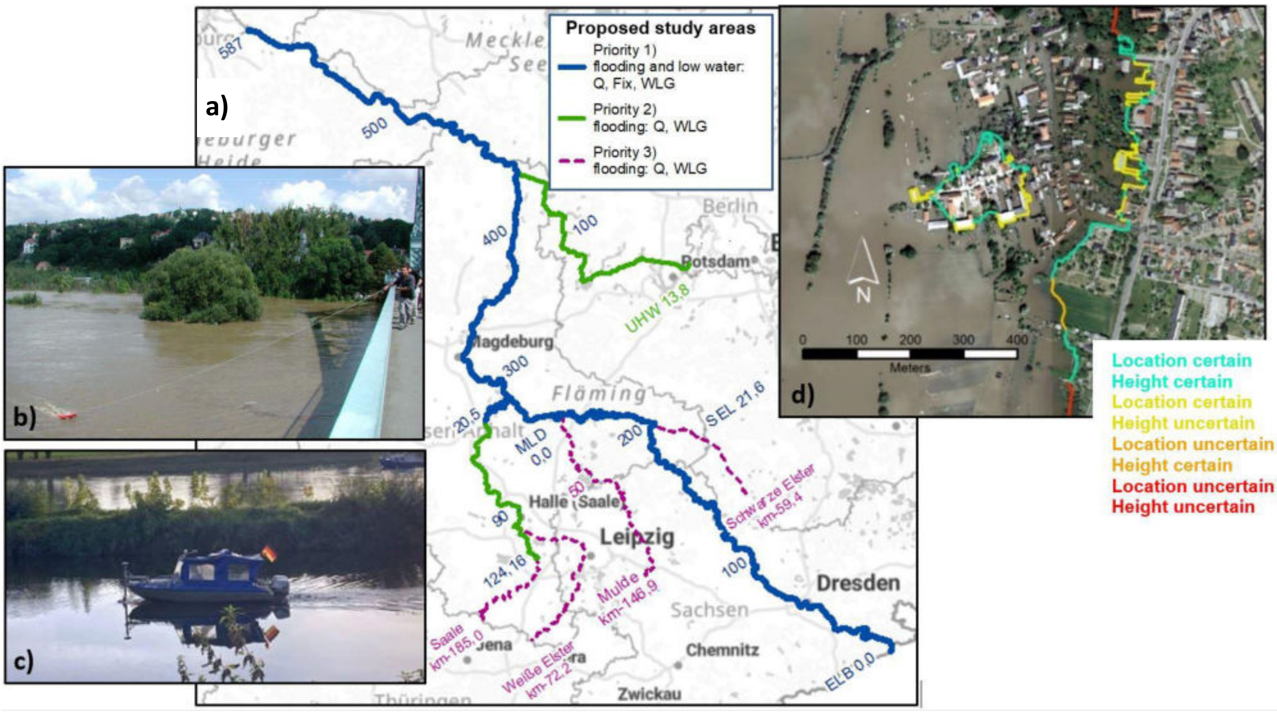

Fig. 2: *(a) Proposed study area of the planned measurement program (MEE), (b) acoustic doppler current profiler (ADCP) measurement for discharge determination, (c) longitudinal water level measurements (©Ingenieurbüro Schmid p.p. BfG), (d) example for attributed water land boundaries and DOPs of the Elbe 2013 crevasse Fischbeck ©BfG*

4. Conclusions and Outlook

Then the collaborative DGM-W Elbe will be published end of 2024, it can be used for future analysis and plannings, particularly for cross-state studies which require concerted and homogeneous databases.

For the hydrological measurement program MEE, the FGG-Elbe will decide future actions based on the scientific and organisational concept. If evaluated positively, tender documents will be finalized for the essential talks that cannot be undertaken by existing staff. Altogether, this measurement program will ensure to be prepared to start the required measurements as soon as possible in the case of an extreme event.

5. Acknowledgements

We thank the project groups of the DGM-W Elbe and the Measurement Program MEE for their continuous and constructive work.

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Microbial contamination of the Vltava River below Prague

Hana Zvěřinová Mlejnková, Adam Šmída

Introduction

Surface waters are naturally inhabited by autochthonous microorganisms, which help with the self-cleaning processes. As a microbial contamination we consider the presence of microorganisms with hygienic impact (pathogenic bacteria, viruses; antibiotic resistant bacteria, and others) which are introduced into the water artificially. Their indicators are commonly determined in waters as they warn us about the faecal and organic pollution. The importance of faecal indicators monitoring in surface waters resides in the ability to maintain the state of surface waters in a condition that doesn't represent a health risk and a possibility of its dissemination.

The most significant source of microbial contamination of surface waters are municipal wastewaters (WW). The main contributions to the recipient waters are purified WW from wastewater treatment plants (WWTP).To a lesser extent, free outlets or rainwater alleviators of untreated wastewater contribute.

The aim of our study was to characterize the microbial contamination of the longitudinal profile of the Vltava below Prague. We determined the rate of increased health risk and the extend of the water's usability burdened by the faecal contamination caused by the discharge of Central Wastewater Treatment Plant (CWWTP). Our obtained measurements were then compared to the historical data to evaluate any possible trends in the development of water quality.

Methods

An approximate length of 10 km of the Vltava River (from Vltava-Trója to Vltava-Řež) was monitored monthly from April 2022 till March 2023. The locations of the sampling site capture the influence of the discharge of the CWWTP (1.2 million people connected) and the discharges of smaller WWTP on the tributaries (26.8 thousands of people connected).

The water samples were analysed by standard cultivation methods for presence of *E. coli*, intestinal enterococci, thermotolerant (faecal) and coliform bacteria [1], [2]. The results were classified into quality categories according to ČSN 75 7221 [3] and compared with EQS limits (environmental quality standards) for surface waters according to Government Regulation No. 401/2015 Coll. [4]. The results were also compared with limits for bathing waters according to Decree No. 238/2011 Coll. [5]. The obtained results are presented in Fig. 1.

Results and conclusions

The evaluation according to [3] shows the best microbial quality at the control site profile Vltava-Trója which was classified as slightly polluted water (II. quality class). However, the discharge of the treated wastewater from CWWTP shifted the class of the profile Vltava-Podbaba to very heavily polluted water (V. quality class).

EQS [4] limits were exceeded for almost all of the faecal indicators at 60 – 80 % of the profiles. The Vltava-Trója profile shows surprisingly good quality water according to EQS despite its intake of pollution from many sources during its flow through Prague.

There was a significant increase in the number of microbial indicators under the outfall of the treated WW on the two water lines of the CWWTP Praha, despite the high cleaning efficiency, which corresponds to the requirements for the best available technologies and the active introduction of other improvements (disinfection by UV radiation).

