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Transboundary Management of Pollutants

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Session 1: Monitoring

A monitoring network platform for automated data assessment and its long-term application as surveillance system for transboundary water pollution

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The high potential of online sensors for water quality monitoring and assessment has been widely recognized during the last decade. Nevertheless, growing complexity of water monitoring instrumentation hampers sensor integration into one monitoring network for automated data inspection, automated export right up to web-based data publication and user friendly data management for further data processing. Despite efforts of sensor developments and of standardization for data interfaces and protocols, challenges regarding the robustness of single signals and the subsequent combination of several devices to gain the complete picture in terms of water quality are obvious.

The examined river Raba flows from Austria to Hungary. Its catchment in Austria includes an area of about 1100 km^2 with significant anthropogenic pressure stemming from industrial as well as municipal wastewater discharges and agricultural production. During the noughties, Hungary raised severe concerns about water quality of River Raba entering from Austria, which even evoked intergovernmental disputes. It took many efforts in the Austrian catchment in respect to monitoring, research, advance industrial wastewater treatment and river restoration to calm down Hungarian concerns.

Already in the beginning of the dispute, it became clear that sound high-resolution water quality monitoring is a decisive tool to observe activities in the catchment and support identification of cause effect relations for water pollution. Since 2005, an online monitoring station installed by the TU Wien little upstream from the border between Austria and Hungary is in continuous operation, provided with financial support from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management. The following parameters are recorded sensor based at sampling intervals of 6 minutes, calibrated and validated against analyses from regular and event based sampling: temperature, oxygen content and saturation, pH, conductivity, turbidity/suspended solids, UV extinction, TOC, NH_4-N, NO_3-N, PO_4-P, filtered and unfiltered TP and chloride. Additional channels, for example flow data from gauge level reading of a national monitoring station in close vicinity, are included into the monitoring network. The monitoring station has to fulfill the following main tasks:

- Continuous monitoring of selected parameters to identify transboundary pollution events.
- Automated plausibility check of monitoring data to avoid real-time presentation of erroneous values and to mark them for post processing.
- Real-time monitoring data publication (http://iwr.tuwien.ac.at/wasser/Raab.html).
- Prompt information of Austrian authorities in case of agreed threshold value exceedance.
- Triggering sampling for laboratory analyses at specific, automatically detected pollution events.
- User-friendly data management for data post processing.

In order to perform these tasks the development of the intelligent monitoring network i^{TUW}mon was necessary and accomplished during the years. The main innovations of this monitoring network are:

- A common, abstract measurement data format, independent from various manufacturers,
- precise, network wide measurement- and cleaning cycle triggering in the time domain,

- measurement station specific, automated plausibility checks delivering a comprehensive first view of water quality and
- seamless data integration from sensor to report level, including a comprehensive data examination and export toolset.

This contribution will present experiences from long-term transboundary monitoring at river Raba with specific focus on the development of the intelligent measuring network i^{TUW}mon and the presentation of examples out of the long-term data on pollution events, modelling substance concentrations from monitored proxy parameters and data reliability.

Ship-borne measurements of enzymatic GLUC activity on large water bodies: A rapid screening tool to localize point sources of potential microbial pollution

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Rivers and lakes are as receiving water bodies widely impacted by discharge from urban or agricultural areas. The utilization of these water resources as reservoirs, or for recreational purposes demands a health related water quality monitoring. Especially in respect to microbiological parameters such surveillance states a time and staff ambitious strategy, which often cannot be implemented into early warning systems. The detection of enzymatic activities has been proposed as a rapid surrogate for the culture-based microbiological pollution monitoring of water resources. Automated on-site measurements of enzymatic activity are nowadays feasible from a technical point of view, have been conducted at stationary monitoring stations and can be used as an indicator for microbiological contamination of water on a catchment specific basis.

In this work, spatial variability of enzymatic activity on large fresh water bodies is highlighted for the first time by means of rapid and automated measurements of enzymatic activity from a mobile research vessel. Surveys have been performed on the Lower Columbia River (WA, OR), the Upper Mississippi River (WI) and on Lake Mendota (WI) covering up to 500 km river course or 50 km^2 lake area, respectively. The aim of the conducted research was (i) to test the technical applicability of prototypes for the mobile determination of enzymatic activity, (ii) to disclose spatial and temporal patterns of enzymatic activity on large water bodies and (iii) to gain information about the habitat specific correlation of enzymatic assays with standard culture-based assays.

