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RIVER BASINS 2026

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Sources and Sinks

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Abstracts of the Conference

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Table of Contents

1. Program 1
2. Abstracts of Oral Presentations 4
Yearly key figures of concentrations and loads of trace contaminants in rivers – which sampling strategies lead to reliable results? 5
PET – An Open-Source Shiny Application for Scalable Quality Assurance and Exploration of Transnational River Basin Monitoring Data 6
Interactions of sediments with nutrients and pollutants – hydraulic flume experiments and implications for the aquatic environment 8
Evaluation of Cd, Pb, and Ni as Toxic EQS Elements in the Ishëm River Basin (Albania) 9
EU-Hydro 2.0: A Copernicus high-resolution hydrography dataset across Europe based on latest generation elevation and ancillary data 10
Model-based selection of WWTP for quaternary treatment with minimum costs to meet EU-EQS for diclofenac 12
Identifying Key Pathways of Priority Trace Chemicals in the Danube River Basin 14
Towards a global mass balance of TRWP accounting for the variability of climate and socio-economic conditions 16
Modelling history for future considerations: Nutrient emissions into German surface waters in 1880 17
Emission modelling in the Danube Basin, from pilot action to capacity building 18
Coordinated strategy for the transnational control and management of trace contaminants in surface water bodies in the Danube River Basin under changing pressures, challenges and targets 20
Stimulated Communication as a Prerequisite for Effective Water Protection: Insights from the Magdeburgian Water Protection Seminars in the German/Czech Elbe River Basin 21
From Macrophytes to Micropollutants: Evolving Wastewater Strategies under Regulatory Frameworks in Baden-Württemberg 23
Web based river basin management with the MoRE-DE toolbox 26
3. Abstracts of Poster Presentations 28
Characterizing Temporal Variability in Continuous Water Quality Data Using Frequency Analysis: Implications for Sampling Strategy Design in Hungarian Streams 29
Fluorescence-based in situ measurement of cyanobacteria: state of the art, potential, limitations, compensation methods and further development of an optical sensor system ..31
Integrating ASTER Remote Sensing and Electric Resistivity Tomography for Post-Fire Hydrological Assessment 32
An open database tool for collection of concentration data from multiple environmental matrices to support inventorying of emissions to surface waters 33

The Proportion of Treated Wastewater in the Discharge of Large Rivers Based on Spatially Aggregated Wastewater Volumes 35

Deriving emission factors for municipal wastewater treatment plants in large river basins 37

Identification of sediment inputs via ditches in an agriculturally dominated catchment 39

A Modelling Framework for Pollutant Transport and Retention Processes in River Networks — Concept and First Simulation Results 40

4. Index of Authors 41

1. Program

Program
Thursday, 11th June

09:00 – 09:30	Registration
09:30 – 10:00	**Welcome and Opening** *Stephan Fuchs, Head of Water Quality Management, KIT*
Monitoring & Modelling	Chairs: Stephan Fuchs, Matthias Zessner
10:00 – 10:30	Yearly key figures of concentrations and loads of trace contaminants in rivers – which sampling strategies lead to reliable results? *Nikolaus Weber – TU Wien, Austria*
10:30 – 11:00	PET – An Open-Source Shiny Application for Scalable Quality Assurance and Exploration of Transnational River Basin Monitoring Data *Severin Osten – TU Wien, Austria*
11:00 – 11:30	**Coffee break**
11:30 – 12:00	Interactions of sediments with nutrients and pollutants – hydraulic flume experiments and implications for the aquatic environment *Peter Flödl – BOKU, Austria*
12:00 – 12:30	Evaluation of Cd, Pb, and Ni as Toxic EQS Elements in the Ishëm River Basin (Albania) *Vjola Bakillari – UBT, Albania*
12:30 – 13:00	EU-Hydro 2.0: A Copernicus high-resolution hydrography dataset across Europe based on latest generation elevation and ancillary data *Linda Moser – GAF, Germany*
13:00 – 14:00	**Lunch break**

14:00 – 14:30	Pitch presentation of posters	Chair: Jos van Gils
Characterizing Temporal Variability in Continuous Water Quality Data Using Frequency Analysis: Implications for Sampling Strategy Design in Hungarian Streams *Katinka Virág – BME, Hungary*		
Fluorescence-based in situ measurement of cyanobacteria: state of the art, potential, limitations, compensation methods and further development of an optical sensor system *Vincent Idel – TU Wien, Austria*		
Integrating ASTER Remote Sensing and Electric Resistivity Tomography for Post-Fire Hydrological Assessment *Halil Yildiz – CTU, Czechia*		
An open database tool for collection of concentration data from multiple environmental matrices to support inventorying of emissions to surface waters *Steffen Kittlaus – TU Wien, Austria*		
The Proportion of Treated Wastewater in the Discharge of Large Rivers Based on Spatially Aggregated Wastewater Volumes *Benjamin Schima – BfG, Germany*		
Deriving emission factors for municipal wastewater treatment plants in large river basins *Máté Kardos – BME, Hungary*		
Identification of sediment inputs via ditches in an agriculturally dominated catchment *Julia Nowak – KIT, Germany*		
A Modelling Framework for Pollutant Transport and Retention Processes in River Networks — Concept and First Simulation Results *Ruoyi Qiu – KIT, Germany*		
14:30 – 15:30	**Poster discussion + Coffee break**	

Modelling & Management	Chairs: Martine Broer, Steffen Kittlaus
15:30 – 16:00	Model-based selection of WWTP for quaternary treatment with minimum costs to meet EU-EQS for diclofenac *Anja Multhaup – RPTU, Germany*
16:00 – 16:30	Identifying Key Pathways of Priority Trace Chemicals in the Danube River Basin *Máté Kardos – BME, Hungary*
16:30 – 17:00	Towards a global mass balance of TRWP accounting for the variability of climate and socio-economic conditions *Jos van Gils – Deltares, The Netherlands*
19:00	**Conference dinner at Cantina Majolika, Ahaweg 6-8, 76131 Karlsruhe**

Program
Friday, 12th June

Modelling & Management	Chairs: Stephan Fuchs, Steffen Kittlaus
09:00 – 09:30	Modelling history for future considerations: Nutrient emissions into German surface waters in 1880 *Karoline Morling – KIT, Germany*
09:30 – 10:00	Emission modelling in the Danube Basin, from pilot action to capacity building *Martine Broer – UBA, Austria*
10:00 – 10:30	Coordinated strategy for the transnational control and management of trace contaminants in surface water bodies in the Danube River Basin under changing pressures, challenges and targets *Matthias Zessner – TU Wien, Austria*
10:30 – 11:00	**Coffee break**
11:00 – 11:30	Stimulated Communication as a Prerequisite for Effective Water Protection: Insights from the Magdeburgian Water Protection Seminars in the German/Czech Elbe River Basin *Wolf von Tümpling – UFZ, Germany*
11:30 – 12:00	From Macrophytes to Micropollutants: Evolving Wastewater Strategies under Regulatory Frameworks in Baden-Württemberg *Adrian Wagner – LUBW, Germany*
12:00 – 12:30	Web based river basin management with the MoRE-DE toolbox *Micha Gebel – VisDat, Germany*
12:30	**Conference closure**

2. Abstracts of Oral Presentations

Yearly key figures of concentrations and loads of trace contaminants in rivers – which sampling strategies lead to reliable results?