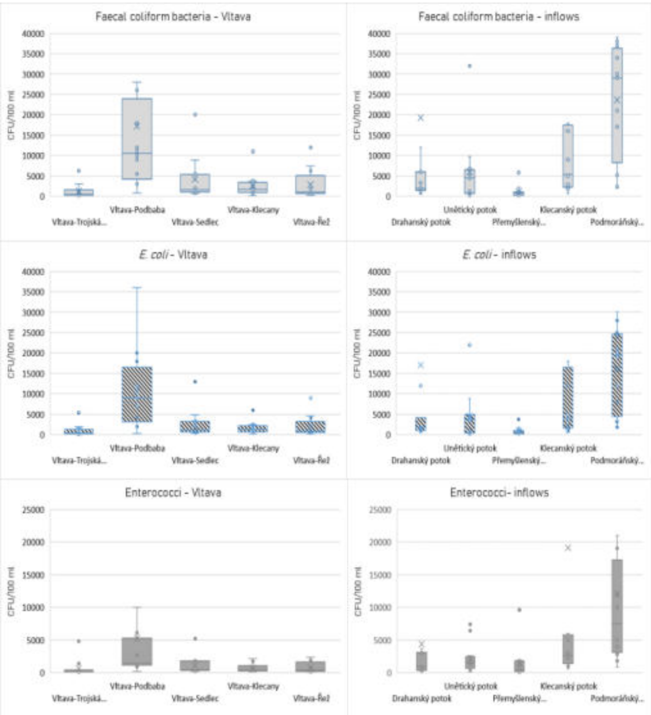
However, the heavily affected section is relatively short and thanks to the intensive dilution and self-cleaning abilities of the river, there are already an order of magnitude fewer microbial indicators in Vltava-Sedlec (III. quality class), approx. 2 km below the CWWTP discharge. The next profile Vltava-Klecany already meets the limits of EQS.

Surprising differences were found in the microbial water quality of the tributaries. Critical pollution was found in the Klecanský and the Podmoráňský brook. However, due to the relatively low flow rates of the polluted tributaries, the impact on the Vltava below their inflow is not significant.

According to the indicative assessment according to [5], the quality of the Vltava was not acceptable for bathing in any of the sampling profiles during the period under our observation. However, on the Vltava-Trója profile, a condition corresponding to the limits for 'acceptable' quality was found during the period suitable for recreation, i.e. from May to September. Also on the Vltava-Řež profile, approximately 10 km away from the CWWTP discharge, 70 % of the indicator values show acceptable quality during the period suitable for recreation. In addition, some of the sampling was carried out after heavy rainfall, which adversely affected the water quality.

An update of historical data describing microbial contamination of water in the Vltava River below Prague between 1930 and 1996 showed a favourable trend, which is the result of improving wastewater treatment technologies.

Fig. 1: Microbial water quality of monitored sites of the Vltava and its inflows



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Harmonized LC-HRMS non-target screening in monitoring practice of the international monitoring stations on the Rhine

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1. Introduction

Emerging micropollutants (MPs) enter surface waters via point or diffuse sources. The sheer number of MPs pose a challenge for monitoring performed by target analysis limited to a small list of substances. In contrast, Non-Target Screening (NTS) extends the number of detectable compounds (known and unknown) via 1) Screening – database assisted search for detection of known MPs and 2) Identification – detection, prioritization and identification of unknowns. For effective use, exchange and comparability of NTS data across monitoring stations is essential. This is addressed in the Rhine Project NTS by the development of a harmonized analysis, processing and storage solution for NTS data from the River Rhine. The developed NTS Tool will provide:

a. Centralized processing and shared database for extensive screening of > 1450 MPs
b. Data aggregation along the river course supporting rapid identification of MPs' sources
c. Assistance in the identification of unknowns by supporting knowledge exchange

The concept includes a harmonized LC-HRMS method and a server hosting the NTS processing and data aggregation software (enviMass). Starting January 2023, stations perform harmonized measurements with centralized data processing.

2. Detection of a new micropollutant

An unknown MP was detected in water at the international monitoring station Basel-Weil am Rhein. The compound was identified as 2-ethoxyethyl (2Z)-2-cyano-2-[3-(3-methoxypropylamino)cyclohex-2-en-1-ylidene]acetate also referred to as DTXSID901019869 [1]. Subsequently, the MP was traced along the River Rhine by the NTS Tool means of the harmonized LC-HRMS method. Its occurrence was used for testing the NTS Tool and its ability to a) detect the micropollutant at each station and b) track the industrial emission across the River Rhine.

3. Identification and tracing the emission

Identification of DTXSID901019869 at the station Basel-Weil am Rhein allowed for rapid verification of its presence at other stations. For this, LC-HRMS data was compared in terms of precursor adduct ions (MS1), fragment ions (MS2) and retention times (RTs). For emission tracing, so called emission profiles, time-intensity variations of the MS1 precursor mass ($[M-H]^-$), are used. The recorded profiles of the DTXSID901019869 per station are displayed in Fig. 1.

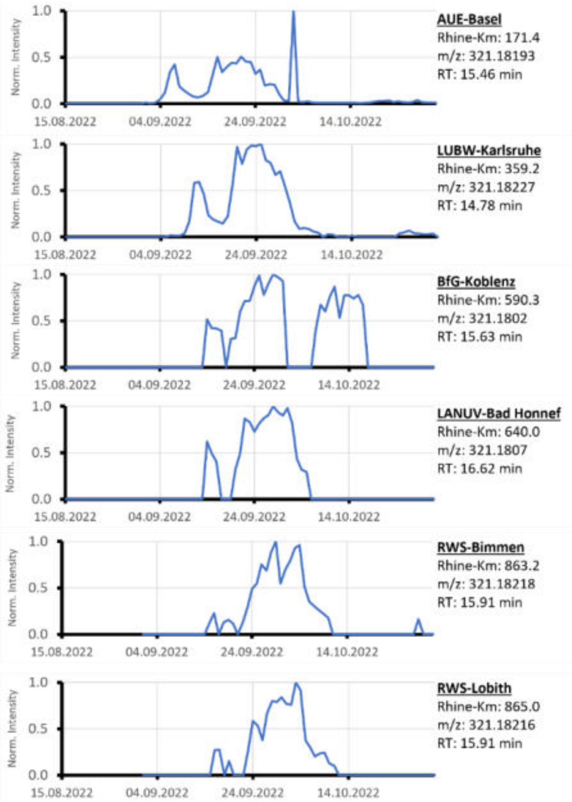

Fig. 1: *The profiles for DTXSID901019869 for specified measuring stations.*

4. Conclusions

The comparison of the LC-HRMS data, in terms of precursor adduct ions, fragment ions and harmonized RTs demonstrated the ability of the NTS Tool to detect the MP at each station. Recorded time-intensity variations of the chosen precursor mass confirmed the ability to track the emission over several months. The substance DTXSID901019869 was added to the joint screening database and a re-occurrence of this pollutant will be automatically detected and tracked across involved stations. As a result, the NTS Tool has a tremendous potential for warning of emissions and thus to provide a key information for water supply and to prevent ecological damage.

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The potential of fishponds for retention and subsequent recycling of nutrients – a case study of the Rožmberk fishpond

Jan Potužák, Jindřich Duras, Michal Marcel, Aneta Mondeková

Orlik reservoir is the largest body of water by volume in the Czech Republic and a step in the cascade of man-made impoundments on the Vltava River [1]. Its dam was built in the early 1960s. Overall quantity of the water in Orlík reservoir gradually deteriorated during the 1980s and water blooms occasionally occurred in the transition zones of both the Vltava and Otava inflows [2]. This significantly reduces the recreational use of this reservoir. Nutrient balance study estimated the annual phosphorus emissions in its catchment area at 397 tonnes. Then 304 tonnes of phosphorus enter in reservoir each year, with an average total phosphorus (TP) concentration of 0.12 mg l^{-1}. Thus, 93 tonnes of phosphorus per year (23 %) are retained in the catchment area [3]. The greatest retention rates can be expected in areas rich in large fishponds. Fishponds generally have a high natural potential to retain phosphorus. The natural retention rate is mainly dependent on the length of water retention in the fishpond [4]. Even a fishpond with a relatively low water retention can retain 20 - 30 % of phosphorus. Many factors influence the reduction of natural retention for phosphorus, such as the phosphorus load in sediments, the overloading with untreated or poorly treated municipal wastewater, or unbalanced fishery management. On the other hand, a heavy loaded fishponds release phosphorus instead of retaining it. Advancing climate change highlights this process.