The tested prototype proved to be reliable under the challenging set of field conditions to which it was subjected. The results show spatial patterns of beta-D-glucuronidase (GLUC) activity on the surveyed water bodies with a reasonable correlation to culture-based *E. coli* analysis, localizing point sources of potential microbiological contamination such as tributaries. Furthermore temporal dynamics of beta-D-glucuronidase activity of lake water due to changing weather and run off conditions were captured. The capability of rapid enzymatic activity assay as a direct proxy for culture-based standard assays was not confirmed; nevertheless the results show that this mobile and rapid assay has significant potential to enhance the monitoring of water resources. The use of this biochemical indicator as a rapid screening tool on large water bodies may allow a more purposeful selection of sample points for further analyses and has great potential to be implemented into early warning systems. The integration of such prototypes into well-established systems for ship-borne measurements of physico-chemical parameters, such as the *FLAMe*, paves new ground for data interpretation and process understanding.

The impact of the Sava river pollution on biomarkers response in the liver and gills of three cyprinid species

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Due to the presence of a large number of different pollutants, monitoring of the surface water quality based solely on the analysis of a limited number of xenobiotics, cannot be considered as reliable. Beside toxic, these agents can exert genotoxic effects, inducing damage in the DNA molecule, which, if not repaired, could lead to mutations and alterations in cells, tissues, organism, whole population and the ecosystem. The surface waters are under the pressure of both anthropogenic and natural sources of pollution. Additionally, extreme hydrological events, such as water scarcity and flooding, may further impair the state of freshwater bodies. Fish may be exposed to harmful substances through water, sediment and food. In ecogenotoxicity studies, gills are used as they represent the first organ in direct contact with water and waterborne pollutants, while the liver, as a key organ that controls many life functions is used as a major organ for metabolic breakdown of xenobiotics [1]. Common bream (*Abramis brama*), white bream (*Blicca bjoerkna*) and white-eye bream (*Ballerus sapa*) are three closely related, benthivorous cyprinids, native for the Sava River. The sampling site Duboko (23 rkm), on the Sava River, is chosen as it is exposed to the untreated wastewater from the town of Obrenovac (more than 70,000 inhabitants), intensive agricultural activity and close proximity to the largest thermal power plant in Serbia (TENTA) and belonging ash field. This study was conducted to assess the impact of multiple stressors during different seasons on different levels of biological organization, subcellular (genotoxic effect) and cellular/tissue level (histopathological effects), in the liver and gills of three bream species. As a biomarker of exposure DNA damage was measured by applying the alkaline comet assay, while histopathological alterations were monitored as a biomarker of effect. In parallel, concentration of metals and metalloids were assessed in gills, liver and muscle.

Basic physical (pH, temperature, oxygen concentration, electrical conductivity) and chemical (NO_2, NO_3^-, NH_4^+, PO_4^{3-}) parameters were measured on site. Microbiological indicators of faecal pollution, total coliforms (TC), *Escherichia coli* (EC) and Enterococci (EF) were assessed by using a most probable number approach (MPN). Presumptive *Clostridium perfringens* (CP) numbers were determined by using membrane filtration and incubation on TSC (Tryptose Sulphite Cycloserine) media. Sampling of fish tissue for comet assay and histopathological analyses was performed in 2014, during winter (January and February), spring (March and early June), and summer (late June, July, and August), once per month, for a total of 52 specimens. Analysis of metals and metalloids was performed only on fish sampled in February, early June and in August, in total 15 specimens. In the mid May extreme hydrological events led to extensive flooding in the studied area. Comet assay was conducted on the

liver and gill cells according to Kostić et al. [2]. Tail intensity, % of DNA in the comet tail (TI) was used to express the DNA damage level. Histopathological analyses included the use of conventional histological methods, staining of tissues sections using hematoxylin eosine differential staining, and examined under the microscope. The type and the extent of histological alterations were described by using a method developed by Bernet et al. [3]. Analysis of metals and metalloids was performed by inductively-coupled plasma optical emission spectrometry (ICP-OES), and included assessment of concentrations of 16 elements (Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr and Zn). To compare the total metal content in different tissues and through different seasons metal pollution index (MPI) was calculated according to equation MPI = (cf1 x cf2 x cf3 x…cfn) $^{1/n}$, where cfn = concentration of the metal n in the sample [4].