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Background: Water quality assessment must rely on representative samples, but obtaining them is increasingly challenging given the growing number and diversity of trace contaminants emitted into water bodies. This study investigates whether and to what extent monthly grab sampling (GS), widely used in official monitoring programmes, provides reliable and accurate estimates of annual mean and maximum concentrations, and of annual riverine loads. Through a one-year systematic survey in two rivers using three sampling techniques in parallel, we evaluate low-frequency GS against time-proportional composite (TPC) and flow-proportional composite (FPC) sampling. The scope of 450 contaminants encompasses potentially toxic elements (PTE), pharmaceuticals, biocides, pesticides and PFAS, covering a broad diversity of emission patterns and environmental fate.

Results: For dissolved PTEs and pharmaceuticals, monthly GS delivered approximately correct annual average concentrations, but potential underestimation and overestimation were also observed. Contaminants with seasonal patterns or those emitted during short-term events, such as many pesticides and biocides, PFAS and total PTEs, were not adequately depicted by low-frequency GS, leading to varying degrees of underestimation and seldom also to overestimation. This applies to average annual concentrations but particularly to loads. Integrated composite sampling, especially flow-proportional, performs significantly better for such contaminants. Worthy of attention are cases of low and highly variable concentrations, such as ibuprofen, lindane and PFNA in this study. While integrated composite samples clearly demonstrated their non-negligible presence, monthly GS failed to detect them.

Conclusion: The widely applied monitoring approach relying on monthly GS is only sufficiently reliable for contaminants being emitted fairly constantly and transported primarily in the dissolved phase. Even then, its good performance is mostly limited to assessing average concentrations and thus chronic exposure, while integrated composite sampling can significantly improve the accuracy of load calculations. For contaminants with variable and dynamic concentration patterns, FPC sampling performs considerably better, especially in terms of load calculations, followed by TPC sampling. However, the latter is simpler to implement. GS-based underestimations pose a significant risk of incorrectly assessing compliance with environmental quality standards if the concentration level in rivers is not very far below or above the thresholds, as was often the case in our study area.

PET – An Open-Source Shiny Application for Scalable Quality Assurance and Exploration of Transnational River Basin Monitoring Data

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River basin management is an inherently interdisciplinary and transnational task, increasingly challenged by the widespread occurrence of pollutants originating from diverse industrial and urban sources. Many of these substances remain insufficiently understood regarding their environmental fate and ecological impacts. Within the European Union, these challenges are addressed through the Water Framework Directive (2000/60/EC) and associated guidance documents, which explicitly require the establishment of integrated, multi-compartment inventories of emissions, discharges, and losses. These data infrastructures form the foundation for evidence-based assessment, modelling, and decision-making in river basin management.

In this context, the Institute of Water Quality at TU Wien has developed a centralized, multi-compartment concentration database within the framework of the Tethys project. The database is designed as a robust and scalable infrastructure to support national and transnational monitoring activities and is already operational for data contributions from multiple partners across the Danube River Basin. However, the practical use of such complex database systems remains a major challenge. Data import, validation, curation, and exploration typically require substantial technical expertise in database technologies and programming, posing a significant barrier for many domain experts.

To address this gap, we present the Pollution Evaluation Tool (PET), an open-source R package implemented as a Shiny application using the {golem} framework. PET provides a user-friendly, scalable interface for interacting with databases structured according to the Tethys data model. It fully integrates with existing authentication mechanisms and complies with local database constraints, enabling secure and standardized access across institutions.

The currently operational module of PET focuses on structured data quality assurance. It implements standardized, best-practice QA/QC workflows that integrate quantitative and qualitative cross-table consistency checks across core database entities, including sampling sites, samples, measurements, determinants, laboratories, analytical methods, and associated classifications and standards. These workflows support systematic detection of inconsistencies, missing information, and structural errors, thereby improving data reliability for downstream applications such as emissions modelling and large-scale assessments.

Beyond quality assurance, PET provides advanced filtering, constrained selection based on valid metadata, and functionality for updating and creating database entries through guided

interfaces, substantially reducing the need for direct interaction with the database backend. A second development phase, currently conceptualized, will extend the system towards comprehensive cross-database exploration, including flexible visualization, environmental statistical analyses, metadata management, complex error detection, and tailored dataset generation.

This work represents a methodological and infrastructural contribution by operationalizing standardized, scalable, and open workflows for quality assurance and exploration of large, transnational environmental monitoring databases. PET lowers technical barriers for domain experts and supports the practical implementation of FAIR data principles, thereby enabling more effective use of emerging large-scale river basin data infrastructures.

Interactions of sediments with nutrients and pollutants – hydraulic flume experiments and implications for the aquatic environment

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Anthropogenic disturbances have deeply altered and disrupted aquatic ecosystems. In rivers, this has resulted in habitat fragmentation, altered flow regimes and a significant decline in biodiversity. Climate change also promotes more frequent and prolonged cyanobacterial blooms in standing waters. Studies on sediment transport and nutrient distribution are available, but key mechanisms remain unclear. In particular, it is unclear how local sediment-nutrient interactions influence substance fate. Event-driven remobilisation during floods and summer stagnation phases increase spatial and temporal heterogeneity. This knowledge gap complicates the modelling of eutrophication processes, risk assessment and river basin management. It also hinders the derivation of effective local measures in rivers. Closing these knowledge gaps is therefore central to improving aquatic ecology in line with the EU Water Framework Directive.

Presented will be the results of the research project "*Particle-bound nutrients in (semi-)natural rivers: Do simplified assumptions lead to inappropriate recommendations for action?*" (Funded by the Austrian Academy of Sciences (ÖAW) and the Austrian Science Fund (FWF)). In this project, a novel method was used to investigate the interactions between sediments and nutrients in hydraulic flume experiments. Initial results showed clear differences in temporal and spatial distributions, depending on whether particle-bound or liquid nutrients were added. The application of liquid fertilisers led to an initial peak effect, while the addition of animal manure showed a delayed release over several hours. In the case of soil material addition, variations in concentrations and time courses were observed. The composition of the sediment core (stratification, grain fractions) also influenced nutrient release. The temporal course of the ammonium concentration differed when finer substrate (dm < 0.8 mm) was applied to coarser suspended sediment (dm < 8.0 mm) than under inverse stratification. These results suggest that morphology has an influence on the distribution of nutrients and pollutants. This is particularly important for benthic organisms, as they are dependent on the substrate composition in the river. In addition, the results will be discussed in a broader context: effects on the selection of measuring sites, modelling approaches, as well as consequences for water management and legal requirements (EU Water Framework Directive).