The highest nutrient loading to the Orlik water reservoir comes from the Lužnice River (129 tonnes per year) [3]. The high concentration of large fishponds occurred in the Lužnice catchment area. Long-term monitoring of the water quality of the Lužnice River shows, that the water quality significantly negatively affects the Rožmberk fishpond (the largest fishpond in the Czech Republic, water area 4,89 km^2) [5]. This fishpond recently releases from 1.8 to 7.0 t of TP per year fish production cycle and therefor represents an important source of phosphorus for a catchment area. This negative effect on downstream situated water bodies become more apparent when compared with modelled retention efficiency assuming retention capacity of 11 - 12 t of inflowing TP. The Rožmberk pond thus represents the largest emission source of phosphorus in the reservoir Orlík catchment area (almost 3% of total phosphorus emissions).

Several balance studies of fishpond Rožmberk present that the high risk is the old phosphorus load in sediments and current emissions from untreated wastewater from the town of Třeboň. The phosphorus input from the fishery management is currently negligible [5].

It is necessary to switch Rožmberk from the state of releases phosphorus to a state of retains phosphorus. This would be an important step for reduction of eutrophication in the water reservoir Orlík catchment area. At the same time, the supply of phosphorus as well as nitrogen and organic matter in the sediment is potentially valuable for agricultural use. Currently, mostly unacceptable agricultural management combine with characteristic of field structure highly increase erosion of agricultural land. The main result is high loss of soil particles rich in nutrients and decrease of organic matter as well as general soil fertility [6, 7]. Simultaneously, rock phosphate shortages will be exhausted in the future [8, 9]. It is therefore important to focus on possibilities of phosphorus recycling.

In September 2021, Povodí Vltavy, state enterprise in cooperation with Rybářství Třeboň, a.s. investigated the quantity and quality of Rožmberk sediments. It was found that the pond currently retained 670,000 m^3 of sediment, which contains 264 t of phosphorus! The amount of bounded phosphorus in fishpond sediment is not only a significant threat to the Orlik reservoir, but also an opportunity for reuse, i.e., the recycling of nutrients in agriculture landscape.

Rybářství Třeboň, a.s. in recent years carries out a local sediment remove using suction dredger before Rožmberk harvesting. Sediment is pumped to the lagoons, where it is drained and then offered to local farmers for application to agricultural land. The amount of sediment removed has gradually increased up to 3,600 m^3. An estimated 1.2 t of total phosphorus (TP) was removed from the fishpond and applied on farmland in 2022. The recycling of phosphorus with pond mud onto farmland needs to be encouraged and further developed.

Fishponds have considerable potential for phosphorus retention, and they are important transformation elements which could play an important positive and/or negative role in transport processes in catchment areas. We see good opportunity to control eutrophication using fishponds in the system of phosphorus recycling in small catchments. This concept could bring better quality of surface waters, decrease of water reservoirs infilling and also elimination of nutrients and soil particles loss from agricultural landscapes. Nutrient recycling belongs to fishponds important ecological functions and is necessary for effective landscape management.

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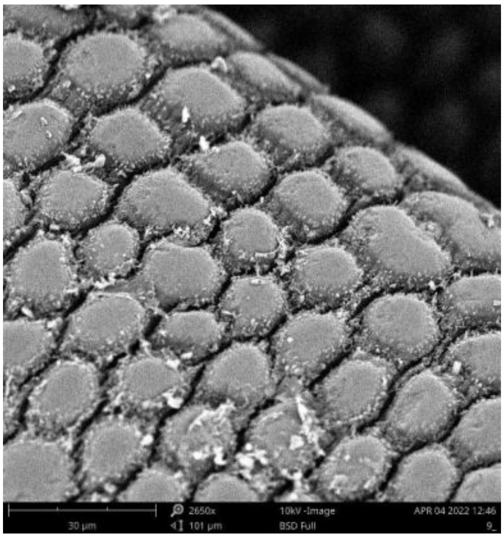
Scanning electron microscopy (SEM) with elemental analysis (EDX) - practical aplications in the water laboratory.

Václav Koza, Jan Špaček

Scanning electron microscopy has been used in the water laboratory of the Povodi Labe, state enterprise since 2015. So far, the main focus of its use has been the refinement of the identification of organisms. In particular, it concerns some groups of algae in connection with the management of water reservoirs. Many species of the groups of centric diatoms (Bacillariophycae, Centrales) (fig. 3, 4) and golden algae (Chysophycae) cannot be reliably identified at the species level in an optical microscopy. As they are often dominant species or species with important bioindicator properties that significantly influence the assessment of ecological status, the use of SEM is necessary. Furthermore, SEM is used to identify some other groups of water invertebrates that have structures with identification features that are beyond the resolution of an optical microscopy, such as Copepoda, Hydrachnellae, and Nematomorpha (fig. 1, 2).

The device was also used for external orders. E.g. monitoring of zeolite filter structures. When collaborating on research projects with some universities. With the Faculty of Science of the University Hradec Králové during the research of ants (Formicidae), or the Faculty of Pharmacy of Charles University in monitoring the structure of particles of so-called drug carriers.

New from the beginning of 2023 is the module for element analysis (EDX). The results of this analysis (fig. 5) are used to pre-identify the composition of unknown solid suspended objects in water samples or directly in sediments. The aim of these preliminary analyses is to optimize the range of subsequent chemical determinations, for example in water pollution accidents. This module is currently tested on both real samples and defined samples and data validation is underway by comparison with sample analyses on ICP – MS.



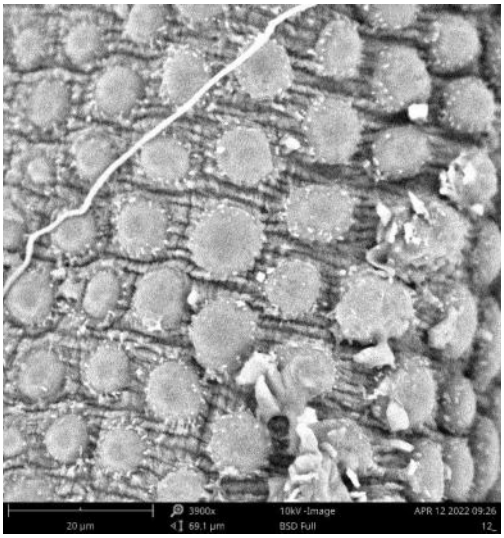


Fig. 1,2: *Cuticular structure differences (Gordionus violaceus fig.1; Paragordionus bohemicus fig.2).*