Statistical analysis of data from the individual months showed the highest DNA damage in gill cells during early June (spring). Gill histopathological index (IG) did not show significant seasonal variations, however it was the lowest during winter, the highest in spring, and slightly decreased in summer. A possible cause of this incidence could be a withdrawal of water which took place in June, after the flooding event that occurred in the middle of May. In liver the highest DNA damage was observed during August. Histopathological index of liver showed significantly higher values in summer in comparison to spring. This could be prescribed to a higher metabolic rate of fish liver during warm seasons and also could be a consequence of processing a large quantities of xenobiotics introduced into the water column due to withdrawal of water after floods and sediment disturbance. According to the MPI, gills were under the highest pressure of metal pollution during spring and summer. Liver was under the highest pressure of metal pollution during winter, while the muscle was the least affected tissue during all three seasons.

Overall, gills as the first organ in direct contact with water showed a higher response in terms of DNA damage (molecular level), while the liver as the major organ for processing of xenobiotics both from water and food showed a higher degree of histopathological alterations in comparison to gills (tissue/organ level). Increased response of both biomarkers during spring and summer indicates a joint effect of the flooding event and seasonal changes of climate and hydrological parameters.

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Session 2: Monitoring and Modelling

Multidimensional monitoring of microbial faecal pollution reveals dominance of human contamination along the whole Danube River

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Microbial faecal pollution of rivers is an important problem for a variety of human activities relying on good river water quality. Drinking water production from river bank filtration, water used for crop-irrigation and watering of animals, and river stretches used for bathing are the most relevant river ecosystem services directly affecting the health of humans and animals. In the Danube River basin, microbiological contamination from faecal pollution by anthropogenic sources is considered to be a crucial problem imposing a threat to all kinds of water uses. In many sections, the river and its tributaries receive incompletely treated wastewater leading to serious debasement of water quality. Thus, detailed knowledge on the extent and origin of microbial faecal pollution is crucial for watershed management activities in order to maintain safe water use according to the quality targets. During the Joint Danube Survey 2013, microbial faecal pollution levels were monitored along a 2580 km stretch of the river in the midstream and at both river sides as well as in the Danube´s most important tributaries. In order to track the origin of faecal pollution, host-associated genetic faecal markers for different host groups were determined simultaneously. The spatial resolution analysis was followed by a time resolution analysis of faecal pollution patterns over one year at three selected sites. By this a comprehensive picture of faecal pollution patterns and main polluters along the Danube was created. Along the whole river, human faecal pollution was demonstrated as the main pollution source, while animal faecal pollution was of minor importance. Moreover, our data showed that at several, partly unexpected, sites high pollution levels occurred at the lateral zones of the river while the midstream zone had good microbial water quality. Thus, in order to reduce microbial faecal pollution along the Danube, efforts should be directed towards the new construction and upgrading of wastewater treatment plants especially at the lower sections of the river. In addition, detailed spatial monitoring and surveillance of microbiological water quality along the Danube should be performed, also at stretches where good microbiological water quality is assumed.

Transboundary riverine transport of suspended sediment and chemicals from Czech Republic

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European watershed diverges into three directions in the Czech Republic: Labe – North Sea, Odra – Baltic Sea and Morava – Danube – Black Sea. Czech Hydrometeorological Institute, Department of Water Quality manages continuous monitoring of suspended sediments concentration as well as regular monitoring of chemical quality of these fine particles in basins of major rivers. Monitoring has been started in order to describe solid particles and chemical pollutant concentration and consequent evaluation of their fluxes through river systems. Some of the stations and monitoring points have been established nearby country borders (Germany, Poland, Slovakia / Austria) for monitoring of transboundary transports.

We would like to present outcomes of monitoring in recent years (2014-2015, 2016 – if complete data will be available from laboratory) with evaluation of transboundary fluxes. The focus is mainly on Labe (Elbe) river as its water carries chemicals as HCB, Hg, Cd and TBT into Germany. Simultaneously, level of pollution of river Labe is over average among monitored rivers in Czech Republic that can potentially create thread for water ecosystems in long time perspective. Suspended sediment concentration is being monitored on daily basis and creates together with daily averaged water discharge information basis for evaluation. Chemical load carried by particles is measured four times a year and particles are extracted from water *in situ* by centrifugation. Combining these two datasets we are able to estimate chemical fluxes quite precisely.

Unusually dry period with average water discharge about one third of normal have occurred in 2014-2016 and low discharge records have been broken. Annual discharge was 207m^3s^{-1} and 198m^3s^{-1} in 2014 and 2015 respectively when long term average is 319m^3s^{-1}. Hence, presented period of monitoring can be considered as the lowest possible transport rate. Additional result represents comparison of fluxes in longitudinal scale of Labe where data from five stations along the river basin are evaluated. This can help to determine paths of pollutants in finer scale.