Evaluation of Cd, Pb, and Ni as Toxic EQS Elements in the Ishëm River Basin (Albania)

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Keywords: Monitoring framework, Pathway-specific emissions, Anthropogenic pressures, MoRE modeling, GIS-based regionalization

The Ishëm River basin in central Albania is among the most impacted aquatic systems in the region, receiving untreated municipal wastewater, industrial discharges, and diffuse inputs from agriculture. Scientific information on heavy metal dynamics in this basin has so far been limited and inconsistent. The objective of the present study is to establish a methodological basis for assessing the occurrence and pathways of selected heavy metals (Pb, Cd, Ni) in surface waters. For this purpose, a structured monitoring framework was implemented to capture spatial and temporal variability. Representative stations were located along the main channel and tributaries, covering urban, industrial, and rural sub-catchments. Water and sediment samples were collected and analyzed according to ISO standards. Atomic Absorption Spectroscopy (AAS) was applied for quantification of the target metals, while *in situ* measurements provided complementary physicochemical data. The monitoring concept is designed to generate substance- and pathway-specific datasets suitable for subsequent modeling applications.
The measured concentrations of Cd, Pb, and Ni in surface waters of the Ishëm River basin exhibit clear spatial variability and frequently exceed EU environmental quality standards. Cadmium concentrations ranged from 0.17 to 0.43 µg/l, Lead concentrations ranged from 6.53 to 35.91 µg/l, and Nickel concentrations ranged from 11.80 to 53.34 µg/l, with higher values generally observed in urban and industrial sub-catchments. These results indicate a strong influence of anthropogenic activities on heavy metal distribution within the basin.
Future integration of these data into the MoRE (Modeling of Regionalized Emissions) framework will enable emission quantification, specification of heavy metal transport parameters for each pathway, and spatial regionalization via Geographic Information Systems (GIS). This combined monitoring-modeling approach is expected to provide a robust tool for emission assessment, hotspot identification, and compliance with the EU Water Framework Directive.

EU-Hydro 2.0: A Copernicus high-resolution hydrography dataset across Europe based on latest generation elevation and ancillary data

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EU-Hydro is a hydrographic reference dataset part of the Copernicus Land Monitoring Service (CLMS) portfolio, implemented by the European Environment Agency (EEA). It offers detailed information on the geographical distribution and spatial characteristics of water resources throughout Europe, such as river networks, surface water bodies and watersheds. However, its use for hydrological modelling remained limited due to shortcomings in data structure, resolution, and quality. The new EU-Hydro 2.0 production is tackling the needs of a modern hydrographic reference product within the pan-European hydrological domain, uniting the requirements of both the hydrographic mapping and the hydrological monitoring communities. New, advanced hydrological conditioning algorithms and latest ancillary data improve hydrological representation and consistency of current methods. As a result, it supports various use cases beyond mapping, including hydrological modelling and prediction as well as environmental assessments related to river connectivity and the evaluation of anthropogenic impacts, all with the goal to strengthen water resilience across Europe.

EU-Hydro 2.0 builds upon a latest generation Digital Elevation Model (DEM) based on the TanDEM-X mission: the Copernicus DEM at 10m resolution on pan-European scale, supported by the Copernicus DEM at 30m resolution for catchments that flow in and out of the EEA38+UK area. The production of EU-Hydro 2.0 involves best-suitable and most recent ancillary data of hydrography, land cover, and infrastructure, as well as very high resolution (VHR) satellite data for quality control, editing (e.g., river corrections, coastline mapping) and validation. The product suite consists of eight main layers: The three main raster products are the hydrologically conditioned DEM (Hydro-DEM), the flow direction (Hydro-DIR) and the flow accumulation (Hydro-ACC) products, supported by additional raster layers for expert hydrological use. The five vector products are the river network (Hydro-NET), water bodies (Hydro-WBO), basins and sub-watersheds (Hydro-BAS), a product on artificial hydrographic structures (Hydro-ART) and a

coastline (Hydro-COAST). In addition, a cartographically enhanced river product in focus regions (Carto-NET) is being produced. All layers are interrelated, scalable and logically consistent.

Between 2024-2025 a test phase was carried out in six test sites of different hydrological and terrain characteristics (full Po catchment, N-Sweden, S-Spain, Slovenia/Croatia, Central Türkiye, and boundary area Romania/Moldova). An independent validation of the different layers in the test sites, considering geometry, topology, attribution and complex interrelations between different layers was performed, in order to evaluate fitness for potential mapping and modelling use cases. The validation utilized national/regional reference data and VHR image interpretation and concluded that every layer is generally performing well, with some layers exceeding expectations whereas for other layers some issues on harmonization remain to be addressed. The EU-Hydro 2.0 production is planned to be made available towards the end of 2026. The approach aims at transparency and automation to the extent possible, supported by manual corrections where needed to increase quality and meet user requirements. This will ensure reproducible data processing and facilitate further updates of EU-Hydro into the future.

Model-based selection of WWTP for quaternary treatment with minimum costs to meet EU-EQS for diclofenac

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The recast of the EU directive on environmental quality standards (EQS) for surface waters, expected in 2026, will introduce limits for several organic micropollutants, including diclofenac (EU 2025). Diclofenac is widely used as a painkiller and is poorly removed in wastewater treatment plants (WWTPs) with a mechanical-biological treatment (Margot 2015). The proposed annual average EQS (AA-EQS) for diclofenac is 40 ng/L, while concentrations in rivers impacted by WWTPs often exceed this value (Launay 2017). Depending on their size and location, WWTPs must be equipped with advanced treatment technologies in accordance with the EU Wastewater Treatment Directive (EU-UWWTD, EU 2024).

Depending on the number and size of WWTPs in a river basin, the requirements of the EU-UWWTD may be insufficient to meet the AA-EQS of diclofenac. The question remains which WWTPs within a river catchment should be upgraded to achieve compliance with the EQS in the most cost-efficient way? To address this problem, the mass-balance model *StoffFLUSS* is applied in combination with a single-objective optimization approach to the catchment of the Upper Blies, Saarland Germany. The investigated river section has a length of 55 km and includes 33 municipal WWTPs with a total capacity of about 305,000 population equivalents (PE).

The model was developed by the department WIR (Water Infrastructure Resources) at the RPTU Kaiserslautern-Landau (Knerr et al. 2020; Venditti et al. 2022). Loads and annual average concentrations of selected organic substances along a river are calculated. Emissions from municipal WWTPs are estimated using a specific per-capita load entering the sewer system. A fraction of the load is discharged directly to the receiving water via combined sewer overflow. The remaining load is reduced in the WWTPs considering quaternary treatment due to the defined variants. Degradation along the river is represented by a pseudo-first-order kinetic depending on the hydraulic retention time in the river segment. Concentrations are obtained by dividing the calculated loads with the spatially corresponding mean river discharge (MQ). A 20% reduction of diclofenac input to the sewer system is assumed to represent source-control measures.

To determine upgrade strategies, a single-objective optimization is applied. The objective is to identify the selection of WWTPs that need to be equipped with advanced treatment so that the calculated diclofenac concentration at the catchment outlet remains below the AA-EQS of 40 ng/L while minimizing overall costs. The decision variables are binary and determine whether WWTPs are upgraded or not. Costs are represented by a cost function including investment and operational expenditures for advanced treatment, expressed as annualized costs.

The results of the optimization are compared with a manual selection strategy. To meet the EQS with a low number of WWTP, mainly the largest WWTPs in the area are prioritized for upgrades. In

contrast, the single-target optimization identifies a different configuration including a larger number of WWTPs and several smaller facilities (<2.000 PE). This reflects the spatial distribution of emissions within the catchment and the influence of treatment location on downstream concentrations. The study examines how the cost function effects optimization results, comparing approaches such as lowest cost and lowest number of upgraded plants.

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Identifying Key Pathways of Priority Trace Chemicals in the Danube River Basin

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Keywords: hazardous substance emission modelling, micropollutants, PTE, PFAS, pharmaceuticals, MoRE model

In addition to common pollutants such as organic matter and nutrients, an ever-growing range of chemicals increasingly threatens the quality of rivers and lakes, as well as the health of aquatic ecosystems. Understanding the main sources and transport pathways of these substances therefore represents a key scientific and management challenge.