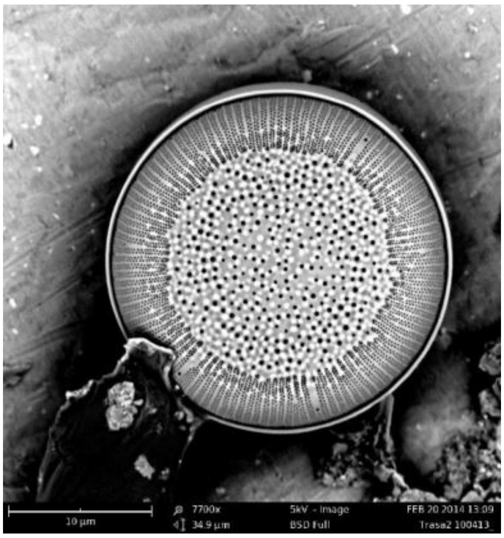


***Fig. 3:** Cyclotella balatonis (Bacillariophycae)*

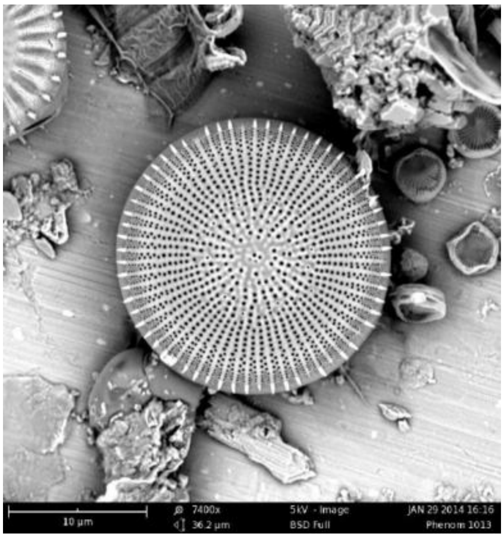
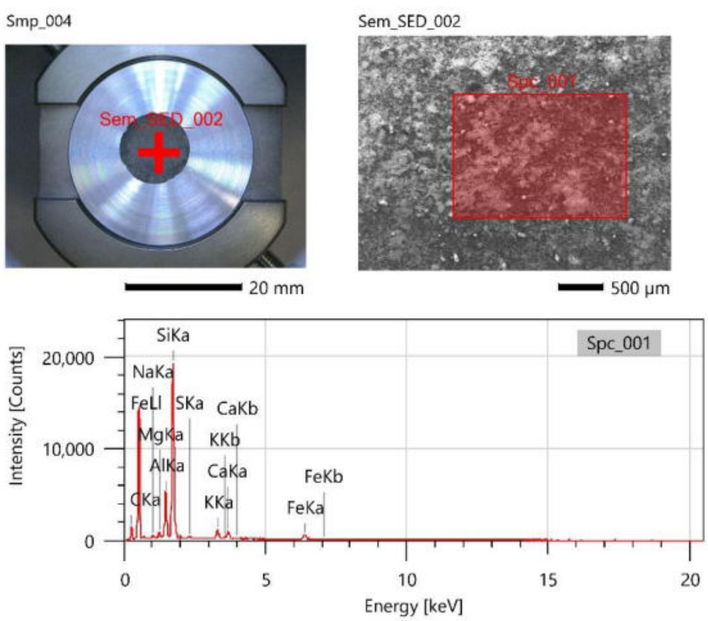


***Fig. 4:** Stephanodiscus hantzschii (Bacillariophycae)*



Signal SED
Landing Voltage 15.0 kV
WD 12.4 mm
Magnification x37
Probe Current Mode High-PC
Vacuum Mode HighVac.

Items	Value
measurement conditions	
Acceleration voltage	15.00 kV
Probe current	-
Magnification	x 37
Process time	T1
Measurement detector	First
Live time	30.00 seconds
Real time	31.54 seconds
Dead time	4.00 %
Count rate	16084.00 CPS

Display name	Standard data	Quantification method	Result Type
Spc_001	Standardless	ZAF	Metal

Element	Line	Mass%	Atom%
C	K	35.02±0.57	57.99±0.95
Na	K	0.64±0.05	0.55±0.04
Mg	K	1.03±0.05	0.84±0.04
Al	K	8.90±0.15	6.56±0.11
Si	K	37.87±0.32	26.81±0.23
P	K	0.39±0.04	0.25±0.03
S	K	0.64±0.05	0.40±0.03
K	K	3.76±0.13	1.91±0.07
Ca	K	3.53±0.13	1.75±0.07
Fe	K	8.21±0.33	2.92±0.12
Total		100.00	100.00
Spc_001			Fitting ratio 0.4420

***Fig.5:** EDX record of sample results*

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Trace metal adsorption on tyre and road wear particles in surface waters – A problem to water quality?

Angus Rocha Vogel, Wolf von Tümpling

1. Introduction

Germany-wide between 80,000 and 100,000 t a^{-1} of tyre wear particles (TWP) are emitted into the environment [1,2]. This amount is likely to increase since there are more cars being permitted. Even the politically motivated electrification of cars will lead to an increase in TWP emissions, due to the fact that electric cars are on average ca. 20% heavier than cars with combustion engines until today [3].

According to simulations by Baensch-Baltruschat *et al.*, up to 20,000 t a^{-1} of TWP are emitted into the aquatic environment in Germany [1]. Investigations regarding tyre particles in water systems mostly focus on the ecotoxicological effects of the particles itself or their potential leachates [4,5]. Additionally, water pollutants may adsorb on the particle surface, adding another risk. Microplastics in general are capable of adsorbing trace elements like heavy metals. Those could become bioavailable by ingesting by organisms and freed uo inside their bodies. Fan *et al.* already proved the adsorption of Cd^{2+} and Pb^{2+} using artificial heavy metal solutions [6].

The aim of this work was to conduct close-to-nature experiments with “real” tyre wear material and water samples of a natural river, to estimate the endangering potential.

2. Materials and Methods

We used tyre wear particles that were collected behind a car wheel. This material, so called *tyre and road wear particles including road sediment* (TRWP+RS, ≤ 125 µm), contains tyre wear particles encrusted with road wear and road related particles as well as other fine particles on the road. Water samples were taken from the Freiberger Mulde, Rothenfurth, Middelsaxony, as an example of a river containing a high amount of trace elements and heavy metals.

The water samples were filtered to 0.2 µm. To 600 mL of filtered water samples, 10 mg TRWP+RS were added to obtain a concentration of 16.7 mg L^{-1}. This lays in between 0.03–17.9 mg L^{-1} that Wik and Dave expect for TWP in water systems [7]. Measurements were conducted at 6 h, 24 h and 96 h, because previous investigations showed that the highest adsorption was reached within 6 h and the equilibrium within 24 h.

After the experiments, the TRWP+RS were separated from the solution by filtration (0.2 µm), dried in a desiccator and digested in a microwave with reverse aqua regia ($V(HNO_3):V(HCl) = 3:1$). The content of trace elements was determined by ICP-MS/MS and afterwards evaluated by using the classification system of the LAWA (Bund/Länderarbeitsgemeinschaft Wasser) [8].

3. Results and Discussion

The characterization of TRWP+RS by ICP-MS/MS revealed a content of “pure” tyre wear of approx. 12%. The estimation was done comparing the zinc content of TRWP+RS with the zinc content of a reference of 10 tyres from different manufacturers taking into consideration that 78% of the zinc emissions in traffic are related to tyres [9].

Assuming that after rainfalls the tyre particles remain as suspended matter in river systems one can apply the classification system of LAWA for evaluation the potential risk of TRWP+RS and/or TRWP+RS with adsorbed trace elements on the water quality. The results are given in tab. 1.

Clearly the “pure” TRWP+RS would only be an endangering for Cu and Zn, comparing with the suspended matter of the river Elbe, one could argue the TRWP+RS to not be endangering at all regarding the water quality.