History, results and methodological remarks to monitoring of total organic carbon in the riverine water of Danube River basin under TransNational Monitoring Network (TNMN)

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Total organic carbon (TOC) is not only synthetic indicator of water pollution, but also is an important parameter showing the resultant of freshwater ecosystem productivity and natural regulators of organic matter transfer from land to oceans. The increasing interest of TOC in freshwaters is affected by global changes of carbon cycle and increase of greenhouse gases concentration.
Determination of this parameter was implemented by a part of participated countries from the beginning of TNMN and up to this time is not cover all monitored waters. TNMN data bank can be enriched by data collected by Swiss NADUF, parallel monitoring system from upper Inn River. The recent and direct TOC monitoring in Danube River ends in the Silistra station (375 km from river mouth) and not covers area of river delta. Archived TOC data is not homogeneous caused by not continuous series (especially during high flow), not universal protocol of samples preparation prior instrumental analysis and in some situation the problem of apparatus calibration exists.
Estimation of riverine total organic carbon resources in Danube river basin were presented for the first period of monitoring activity (2005) with limited number of data and rivers. Presented study are based on TNMN database provided by ICPDR from 4 years (2010-2013), contains data from 12 station along Danube river course from Dillingen to Silistra, 10 station in the main tributaries, located near the inflow to Danube and 13 station in tributaries courses or smaller rivers. Waters of Danube River have low TOC concentrations with mean in the range 2,4-4,2 $mgCdm^{-3}$, much lower than other large European rivers. Specific, two times increase of TOC load was documented in Serbian part where the largest tributaries Drava, Sava and Tisa rivers supplied a large TOC load. Lower and multidirectional changes of TOC load in Danube course are resulted by water storage in reservoirs. The Tisa, Velika Morava and Morava (northern) rivers had highest TOC concentrations with means two times more than in main river. Hydrological regime of rivers in the different way creates seasonality of TOC, but TOC variability is lower than river discharge. Unit runoff from subbasins is positively correlated to TOC concentration, but significant negatively correlated to annual export. Generally TOC export from subbasins is low, mostly below 1,5 $gC\ m^{-2}\ a^{-1}$, except a few subbasins where anthropogenic pollutions are noted. In the years with higher river discharge (flood or summer heavy rains) the annual TOC export was twofold o higher than mean data, indicated the large role of hydrological events in organic carbon fate in water transport from land to Black Sea. In the future TNMN the following postulates are proposed:
1. For the full understanding of organic carbon cycle in Danube river basin, TOC monitoring should be more developed in the lowest part, including Prut and Siret rivers basins and also area of delta.
2. Evaluation of sample preparation procedure from high flow periods and interlaboratory standardization are need for more accurate TOC analysis.

Session 3: Modelling

Predicting levels of microorganisms and viruses in river Danube water resources with a lumped hydrological water quality and infection risk model

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The sustainable protection of water resources is a major policy goal worldwide. Inspired by the Rotorua Declaration (HRWM 2011) and the European Water Framework Directive, the microbial contamination catchment model QMRAcatch was recently developed (Schijven et al. 2015). The model domain encompasses a main river with wastewater discharges and a floodplain which is regularly flooded by river water. The tool computes, on a daily basis, microbial and enteric virus concentrations in surface water resources based on input parameter values drawn randomly from predefined statistical distributions. The calibrated model can further be used for investigating faecal pathogen concentrations for specific scenarios. The model was previously successfully applied at the River Danube in Austria and a river/floodplain area focusing on the impact of human faecal sources (Derx et al. 2016, Schijven et al. 2015). The aim of this study was to test the model for the same site for predicting *E.coli* and enterovirus concentrations in the floodplain river with the support of human-, deer-, boar- and bird-associated MST markers for 2012 and 2013.

The model boundary conditions were set at five wastewater treatment plants (WWTPs) along the River Danube (Figure 1). Human faecal sources from visitors and wildlife faecal sources from boar, deer and birds were further set as boundary conditions in the floodplain area. Default values for the microbial and enteric virus concentrations in faeces were assumed based on the literature. Mean daily river discharges, river and floodplain river water temperature and precipitation were read from observed data into the model. The model was first calibrated to the different host-associated MST marker concentrations in the floodplain river and then tested against the observed *E.coli* and enterovirus concentrations in the floodplain river.