Within the framework of the Tethys project, a hazardous substance emission model was developed for the Danube River Basin (DRB) through close cooperation among nine Danube countries. The modelling work was based on the systematic collection of concentration and emission data for multiple transport pathways, resulting in a substance-specific inventory that served as the foundation for emission modelling.

A common Danube-wide modelling tool was implemented using the MoRE (Modelling of Regional Emissions) framework. The model represents between four and eleven emission pathways for three substance groups: potentially toxic elements (PTEs), including six heavy metals and arsenic; industrial chemicals represented by the two most widespread per- and polyfluoroalkyl substances (PFOS and PFOA); and human pharmaceuticals represented by a widely used analgesic (diclofenac) and a psychoactive compound (carbamazepine). In addition to major point sources, the model accounts for numerous diffuse pathways, including groundwater, surface runoff, tile drainage, erosion, atmospheric deposition, and various legacy pollution sources such as landfills, aerodromes, and industrial disposal sites.

The modelling framework includes a newly developed retention approach that explicitly accounts for riverine retention for each substance group, as well as an uncertainty assessment module designed to quantify parameter uncertainty. This module is implemented within an R-based computational engine of the MoRE model.

Model validation was performed using long-term river monitoring data from existing operational monitoring networks, complemented by additional datasets collected by partner institutions during project implementation. Discharge data were provided by the participating countries.

The modelling results indicate that erosion, groundwater, municipal and industrial wastewater systems are the dominant emission pathways for PTEs, with pronounced spatial variability along the DRB. Point source contributions dominate in the Upper Danube, whereas agricultural-related diffuse pollution becomes increasingly important in the Lower Danube. For PFASs and pharmaceuticals, municipal wastewater represents the main emission pathway in most sub-catchments. In the case of PFASs, soils also act as relevant reservoirs, and associated pathways such as surface runoff, erosion, groundwater flow, and tile drainage may contribute substantially to riverine loads.

Towards a global mass balance of TRWP accounting for the variability of climate and socio-economic conditions

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Tire and road wear particles (TRWP) are formed at the frictional interface of the tire and road surface and consist of polymer-containing tread with pavement mineral and binder encrustations. Their detection in various environmental compartments globally sparks increasing societal and regulatory interest. Solid quantitative information as a basis for managing and mitigating TRWP in the environment is lacking however.

In recent years, a model approach was developed and demonstrated that produces catchment-scale terrestrial and aquatic TRWP mass balances anywhere in the world. A spatially and temporally explicit modelling method was used that builds on publicly available global datasets and process-based open-source modelling frameworks to describe hydrological processes, TRWP releases, fate and transport under a wide range of climatic conditions. High resolution (< 1km) models were implemented and evaluated by demonstrating consistency with available field data for four watersheds on different continents. The approach provides comprehensive mass balances to underpin management of TRWP that account for socio-economic, climate, geography and stormwater management gradients. Case study results revealed strong climate induced differences and a strong impact of stormwater management infrastructure.

The abovementioned four detailed models are currently being used to relate the fate of TRWP to specific climate and socio-economic indicators, under different stormwater management scenarios. By mapping these indicators for all watersheds on the globe, these correlations can be applied to build a global TRWP balance, accounting for the variability of stormwater management. The presentation will discuss the above backgrounds, the results and implications of our work.

Modelling history for future considerations: Nutrient emissions into German surface waters in 1880

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Historical nutrient emissions from inland waters into the sea are often considered as marine reference conditions. However, the application of different models resulted in significant uncertainties of these reference conditions and resulting reduction requirements in marine environments. Thus, the substance emission model MoRE (Modelling of Regionalized Emissions) was used for a revised historical scenario for 1880 for all German river basins.

MoRE was used to calculate nitrogen and phosphorus emissions via different pathways into surface waters and their resulting transported riverine loads. The approach is using the water balance model LARSIM-ME, which provided the necessary runoff components of the 1880 period as model input for MoRE. Recently published datasets for historical conditions as well as historical literature were used to derive suitable input data for modelling. Currently implemented model approaches in MoRE were adapted and partly simplified to reflect 1880 conditions.

Model results represent an early-industrial state with distinct anthropogenic impact before intensification of agricultural production. Comparison of results to reported concentrations from historical literature showed an overall good agreement of magnitude. Historical nitrogen and phosphorus emissions into German surface waters were 54% and 65% lower compared to model results of the recent period 2016-2018, respectively. Thus, historical and recent modelling scenarios offer the possibility to explore changes in nutrient dynamics over time due to anthropogenic activities.

Further, the results for 1880 allow for a critical revision of currently implemented target values for nutrients for coastal and marine waters of Germany.

Associated publication:
Gericke, A.; Morling, K.; Haag, I.; Gebel, M.; Krumm, J.; Bruns, G. et al. (2025): Are historical conditions reference conditions? Revising the modeled riverine nutrient input into the German North Sea and Baltic Sea around 1880. In: *Environ Sci Eur* 37:133 (133). https://doi.org/10.1186/s12302-025-01185-8

Emission modelling in the Danube Basin, from pilot action to capacity building

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Two consecutive projects financed by the Interreg Danube Transnational Program, Danube Hazard m3c (2020-2023) and Tethys (2024-2026) with an emphasis on emission modelling of hazardous substances in the Danube Basin were carried out. Emission modelling is widely used as a supportive tool to support the WFD management cycle with respect to close knowledge gaps from monitoring strategies, to provide input to risk analyses and to estimate the effectiveness of mitigation measures.

In the first project an emission model was set up for 7 pilot areas in four different countries (Austria, Hungary, Romania, Bulgaria) to demonstrate the use of a pathway-oriented emission model throughout the Danube Basin. It was shown that the emission model could be run, with plausible results, even in pilot areas in Romania and Bulgaria, where the experience with emissions modeling and data availability is not as pronounced as in Austria and Hungary (Output T2.2, DH m3c).

Consequently, in the follow-up project Tethys, one of the main objectives was to set up national emission models for hazardous substances in 9 different countries in the Danube basin. A very substantial part of setting up the national models was guiding the involved institutions in setting up their own emission model. An additional challenge was the very big difference in capacity with emission modelling between the project partners, which reached from no experience till decades of experience. The participants came from various backgrounds, such as: hydrology, geography, chemistry, environmental engineering, which resulted in a very diverse group of experts working on the national models.

To meet these challenges, the capacity building consisted of the following elements:

1) An online webinar series with 15 online meetings on different topics related to needed input data, working with the MoRE model, model validation, system and risk analysis and implementation of mitigation measures.

2) General status updates and discussion of upcoming issues, i.e. trouble shooting in parallel to the online webinar series. These status updates were set up as a tour de table.

3) Hands-on modelling workshop. During the project, when all the project partners actively started working on the national emission model an in-person modelling workshop was organized, which was attended by almost all project partners.

All three different forms of meetings in the scope of the capacity building complemented each other.

The main lessons learned from the capacity building was that addressing present topics that are relevant at the moment are promising, while it proved more difficult for the participants to follow presentations on topics that were only relevant in the future. Furthermore, hands-on workshops acted as a catalyst for model implementation and motivation, so a capacity building concept should regularly include meetings with personal contacts.