Tab. 1 Theoretical classification of priority trace elements (Cr, Ni, Cu, Zn, Cd, Pb) and As* by the LAWA (*ARGE ELBE) system for suspended matter [8] for "pure" TRWP+RS and TRWP+RS after 24 h adsorption experiment. Comparison with the classification of suspended matter in the river Elbe [10].

element	Cr	Ni	Cu	Zn	As*	Cd	Pb
"**pure**" TRWP+RS	I	II	III	III-IV	I-II	I-II	I-II
suspended matter in Elbe	*II-III*	*II*	*II-III*	*III-IV*	*II-III*	*III-IV*	*II-III*
adsorption experiment 16,7 mg L^{-1} TRWP+RS	III	III	III	IV	II-III	IV	I-II
rel. enrichment/ depletion	+440%	+270%	–13%	+96%	+161%	+4,100%	+150%

water quality class	I	I-II	II	II-III	III	III-IV	IV

After the adsorption experiment a different picture is drawn. A significant adsorption of the investigated elements (except for Cu) on the TRWP+RS was observed. Therefore, at a TRPW+RS concentration of 16.7 mg L^{-1} an increase of the trace element content by the factors of 2–5 was proven, even up to 40 for Cd. This would lead to a deterioration of the chemical water quality of the suspended mater referring to Cr, Ni, Zn, As and especially Cd.

4. Summary and Outlook

The given tyre and road wear particles including road sediments (TRWP+RS) have an estimated 12% of "pure" tyre wear. Compared to the suspended matter in the river Elbe, TRWP+RS would not deteriorate the chemical water quality of the suspended matter regarding the priority trace elements Cr, Ni, Cu, Zn, As, Cd and Pb. On the other hand, a significant adsorption of Cr, Ni, Zn, As, Cd and Pb was determined after the adsorption experiment of TRWP+RS in a freshwater sample of the river Freiberger Mulde. These adsorptions could lead to a deterioration of the chemical water quality. Meaning, the endangering potential does not derive from the particles themselves but from the adsorption of trace elements.

This work only focused on the direct interaction between the particle surface of TRWP+RS and the dissolved trace elements of the freshwater samples. Further investigations try to consider the effect of different biogeochemical processes on the observed adsorption of trace elements on tyre wear materials.

5. Acknowledgements

The presented investigations were done in cooperation with the working group of Dr. Patrick Bräutigam at the Friedrich-Schiller-University Jena (Institute for Technical and Environmental Chemistry).

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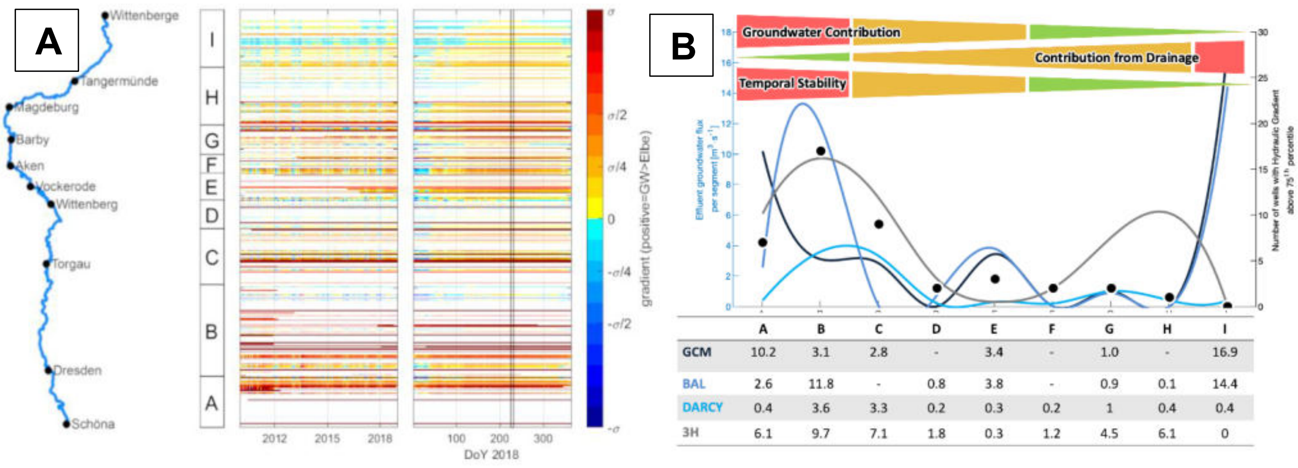
Diffuse nutrient input to large rivers: Quantifying the dimension of groundwater discharge and its effects on riverine eutrophication in the Elbe

Julia Zill, Christian Siebert, Markus Weitere, Ulf Mallast

1. Quantifying groundwater discharge spatiotemporally

Diffuse nutrient inputs and the associated eutrophication represent a serious and as yet often unresolved water quality problem in surface water bodies. Basin-wide strategies to reduce eutrophication requires the consideration of all important nutrient sources. However, the contribution to the nutrient budget or eutrophication in general through diffuse sources, particularly via groundwater discharge, has hardly been analysed for large river systems such as the Elbe River. Therefore, this project addresses the spatial, temporal and volumetric determination and dynamics of groundwater discharge and the systematic analysis of its impact on benthic and planktonic eutrophication.
The study is performed along a 450 km course of the German Elbe River through five complementary methods: i) analysis of daily time series of hydraulic gradients, ii) flux balance for river segments, iii) inverse geochemical modelling of water compositions, iv) a Darcy approach based on the hydraulic conductivity and v) a model of the tritium dilution effect. We were able to identify locations and the temporal dynamics of surface water-groundwater interactions (Fig 1 A). An unexpected but significant contribution to the nutrient load of the Elbe River represent cropland drainage in the lowlands, particularly during low water flow, which might become more frequent in future summers (Fig 1 B). In general, all methods indicate a higher likelihood of groundwater discharge in the upstream parts of the river, which decrease in the middle and lower regions.



	A	B	C	D	E	F	G	H	I
GCM	10.2	3.1	2.8	-	3.4	-	1.0	-	16.9
BAL	2.6	11.8	-	0.8	3.8	-	0.9	0.1	14.4
DARCY	0.4	3.6	3.3	0.2	0.3	0.2	1	0.4	0.4
3H	6.1	9.7	7.1	1.8	0.3	1.2	4.5	6.1	0

Fig. 3: A) *left panel: shows investigated reach of the Elbe River with gauging stations. The reach was divided into different sub-reaches A-I; central panel: normalised hydraulic gradients for long-time period (01. Jan 2010 - 31. Dec 2018) and for the year 2018 (DoY=days of the year), including indication of field campaigns (two black vertical lines).* ***B)*** *Combined results of qualitative and quantitative approaches and its interpretation regarding groundwater contributions, temporal stability and the deduced contribution from field drainages based on a) BAL/GCM/3H and b) DARCY/the number of wells with hydraulic gradients above the 75th percentile. Note that the left blue ordinate axis refers to all line elements while the right black ordinate axis refers to point elements in the figure.*

The colour of the bands in Fig. 1 A central panel indicate either effluent (reddish) or influent (blueish) conditions, where sigma represents the variance of all gradients. Almost everywhere along the river gradients substantially are varying and direction of exchange for many sub-reaches even reverse seasonally. While many areas are characterised by groundwater inflow between early summer and autumn, the typical high-flow regime during winter and springtime leads to the reverse of the gradients and influent conditions.

2. Groundwater affected eutrophication

Groundwater discharge affects the availability of nutrients for benthic (autotrophic biofilms) and pelagic (phytoplankton) algae and the relationship among both communities [1, 2]. Nutrient transport from the groundwater can stimulate the local benthic as they have direct access to the nutrient. However, once it reached the water column, it can also enhance the total algae biomass in the lower parts of the Elbe River, as it can be limited particularly by the availability of phosphorus (P). Here we test the effect of groundwater on benthic algae in field experiments and model the effect of the groundwater-borne P on the surplus of planktonic algae in the lower parts of the Elbe.

Biofilms were seasonal recorded on exposed substratum in the river along a gradient of groundwater discharge and in hydrogeological areas varying in their hydraulic connection. First analyses of the ash-free dry mass as an overall quantitative biofilm parameter, shows distinct differences in seasonality, hydrogeology and groundwater impact. However, the latter is not uniform, and includes both positive and negative effects of groundwater discharge on biofilm biomass. Further analyses of biofilm quantity (including total chlorophyll concentrations as proxy for algae biomass) are in progress. As qualitative parameters, the limiting nutrient P and the carbon/nutrient ratio (C:N, C:P) indicate a strong site effect, with distinct local groundwater impacts, which were, however, not consistent along each sites and seasons.

Effects on planktonic eutrophication (algae biomass) in summer were calculated based on the estimated input of the groundwater-born limiting resource P and the C:P stoichiometry of planktonic algae as measured in the Elbe River [3]. It is based on the finding, that under summer low waters conditions, dissolved soluble reactive P is entirely converted into algae biomass and falls below detection level. The discharged groundwater volume under low flow conditions was taken from the inverse geochemical modelling described in section one. Under the actual assumptions and by assuming a molecular C:P ratio of 90 for algae in the lower Elbe [3], our preliminary calculation showed that the diffuse P input from discharging groundwater leads to a serious increase in the eutrophication potential, contributing up to 0.99 t/d PO_4 over the entire 450 km stretch of the Elbe under low flow conditions in summer 2018. This results in an additional planktonic load of approximately 31 t carbon-related algae biomass per day.

Thus, our study shows that groundwater not only contributes to the nutrient load of the Elbe River, but also enhances the overall eutrophication within the plankton significantly. Furthermore, it seems to alter the benthic eutrophication, however, in a non-consistent way over location and season.

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POLDI Kladno – remediation of part of the Kladno Industrial Zone East

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RNDr. Zuzana Keprtová

Location of site, natural conditions

The Poldi Kladno industrial site is one of the largest old environmental burdens in the Czech Republic, resulting from the historical mining, metallurgical and steel industries. The site was filled with industrial and construction waste from coke plants and ironworks during and after its operation. The first comprehensive survey of the extent and degree of pollution after the former Spojené ocelárny Kladno n.p. (SONP Kladno, currently the Kladno Industrial Zone East) was implemented as part of the extensive project documentation entitled 'Analysis of the Risks of an Old Environmental Burden', commissioned in 2010 by Kladno and subsequently processed by the hydrogeological company Vodní zdroje a.s., Prague, 2013. According to the valid methodological instructions of the Ministry of the Environment, this document established the limits for eliminating health and environmental risks for selected pollutants, and the epicentres of pollution resulting from these risks were identified.

The Kladno Industrial Zone East covers an area of approximately 2.4 km^2. It is located on the north-eastern edge of the city at an altitude of about 340 m above sea level in the cadastral community Dubí u Kladna in hydrological basin no. 1-12-02-0310-0-00 and in hydrogeological zone no. 5140 – Kladno basin. Most of the area is drained by Dřetovický potok (Dřetovice Stream), and the remaining northern part of the site is part of the Týnecký potok (Týnec Stream) basin. Both small watercourses flow into Zákolanský potok (Zákolany Stream), after which they empty into the Vltava. All these watercourses are managed by Povodí Vltava, státní podnik.

Old environmental burden - survey and remediation

On the premises of the former SNOP Kladno s.p., partial remedial measures to reduce environmental risks and the impact of contamination are currently being addressed, and an extensive hydrogeological survey is underway, the results of which will be evaluated in an updated risk analysis. Some rehabilitation projects and remedial measures are co-financed by the European Union within the Operational Programme Environment, Priority Axis 3.

Individual remediation measures are aimed at the removal of extensive, mostly point source subsurface pollution in the industrial complex. The main contaminants here are tars and their mixtures containing high concentrations of PAHs, hydrocarbons C_{10}-C_{40}, phenols and BTEX. The individual remediation projects will gradually dispose of sites where hazardous waste has been stored in the past. This mostly involves the removal of tar ponds, the removal of industrial waste and contaminated soil, and remediation of groundwater where contamination has reached shallow aquifers. The dominant focus of the entire site are tar ponds and spoil tips, which pose an unacceptable health and environmental risk. Tar ponds formed in places where there used to be 'tanks' for separating tar from coke oven wastewater. The tar spilled into terrain depressions without any adopted precautions, from where it seeped into the surrounding environment in both horizontal and vertical directions. In the first phase, contaminated soil and tar were extracted and disposed of. In the next phase, remediation work was carried out, aimed at cleaning the deeper layers of the bedrock of the unsaturated and saturated zones. A protective hydraulic depression was created in the contaminated area through groundwater pumping from the first aquifer. After this, an entire network of pumping, infiltration and monitoring boreholes were drilled. In total, 30 shallow collection boreholes, 70 infiltration boreholes and 7 monitoring boreholes were drilled, including a drainage system. The pumped polluted groundwater was pre-purified in a mobile water treatment plant with a biological product before its re-infiltration.

Rising mine water levels

In 2002, coal mining was stopped in the entire Kladno area, and mine dewatering stopped along with it. Since then, there has been gradual, spontaneous flooding of all mine areas mined out by mining activity. The flooding time of mines with a target level of 300 m a.s.l. was estimated at 8-10 years in 2004. In late 2011, the mines were flooded to a level of 130-150 m a.s.l. Now the water levels have reached 200 m above sea level. As a result of the increase in mine water levels, its quality and the existing groundwater regime are changing. The drainage of mines is coming to an end, and the natural function of connected watercourses will be restored. Changes in the quality of mine waters can occur due to contact with the geological background in mined-out areas, or the washing away of pollution gradually arising from the surface. New findings and data will be evaluated with a hydraulic and geochemical model. The resulting evaluations will complete the overall view of the level and extent of pollution of the entire location, making the prediction of the rise in mine water levels and the risk of potential water endangerment by pollutants in mine waters more accurate. They will become a necessary basis for subsequent projects aimed at preventing secondary pollution of groundwater in the entire aquifer and surface waters in Dřetovický potok (Dřetovice Stream) and Týnecký potok (Týnec Stream) due to the rise of water levels.

Future use

Remedial measures should make it possible to use the area as an industrial zone without health risks in the future, and to ensure the greatest degree of protection of groundwater and surface water and related ecosystems. The concept of remediation of the entire area of interest of the former industrial complex, combined with the removal of pollution in the surface layers, preventing pollution from leaching into groundwater and surface waters, and the gradual transformation of the entire former POLDI Kladno complex into an area that can be used without problems in the future, is a meaningful path to remedying the past activities that have devastated the nature in this territory. The current state of pollution of the upper part of the rocky environment limits the use of the area and the future use of the site in accordance with the land use plan, which was updated according to the land use study conducted in 2018. Kladno intends to transform the neglected brownfield into a functional and modern industrial district. The original plan, anchored in the previous land use plan drawn up before 2013, when this area was to be partly used as a residential zone, is not yet realistic from today's perspective. Of course, the use of the area changes over time, and if significant funds are spent on further rehabilitation works, this may change the purpose of the use of this area in the future.