The aim of the Tethys project is to equipe the projects partners with all necessary knowledge needed to run an emission model on hazardous substances independently in order to take hazardous substance management in the Danube region to a new level and to guarantee maintenance in this development.

References:

Output T2.2, Report on improved system understanding as basis for adapted transnational emission modelling at DRB scale, 2022 Danube Hazard m3c

Coordinated strategy for the transnational control and management of trace contaminants in surface water bodies in the Danube River Basin under changing pressures, challenges and targets

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The European water quality sector is undergoing a significant wave of regulatory and policy changes, with ambitious objectives. At the same time, it is facing major pressures and challenges, including those arising from climate change, geopolitical insecurity, and rising costs. In this context, the transfer of trace contaminant pollution across borders in a transnational river basin obtains environmental, societal, political and legal dimensions even broader and more complex than before.

In two Interreg Danube projects (Danube Hazard m3c and Tethys), several tools, procedures, and workflows have been developed, tested, and demonstrated in order to improve the entire process from monitoring to emission modelling and risk assessment, with the goal of establishing robust, long-term emission inventories and prioritising measures to reduce water pollution. Alongside the development of technical solutions and to extensive capacity-building and harmonisation efforts, the main bottlenecks and obstacles to the effective control and management of trace contaminants in the Danube River Basin (DBR) were investigated, such as national differences in data availability and in the implementation of EU legislation.

Based on the outcomes and lessons learned from these two projects, as well as from other ongoing international projects and initiatives, a joint transnational strategy for the DRB is being jointly developed. Given the complexity of the new water quality targets and objectives, and the heterogeneity of the DRB's conditions, constraints, capacities and possibilities, the strategy will set out specific priorities, coordinated actions and measures for the DRB, considering the three pillars of monitoring, modelling and management.

This presentation will briefly outline the draft strategy, which is expected to be finalised by the end of June 2026 and be subsequently integrated by the ICPDR into the Danube River Basin Management Plan 2027.

Stimulated Communication as a Prerequisite for Effective Water Protection: Insights from the Magdeburgian Water Protection Seminars in the German/Czech Elbe River Basin

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The Magdeburg Water Protection Seminar (Magdeburger Gewässerschutzseminar / Magdeburský seminář o ochraně vod) is a long-established, scientifically grounded, and internationally recognized professional conference in the field of water protection, with a primary focus on ecological, legal, and water management issues in the Elbe River basin. The central objective of the seminar is to promote interdisciplinary and transboundary exchange of knowledge and experience among stakeholders from science, public administration, water management practice, and spatial planning. In particular, experts from Germany, the Czech Republic, and other riparian states of the Elbe convene to discuss current developments, research findings, and practice-oriented solutions.

Since the first time in 1988, the Magdeburg Water Protection Seminar has continuously evolved and now ranks among the most important and well-established conferences on water protection in the Elbe River basin. By bringing together diverse disciplines and stakeholder groups over the long term, the seminar makes a significant contribution to fostering interdisciplinary dialogue and advancing scientifically sound and practically relevant approaches to sustainable water management in the Elbe catchment.

The seminar is generally held biennially and is organizationally embedded in the activities of the International Commission for the Protection of the Elbe (IKSE). The venue alternates regularly between Germany and the Czech Republic, underscoring both the international character of the event and the importance of transboundary cooperation within the Elbe River basin. Thematically, the seminar addresses a broad spectrum of topics, including integrated water resources management, aquatic ecology, and water quality, as well as competing water uses, legal and institutional frameworks, and the impacts of climate change and other anthropogenic pressures on rivers and their floodplains. The thematic focus is continuously adapted to reflect current scientific advances, European and national water legislation, and emerging practical challenges in water management.

For example, the 21st Magdeburg Water Protection Seminar, held on 8–9 October 2025 in Magdeburg, was dedicated to the overarching theme “Water Management in the Elbe River Basin – Past, Present, and Future.” The programme was structured into several thematic sessions addressing issues such as water availability, the ecological functioning of rivers and floodplains,

the role of the Elbe as a navigable waterway, and strategic approaches to the further development of monitoring systems and long-term management strategies. In addition to keynote and technical presentations, poster sessions, moderated discussions, and accompanying field excursions provided further opportunities for in-depth professional exchange.

Thus, over several decades, it has become possible for current research findings to be presented to experts within regulatory authorities on the one hand, and for scientists, on the other hand, to gain early insight into regulatory challenges and strategies in order to seek solutions to these problems in the Elbe catchment area.

From Macrophytes to Micropollutants: Evolving Wastewater Strategies under Regulatory Frameworks in Baden-Württemberg

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Anthropogenic pressures on water resources are intensifying due to profound hydrological changes associated with global warming, ongoing nutrient inputs, and the emergence of novel contaminants. These stressors complicate the attainment of good ecological status under the EU Water Framework Directive (WFD), which requires water bodies to achieve such status by the end of the third management cycle. Baden-Württemberg in particular faces challenges due to high population density, intensive industrial activity, and extensive agricultural land use.

Excessive growth of macrophytes and benthic algae is directly linked to elevated orthophosphate concentrations, making phosphorus a key target for water quality improvement and WFD compliance. Measures at wastewater treatment plants (WWTPs) in Baden-Württemberg have reduced corresponding phosphorus emissions to surface waters by approximately half since 2010 alone (UM 2024a). This reduction reflects both enhanced phosphorus removal and the implementation of effluent limits that are stricter than the minimum requirements of the EU Urban Waste Water Treatment Directive (UWWTD) and corresponding German national legislation in sensitive or high-emission areas.

To identify these areas and to quantify phosphorus sources and pathways, Baden-Württemberg has been using emission models for some years (LUBW 2021). Today, the catchment-scale modelling tool METRIS, a regionally refined version of the MoRE model (Fuchs et al. 2017) is applied. METRIS integrates ten emission pathways, indicating that, in addition to direct WWTP emissions, separate storm sewer discharges and especially the predominant combined sewer overflows also contribute significantly to phosphorus inputs.

The large number of retention structures and complex sewer systems pose challenging conditions. Measurement systems to monitor overflow frequencies and durations have been established for approximately 75 % of the approximately 7,000 combined sewer retention facilities (UM 2024a) and support pollutant load modelling for the optimization of sewer network management. In addition, urban water resource management strategies such as reduced impervious surface runoff and decentralized stormwater management are increasingly recognized as necessary to mitigate episodic substance emissions and reduce hydraulic stress on aquatic ecosystems (UM 2025).

Parallel to nutrient reduction efforts, Baden-Württemberg has advanced micropollutant removal at WWTPs in recent years (LUBW 2023). Starting from individual plants and case studies from the

late 1990s to the 2010s, today approximately 20 % of WWTP effluent in the state is already treated with targeted micropollutant removal technologies in a total of 34 WWTPs (KomS 2026).

Unlike phosphorous removal, the regional approach to advanced treatment has been completely voluntary. Instead, the state published recommendations for site prioritization at emission hotspots, for large WWTPs and for sensitive areas and provides funding for the implementation when the criteria are met (UM 2018 and 2024b). Additionally, a competence center for micropollutants was founded to advance research and support treatment plant operators during implementation as a central hub for information (KomS 2018).