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Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

Lake Medard

Lake Medard is located in the Karlovy Vary Region to the northwest of Sokolov, between Svatava and Habartov. It was created as a project for hydraulic reclamation and revitalization of the area affected by brown coal mining in the former Medard and Libík quarries, which were merged into one unit, later called Medard - Libík, during the mining process. Mining in this location has been going on since 1918 and ended on March 31, 2000.

The filling of the lake has been ongoing since June 2008, when the Sokolovská uhelná company stopped pumping mine water from the Medard retention and ended the rough technical reclamation of the future lake bed. In this phase, the work on the preparation of the terrain was being completed and gradual heating was taking place both with rainwater and with water that flowed from the slopes. In order to achieve the required water chemistry, mine water was even pumped from the Jiří quarry for some time. In 2010, the recultivation project moved into the phase of filling from the Ohře River. The filling was gradual and dependent on the size and quality of the water flow from the river. The lake was completely filled to the target water level in 2017.

The goal of the development activities of the Sokolovská uhelná company in the vicinity of Lake Medard is to naturally connect the treated area with the surrounding residential units and to design a functional structure of the area in such a way as to enable year-round use of the location for housing, provision of services, leisure activities, infrastructure development, and the existing areas are thus transformed to a new cultural and recreational landscape. The purpose of restoring the landscape after mining subsides is to find a new identity, connect functions in the existing settlement structure and improve the overall image of the area. The main emphasis is on ecology, sustainability and employment.

Possibilities for future construction are outlined in the territorial and urban planning study. The connecting element of the entire area is a 13 km long path (Břeh a stezka). Along the eastern part of the lake, there will be a waterfront promenade with block buildings and a port enabling vessels to moor - Svatava - a port city. New developments for residential housing are planned on the southern side of the proposed area near the village of Citice (Bydlénî nad jezerem - Citice), south of the center of Habartov towards Bukovany (Habartov - new quarter) and further on the north-western edge of the lake (Bydlénî nad jezerem - Habartov). Leisure activities will be possible in the newly planned Sports and Recreational Zone and in the Tůní area, which will primarily be used for recreational and sport fishing.

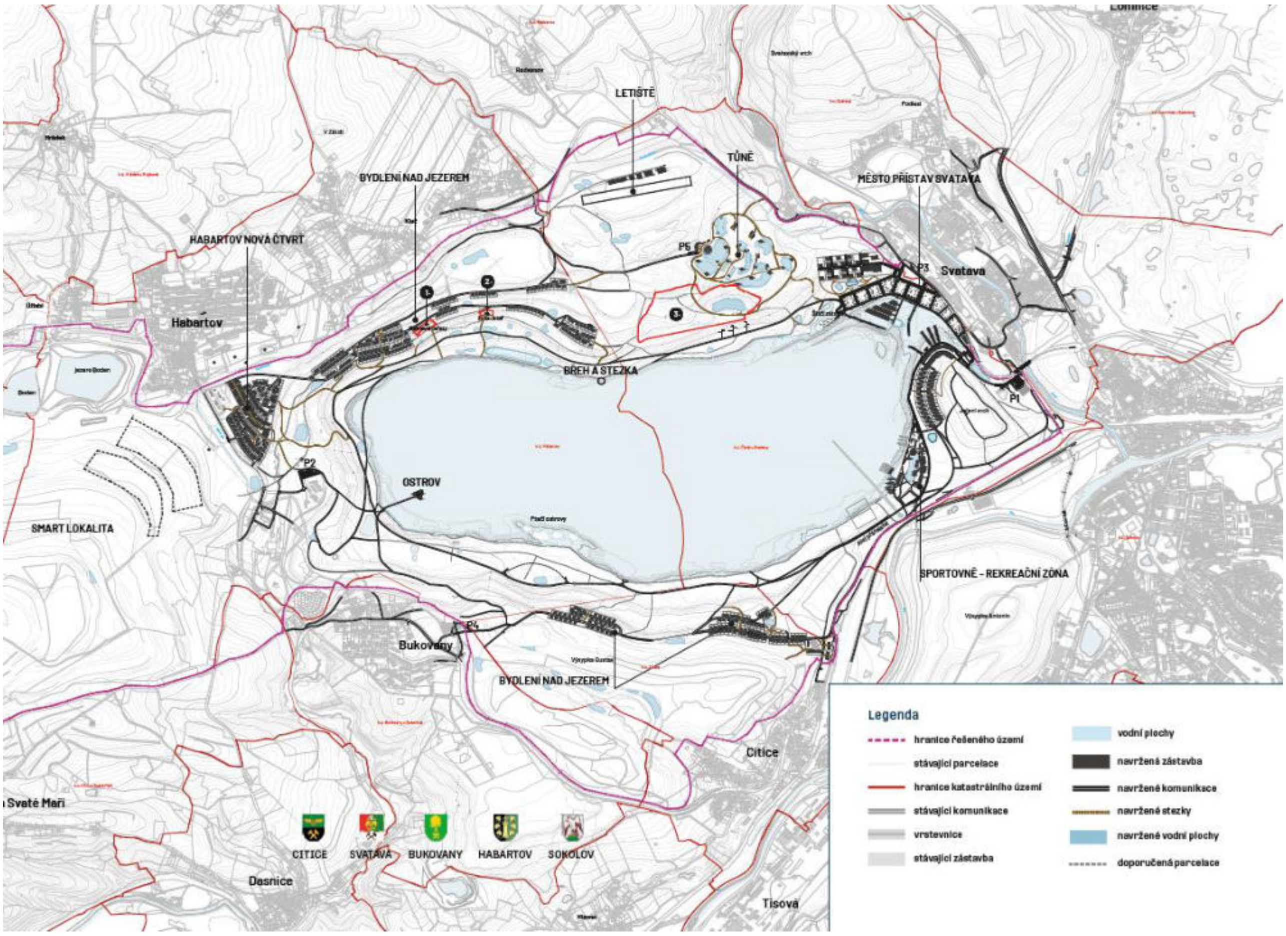
Management of water in the addressed area

The basic requirement is to prevent any inflow of water into the lake, or at least minimize it. With this requirement in mind, new ditches were added to the existing network of amelioration ditches or new ones were designed. In addition, dry settling tanks where the water is retained were added.

In general, water from the surface of roads will preferentially flow freely into the terrain - this applies primarily to roads without motor vehicles. Rainwater from these roads will be diverted using surface surface and linear elements with retention space – weirs, ditches, artificial wetlands, ponds, etc. No road salt will be used on the roads near the shore line of the lake in winter. Rainwater from roads for motor vehicles will be disposed of similarly, but first it must be purified using oil separators and pre-cleaned using sand and gravel filters.

The water flowing out of the Josef tunnel has been evaluated as poor quality and its cleaning based on passive decontamination will take place in a wetland root treatment plant.

In order to avoid contamination of the waters that flow into the lake, a decentralized system of sewage disposal in the form of domestic sewage treatment plants is not considered. Central sewage treatment is planned in the existing WWTP near Citic, in the expanded WWTP near Habartov and the new WWTP near Svatava.