Baden-Württemberg's integrated phosphorus and micropollutant strategies demonstrate how regulatory drivers, modelling insights and combined technological and green infrastructure solutions interact to improve water body status under changing environmental framework conditions. While the wastewater-related activities have provided a head start for a number of the requirements associated with the revised UWWTD of November 2024, the environmental goals of the WFD may not be met in all water bodies of Baden-Württemberg by the end of the third cycle. Wastewater-related measures must continue to be considered holistically, together with measures at the rivers, at the pollutant source, and across all relevant emission pathways.

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Web based river basin management with the MoRE-DE toolbox

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Nutrients and pollutants threaten water quality in surface waters, preventing compliance with legally established environmental quality standards. Knowledge of relevant sources, input pathways and turnover processes is crucial for reducing di□use and point source pollution in water bodies. Current requirements, e.g. those of the EU Urban Waste Water Treatment Directive (2024/3019, UWWTD) and the EU Water Framework Directive (2000/60/EC, WFD) increase the need to link emission and immission information interactively. Both directives address issues relating to the risk assessment of nutrient and pollutant inputs. This requires highly resolved geodata and suitable interactive tools for dynamically linking the available information. In this way, potential risks can be identified in scenario analyses and suitable management strategies developed.

In this context, the web based and publicly accessible MoRE-DE Toolbox (https://sto□eintraegemore.de/) was developed. The web portal presents currently available geodata and model results on soil and water throughout Germany. The data is available topic-specific for numerous catchment-related and administrative areas. Users can visualise (map tool), evaluate (statistics tool) and export data. The web application was technically implemented using the Python framework Django, containerisation with Docker, class-based JavaScript and release management with OpenProject and GitHub. Automated end-point tests based on the Apache Airflow workflow management system help to identify potential errors or inconsistencies at an early stage and continuously ensure the quality of the application. The large amounts of data generated nationwide in a 10m grid are converted into powerful column-oriented data formats and processed using automated ETL processes. This has led to significant improvements in processing times (performance) and correspondingly good usability. Furthermore, an interactive ‘Wastewater Treatment’ tool was integrated into the MoRE-DE Toolbox to link emission and immission information interactively and support stakeholders in their catchment area management. For the first time, this enables a nationwide link between catchment areas and their discharges with the receiving wastewater treatment plants (WWTP). It provides information, e.g. on the proportion of treated municipal wastewater (dry weather runoff and annual wastewater volume) in water bodies and the inventory of WWTP in Germany. For WWTP that must be equipped with targeted micropollutant elimination (4th treatment stage) in the context of the new UWWTD, dilution ratios between riverine runoff and WWTP discharge are provided. A simulation module can be used to perform user-controlled simulations for a selected catchment

area or WWTP, e.g. on the effects of a change in the average total discharge into the water body in relation to dilution ratios, the effects of a change in dry weather runoff from WWTP in relation to dilution ratios and wastewater proportions, and the effects of using wastewater for irrigation purposes on total riverine runoff.

The web application is continuously updated by integrating additional thematic data. Work is currently underway to expand the routing concept for catchment-related modelling of nutrients and pollutants and to map their retention in water bodies during runoff passage nationwide.

3. Abstracts of Poster Presentations

Characterizing Temporal Variability in Continuous Water Quality Data Using Frequency Analysis: Implications for Sampling Strategy Design in Hungarian Streams

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Continuous in-situ monitoring systems generate high-frequency datasets that capture water quality dynamics at fine temporal resolution. This study employs frequency-domain analysis to characterize the temporal variability of multi-parameter monitoring data from small Hungarian streams. The aim is to determine optimal sampling frequencies for each parameter.

Data and Methods

The analysis uses continuous monitoring data from online measurements in Hungarian surface waters, including the Koppány Stream (Törökkoppány and Tamási stations) and the Hosszúréti Stream. Measured parameters are water temperature, dissolved oxygen (concentration and saturation), electrical conductivity, turbidity, and pH, recorded at five-minute intervals. Multi-year datasets are available from university monitoring stations, with detailed analysis currently focusing on summer 2025 data.

Frequency-domain analysis (Fast Fourier Transform and power spectrum estimation) is applied to identify dominant periodicities and characteristic timescales for each parameter. The approach follows principles outlined in classical monitoring optimization studies (Somlyódy and Jolánkai, 1986), examining what temporal frequencies are present in the data and their implications for minimum sampling requirements.

Results

Initial frequency analysis reveals distinct, parameter-specific temporal patterns. Water temperature at Törökkoppány exhibits a dominant periodicity of approximately 24 hours (minimum sampling interval ~12 hours), reflecting diurnal meteorological cycles. In contrast, dissolved oxygen saturation shows an ~8-hour dominant period (minimum sampling interval ~4 hours), likely reflecting biological processes (photosynthesis/respiration cycles) that operate on different timescales than physical drivers.

These findings demonstrate that different water quality parameters have different characteristic frequencies, requiring parameter-specific sampling strategies. Parameters driven by diurnal meteorological cycles may require less frequent sampling than those responding to biological activity or episodic hydrological events.

Current work involves extending the analysis to:

- Additional parameters (conductivity, turbidity, pH) and longer time periods
- Storm event periods to characterize event-driven dynamics
- Multiple monitoring stations to assess spatial variability
- Translation of spectral analysis results into practical, cost-effective sampling protocols

This research represents an exploratory application of signal processing methods to environmental monitoring in small agricultural catchments, combining engineering approaches with water quality management needs and drawing on practical field sampling experience.

Practical Implications

Optimizing data collection frequency is essential not only for maintaining data quality but also for managing operational costs associated with data storage, transmission, and processing. By identifying minimum sampling frequencies that capture essential temporal variability without generating redundant data, monitoring networks can be designed to balance information content with resource efficiency, thereby supporting sustainable long-term water quality assessment programs.

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Fluorescence-based in situ measurement of cyanobacteria: state of the art, potential, limitations, compensation methods and further development of an optical sensor system

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The strong growth of cyanobacteria can lead to the formation of algal blooms. Reports of severe algal blooms, driven, among other factors, by increasing nutrient loads in aquatic systems and presumably by climate change, have risen sharply. Algal blooms can pose significant economic, ecological, and health risks. For this reason, monitoring cyanobacteria at high frequency is important for efficiently managing water resources and ecosystems. One method frequently employed for this purpose is fluorescence-based in situ measurement of cyanobacteria.

This review on fluorescence-based in situ measurements identifies numerous sources of interference that adversely affect the measurements. However, a quantitative ranking cannot be derived from the literature. In some cases, these disturbances lead to fluorescence-probe measurements representing only an estimate of the cyanobacteria concentration. Various compensation methods are identified and described, although more holistic approaches are lacking. Nevertheless, when properly applied, fluorescence probes demonstrate significant potential, for instance as early-warning systems in risk management or as components of cyanobacteria forecasting models.

Moreover, this work establishes an experimental and conceptual foundation for the further development of an optical probe into a fluorescence-based probe for in situ cyanobacteria measurements. It focuses on systematic initial development steps, in particular the evaluation of the fundamental suitability of existing optical probe systems for fluorescence excitation and detection. For this purpose, prototypes are tested under laboratory conditions using the fluorophores Rhodamine WT, Uranine and Pyranine. The results show that, in its current configuration, Sensor 1, which utilises a broadband xenon flash lamp, is not suitable for the intended application, as the weak fluorescence signal is likely masked by the lamp spectrum, rendering it indistinguishable. Sensor 2 uses an LED as light source and, in combination with an external detector, enables reliable excitation and detection of fluorescence. This work demonstrates the pronounced influence of the light source and measurement geometry on fluorescence detectability and provides an outlook on further steps required in sensor development.