LETIŠTĚ
TŮNĚ
BYDLENÍ NAD JEZEREM
MĚSTO PŘÍSTAV SVATAVA
HABARTOV NOVÁ ČTVRŤ
P5
P3
Svatava
Habartov
BŘEH A STEZKA
P1
P2
OSTROV
SMART LOKALITA
SPORTOVNĚ - REKREAČNÍ ZÓNA
P4
Bukovany
BYDLENÍ NAD JEZEREM
Citice
Svaté Maří
Dasnice
Tisová
CITICE
SVATAVA
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Legenda
hranice řešeného území
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hranice katastrálního území
stávající komunikace
vrstevnice
stávající zástavba
vodní plochy
navržená zástavba
navržené komunikace
navržené stezky
navržené vodní plochy
doporučená parcelace

VD Stanovice

The waterworks is part of the Stanovice – Březová water management system. The Stanovice – Březová water management system consists of the Stanovice Waterworks, the Teplička Waterworks, the Teplička Dam and the Březová Waterworks

The main purpose of VD Stanovice is primarily the accumulation of water to supply Karlovarsk with drinking water, ensuring the minimum flow in the profile of the Stanovice-drainage limnigraph, protecting the city of Karlovy Vary from floods and periodic flushing of the channel under the dam. The secondary purpose of the reservoir is to influence the ice regime on the Teplá stream below its confluence with the Lomnické stream by releasing warmer water from the Stanovice dam, the production of electricity, purpose-built fish management at the Stanovice dam and the exercise of fishing rights.
Swelling object - the dam is straight, loose, stony with an instructional asphalt seal. The length of the crown of the dam is 258 m, the width is 8.25 m and the maximum height above the ground is 59.5 m.
The construction of the VD took place in the years 1972–1978, the designer was Hydroprojekt Praha, and the construction was carried out by the following companies: Vodní stavby Praha, Sigma Hranice, ČKD Blansko, EZ Praha, ZPA Praha, ABK Výmar - GDR.
With its retention effect, the Stanovice Reservoir will reduce the culminating flow of a 100-year flood wave from the annual maxima, or from the summer (precipitation) maxima, from a value of 90 m3/s to a value of 13 m3/s in Lomnické Potok. The culminating flow of the 100-year flood wave from the annual winter snow) maximum will decrease from a value of 40 m3/s to a value of 13 m3/s in the Lomnické stream.
The level in the reservoir in both cases reaches an elevation of 515.68 m above sea level. Together with VD Březová, it ensures 100-year protection of the city of Karlovy Vary against floods above a flow rate of 90 m3/s for a flood wave from the set of annual maximums, for a summer flood wave and a winter flood wave.
VD Stanovice is a water reservoir with a defined protection zone. A road leads across the dam, but the areas near the reservoir are permanently closed to pedestrians.
Entrance and entrance to the protection zone of the first degree is prohibited for the public!

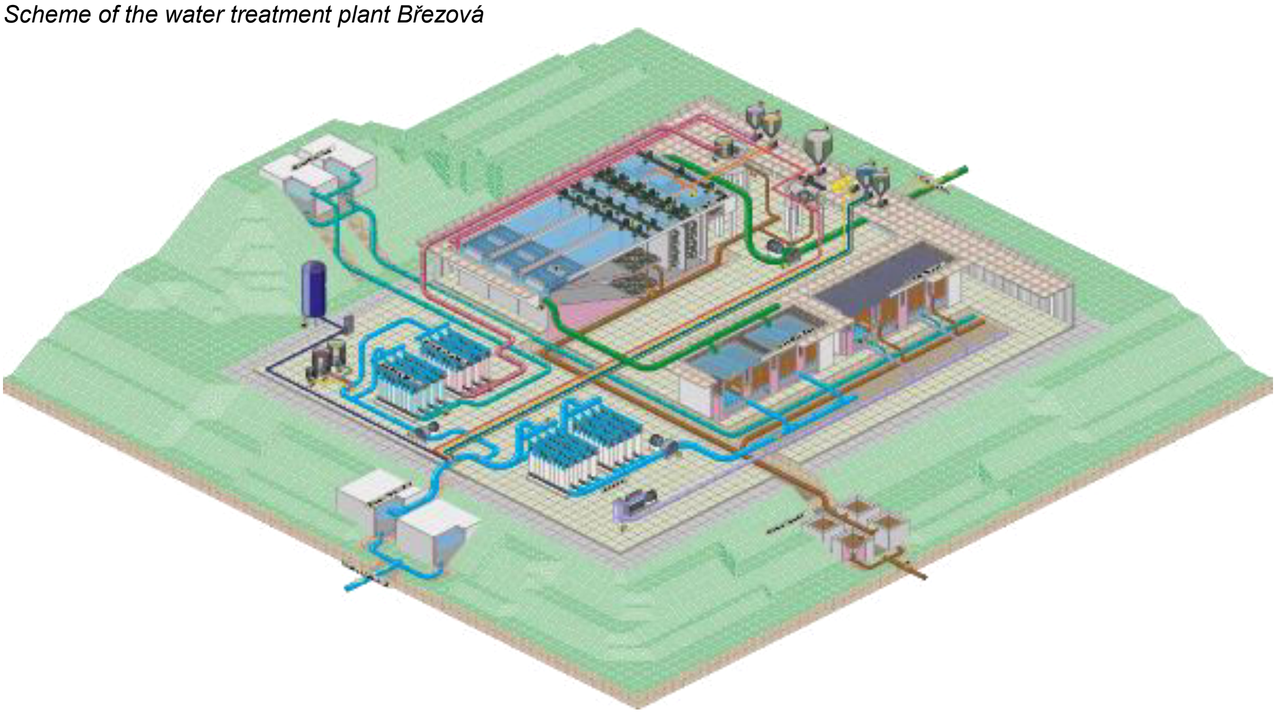
Eat Elbow

The construction of the "Lower Elbow Dam - reconstruction of the weir" began in March 2019 and was completed in December 2019. During construction, the fixed Prague-type weir structure based on wooden piles on the Ohři River at km 191.125 was replaced by a new reinforced concrete structure of the same dimensions.
The work was completed without defects in accordance with the construction schedule, in one calendar year. Representatives of the state enterprise Povodí Ohře and the city of Loket positively evaluated the progress of the construction, the resulting structure of the weir with granite lining takes into account the location of the weir near the historic town's historic zone.

Březová water treatment plant

Water treatment plant Březová is the largest drinking water treatment plant in Karlovy Vary. It is the main source of the Karlovy Vary Regional Water Supply, which supplies more than a third of the population of the Karlovy Vary Region. The treatment plant was built between 1972 and 1982, it was put into operation in 1984. The source of raw water for the treatment plant is the Stanovice reservoir on the Lomnické stream. It is a very high-quality natural resource located in a protective water zone and there is no danger of industrial, agricultural or urban pollution. The treatment plant produces approximately 250 liters of drinking water per second, but its design capacity is more than twice that (650 l/s). Originally, the treatment plant used a two-stage water treatment technology – coagulation and filtration, supplemented by hardening. Between 2011 and 2016, the treatment plant was reconstructed, and the technology was extended by another stage – ultrafiltration. Today, the treatment plant is fully automated and controlled by a computerized control system. The treatment plant is operated 24/7.

Scheme of the water treatment plant Březová



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11.–12. 10. 2023

Extrémní hydrologické jevy a jejich dopady v povodí Labe
Extreme hydrologische Ereignisse und deren Folgen im Einzugsgebiet der Elbe

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