Integrating ASTER Remote Sensing and Electric Resistivity Tomography for Post-Fire Hydrological Assessment

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Keywords: Wildfire, Aster, ERT, River-Basin Model, Soil Hydrology

Accurately identifying near-surface rock masses is crucial for understanding post-fire hydrological responses and managing water-related hazards. Combining ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) multispectral images with Electrical Resistivity Tomography (ERT) allows for the characterization of the surface lithological indexes and subsurface resistivity in fire-affected areas of the Bohemian Switzerland National Park in the Czech Republic. We performed surface mineral mapping using the Spectral Angle Mapper (SAM) algorithm and a reference spectral library to identify key mineral phases, including clay, iron oxides, and carbonates. Removal of vegetation by the fire increased spectral contrast, enabling better detection of exposed subsoil layers and transition zones. ERT investigations provided continuous resistivity profiles, which allowed us to delineate the boundaries of high-resistivity zones that corresponded to shallow, solid rock masses. Integrated analysis revealed spatial correlations between mineralogical models and subsurface resistivity. This provides insight into post-fire hydrogeological behavior, such as runoff regime, flow paths, and water retention. The ASTER-ERT approach is a robust framework for assessing post-fire mineralogical and geophysical conditions and provides as a mask layer for hydrological modeling, land cover, and vegetation recovery assessment.

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An open database tool for collection of concentration data from multiple environmental matrices to support inventorying of emissions to surface waters

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As part of the Danube Transnational Project "Tethys" a database system was designed to enable high-quality, interoperable environmental data management, emphasising structured data organisation, rigorous quality assurance, and user-centric access. The tool prioritizes data integrity and usability, supporting data from diverse environmental compartments with the main focus being the support of modelling of emissions to surface waters at the catchment scale.

Core Features and Benefits

The database employs a two-layer architecture to balance technical robustness and user accessibility: a hidden technical layer stores the data with traceability metadata (e.g., creation/modification records), while a user-accessible layer presents compartment-specific curated data in intuitive schemas and specific views for different purposes. This separation ensures efficient data management for administrators while providing straightforward access for end-users.

Data quality is enforced through multiple mechanisms:

- **Controlled vocabularies:** Qualitative attributes use standardized, predefined lists to eliminate inconsistencies (e.g., uniform terminology across datasets).
- **Traceability:** Every record includes metadata on who created/modified it, ensuring accountability, and information on the original data source, including the data owner and licenses attached to the dataset. Information transformed during data preparation/import are additionally stored in its original format to allow for later check of correct transformation or new mapping.
- **Soft-deletion:** Deleted data are retained in a hidden structure, allowing administrators to restore unintentionally removed information.
- **Rigorous quality assessment workflow:** Distinct roles (data importers and quality assessors) are defined to check data after import and before further use regarding quality issues like data format issues caused by the import, missing meta data or data set duplication. The quality assessors review and flag detected issues which subsequently must be resolved before the data are released as quality checked data for usage.

The database supports management of data from several environmental compartments, namely: i) surface water, ii) groundwater, iii) sediment, iv) wastewater, v) stormwater runoff, vi) atmospheric deposition, vii) soil. Data of different origin, e.g. international, national, or regional data sources, can be stored to support emission modelling, e.g. with the approach of regionalized pathway analysis. Besides this main purpose, it is a versatile tool for diverse other environmental management needs. The data structure and controlled vocabularies align with EU standards (e.g., WISE, UWWTD) to facilitate data exchange and reporting, enhancing interoperability across data management systems.

Conclusion

This database tool provides a structured, high-quality foundation for environmental data management, combining robust technical design, based on open software with a user-oriented interface. By prioritising data integrity, traceability, and interoperability, it enables reliable data use for a range of applications while maintaining flexibility for future extensions.

The tool was applied within the “Tethys” project for usage at the Danube River Basin scale and at national scale. The current version is publicly available, with ongoing enhancements to expand usability and functionality.

The Proportion of Treated Wastewater in the Discharge of Large Rivers Based on Spatially Aggregated Wastewater Volumes

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Discharges of treated wastewater from municipal wastewater treatment plants have negative effects on sur-face water quality. Numerous trace substances, including pharmaceuticals and constituents of personal care products, are not adequately removed by conventional wastewater treatment processes. In rivers, they pose a threat to aquatic organisms and can be a risk factor for drinking water extraction from bank filtrate.

The proportion of treated wastewater in the total discharge volume of a river can be used to estimate the pollution load from wastewater-borne pollutants. The evaluation of its spatial and temporal variability enables the identification of particularly polluted sections and critical periods.

Municipal wastewater can vary in composition depending on weather conditions, the type of sewer system, and the area connected to the treatment plant. A distinction can be made between wastewater from households and small industries, storm water, and sewer infiltration water. Due to the different spectrum and concentrations of the contained pollutants, it is reasonable to consider these types of wastewater separately.

The presented method is applied to large rivers in Germany with their international catchment areas. It is based on spatially aggregated annual volumes of treated municipal wastewater. Within Germany, data are available at the federal state level, outside Germany at the state level. Missing values for individual years, states, or single types of wastewater are estimated based on existing data. The next steps involve the computation of population-specific volumes of treated wastewater and, considering the population in the catchment area, the accumulation of the wastewater discharge volumes for the entire drainage basin of defined monitoring stations. The proportions of treated wastewater discharge are finally determined by involving the river discharge volumes at the respective monitoring stations. Validation of the results is done by including measured concentrations of micropollutants that can typically be found in treated municipal wastewater and are poorly degradable in rivers. Using the measured substance concentration and a typical concentration in wastewater effluents, the proportion of wastewater discharge can be estimated.

The study covers the recent past (2006 to 2022) and highlights possible future developments up to 2070. It takes into account the impact of climate change on river discharge and scenarios for population development.

It is planned to apply this method to numerous stations on Germany's major rivers. An example from the Rhine catchment area illustrates spatial differences in wastewater pollution: The calculated long-term (2006-2022) average proportions of treated wastewater from households and small industries amount to around 2 to 6 percent in the Rhine between Karlsruhe and Lobith, while in some tributaries these proportions are considerably higher and can exceed 13 percent in the Neckar, for example. The average annual maximum values during the same period, which are reached during low flow conditions, are approximately twice as high.

The results can help to assess the pollution of rivers with wastewater-borne pollutants, estimate future developments, and develop targeted measures to limit pollutant inputs.

Deriving emission factors for municipal wastewater treatment plants in large river basins

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Emission models are essential tools for establishing micropollutant balances and assessing future management scenarios in river basins. Municipal wastewater treatment plants (WWTPs) represent key pollution pathways. Current practice determines WWTP emissions by multiplying emission factors—concentrations or per capita emissions—with discharge volumes or connected population figures.

This study presents a framework for deriving WWTP emission factors in large river basins. For each substance under investigation, three hierarchical levels of differentiation are to be examined. First, regional differences in raw wastewater concentrations are investigated, reflecting variations in economic potential, consumption patterns, and local regulations. Second, within each established region, differences must be analyzed according to plant treatment technology. Third, for homogeneous treatment stages, differences between plant size categories are to be evaluated.

Although lognormal distribution of concentration data is commonly observed, this pattern is not universal. Therefore, the framework employs nonparametric statistical tests such as the Kruskal-Wallis H-test and PERMANOVA to assess differences between groups without assuming specific distributional forms.

The method was tested on an international database containing concentration measurements for PFOS, PFOA, Carbamazepine and Diclofenac from wastewater plant across 12 countries of the Danube River Basin. For PFAS, only 12 country pairs indicated significant differences, i.e. regional differences can be neglected. Interestingly, tertiary treatment stage plants significantly differed from secondary treatment and “notreat” plants, but the difference between secondary and “notreat” plants was not significant. Not the lowest, but the second lowest capacity category (2000 < p.e. < 5000) indicated the smallest PFOA concentrations, and concentrations increased with plant size. In each case, concentrations significantly differed from neighbouring capacity classes except between the 5000 < p.e. < 10K and 10K < p.e. < 100K categories. For pharmaceuticals, in particular Carbamazepine, Hungary, and to a minor part, Romania indicated significantly higher concentrations than other countries. There was no significant difference between any of the treatment categories (for this investigation, HU data was excluded), however, just like in the case of PFOA, capacity categories significantly differed from one another except for the two largest categories (above 10K and above 100K).

As a conclusion, the most determining pattern is plant size, and – to a lesser extent – treatment stage and regional differences come into play. Further investigations (e.g. effect of sampling method) should still be conducted.

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Identification of sediment inputs via ditches in an agriculturally dominated catchment

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The Kraichbach River, located in a loess-dominated catchment of 83 km^2, suffers from ecological deficits mainly caused by the inputs of total suspended solids (TSS). Potential sources include agricultural land, wastewater treatment plants, and urban systems discharges. Still, it is not known where the fine particles enter waters, limiting mitigation strategies.

In a further long-term study, TSS concentrations were measured in the Kraichbach River under different discharge conditions. In addition, average annual soil erosion and sediment inputs of agricultural areas were modelled to identify erosion hotspots. The modelling results were applied to smaller sub-catchments. To delineate the sub-catchments, a high-resolution (1 x 1 m) digital terrain model (DTM) was used to derive the flow directions and accumulation in order to estimate flow paths. Field surveys during rain events allowed the observation of the flow paths, revealing an extended hydrological network of ditches. Sub-catchments were defined based on an officially mapped water network of the federal state Baden-Württemberg, knowledge of ditches discharging into this water network, and agricultural areas connected to the sewer system. This enables the determination of the area-specific soil losses for each sub-catchment and prioritization of areas requiring reduction measures. However, the exact location where fine sediment originates, remains uncertain.

In summary, using simply topographic data is insufficient to provide a hydraulically connected stream network including ditches. Compared to the sediment input modeling, the sub-catchment approach (ditches) captures areas that are indeed connected to streams contributing sediment inputs. In this study, potential eroded soil inputs via ditches are quantified using a reduction factor of 6%. These ditches are often not included in the Water Framework Directive and therefore not part of the official river network. Although there is no legal requirement to take action, these ditches can still contribute to a significant amount of sediment transport and should therefore also be considered in reduction measures.

A Modelling Framework for Pollutant Transport and Retention Processes in River Networks — Concept and First Simulation Results

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Retention and transport processes in river systems are essential for water quality management and for realistic estimation of pollutant substance fluxes into rivers and seas. The model system MoRE (Modeling of Regionalized Emissions) is a flexible open-source instrument that models pathway-specific substance emissions into surface water on a catchment scale.

To improve current modelling of retention and transport processes, a node-edge modelling approach is introduced in this work. The river system across Germany is divided into short edges with a median length of approximately 7 kilometers. Point sources, such as wastewater treatment plants (WWTPs) are defined as nodes. By comparing the spatial distances between the WWTP discharge locations and both endpoints of corresponding river edge, the nodes will be assigned to either the start or end points of edge. Transport and retention along each river edge are described using first-order degradation kinetics. Parameters such as discharge, river length and depth, flow velocity, temperature and global radiation are included in the model. With this model structure, varying concentrations of selected substances can be simulated under different hydrological scenarios and across river systems based on the regional-scale input data.

The model is currently applied to the Jagst River (approximately flow length 190 km), a right tributary of the Neckar River located in northern Baden-Württemberg. The Jagst catchment consists of seven sub-catchments in MoRE and served as a study area for implementation and testing. The initial simulations focused on analyzing concentration variations along the main river while emissions as well as discharges from smaller tributaries are considered. The simulation results illustrate how factors like hydrological conditions, tributary inflows and flow velocity affect downstream concentrations.

This framework provides a flexible structure, which can be used for different river streams and hydrological conditions. In the next step, further simulations will be taken placed with different representative substances, including persistence and different degradation behaviors. Moreover, this approach will be further extended to river networks across Germany to optimize transport and retention processes for MoRE.

4. Index of Authors

Bachofer, F.	*10*
Bakillari, V.	*9*
Beer, B.	*8*
Bittmann, L.	*8*
Brahushi, F.	*9*
Broer, M.	*18*
Bürger, S.	*26*
Clement, A.	*14, 29, 37*
D'Amico, Q.	*10*
Dittmer, U.	*12*
Dudas, K.	*14*
Duka, I.	*9*
Ertl, T.	*9*
Flödl, P.	*8*
Fuchs, S.	*9, 17, 26, 39, 40*
Fuentes Monjaraz, M.	*16*
Gabriel, O.	*18*
Gebel. M.	*26*
Grill, G.	*10*
Halbfaß, S.	*26*
Honti, M.	*14*
Hora, T.	*10*
Huch, J.	*10*
Huber, M.	*10*
Hübner, G.	*35*
Huqi, F.	*9*
Idel, V.	*31*
Iorio, V.	*10*
Jolankai, Z.	*14*
Kardos, M.	*37*
Kavka, P.	*32*
Kittlaus, S.	*6, 33*
Kovacs, A.	*20*
Knerr, H.	*12*
Laburda, T.	*32*
Lajko, T.	*14*
Lehner, B.	*10*
Luksikova, J.	*10*
Kardos, M.K.	*14*
Keller, C.	*10*
Kristo, I	*9*
Márton Attiláné Virág, K.	*29*
Morling, K.	*17, 26*
Mortel, G. M.	*10*
Moser, L.	*10*
Multhaup, A.	*12*
Nowak, J.	*39*
Ortigosa, N.	*10*
Osten, S.	*6, 33*
Pathak, D.	*16*
Petrov, V.	*16*
Poto, V.	*14*
Prajapati, M.	*10*
Pressl, A.	*9*
Qiu, R.	*40*
Ram, S.	*10*
Roth, A.	*10*
Rovira, S.	*10*
Rubio Iglesias, J. M:	*10*
Ruiz, I.	*10*
Saliaga, V.	*9*
Sallaku, F.	*9*
Sanz, V.	*10*
Schima, B.	*35*
Schwandt, D.	*35*
Sedki, K.	*12*
Sema, X.	*9*
Shallari, S.	*9*

Skura, E. 9
Sogno, P. 10
Sotiri, K. 9
Stern, G. 10
Uhlig, M. 26
Ullrich, A. 26
Van Gils 16
Van Leeuwen, J. 16
Von Tümpling, W. 21
Wagner, A. 23
Weber, N. 5
Wegscheider, S. 10
Wetzel, A. 10
Yildiz, H. I. 32
Zessner, M. 5, 20, 33
Zoboli, O. 5, 6, 20, 31, 33
Zumr, D. 32