This work demonstrates a model application of QMRAcatch linking standard faecal pollution diagnostics, genetic source tracking markers and enteric faecal pathogens in a river floodplain area. This kind of area is often an important drinking water resource. In the studied floodplain area both human and animal faecal sources are present. It was hence possible to calibrate the model to *E.coli* concentrations only with the support of the human and animal-associated MST marker data. The analyses of this paper are seen as the prerequisite for estimating potential levels of human and zoonotic pathogens. Such analyses will thus support the required water safety management strategies to provide safe drinking water in agreement with risk-based water quality targets.

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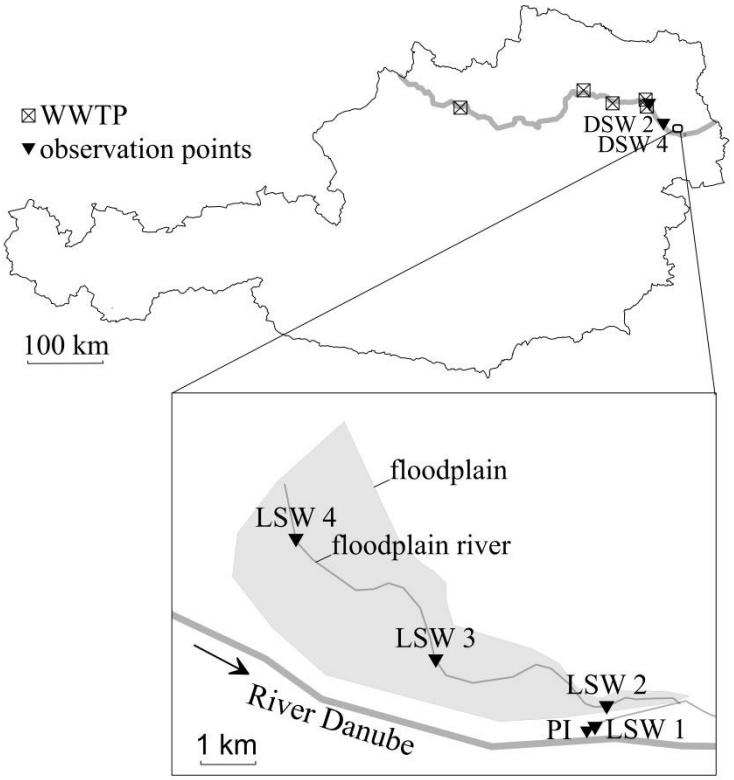

Figure 1. Bird's eye view of the study site.

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Emission inventories for priority substances at catchment levels: Solving the PAH source conundrum with an array of in-stream tools

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Member states have been asked to provide emission inventories for relevant priority substances in their river basins by a tiered process involving point source information, riverine load, pathway and source oriented approaches (Guideline 28 of the common implementation strategy). The suggested approach requires a wealth of information and measurements over longer periods which proves overambitious once it comes to operational scales of river basin management, especially when considering the complex source patterns of a compound group like Polycyclic Aromatic Hydrocarbons (PAH). Here, we present a weight of evidence approach with different methods to elucidate sources, pathways and loads of PAH in the Grand-Duchy of Luxembourg. It starts with classical load balancing at river gauges that are compared to dynamically calculated WWTP, sewer overflow and surface runoff loads. These balances showed that compared to metals, urban drainage and WTTPs are less prominent sources of PAH. These findings are then confirmed by monitoring of flood waves with autosamplers to quantify first-flush contributions by deconvolution of suspended matter chemographs. Land-use oriented base-flow campaigns using suspended sediment nets verified the independence of PAH pollution of urban surfaces and pointed to alluvial contaminated sites as major sources. Finally, a combined method involving the use of sediment nets and Empore disk passive samplers in longitudinal profiles allowed narrowing down source areas and emission pathways of PAH on river stretch scale. The latter approach is now actively used to identify source locations based on preliminary indications by contaminated site cadastres. The presentation will illustrate the complementarity of the different methods to tackle PAH emission sources.

Quantification of Emissions across International Boarders

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River basins models have proven to be an effective tool to manage water quality on the scale of watersheds. To do so they have to be fed with numerous input data characterizing catchment properties and substance concentrations in different runoff components. This is a challenge if one works in a national river basin but becomes a serious problem if the river basin spreads over two or more state territories. The availability and quality of the required information will be very different as well as data formats and methods of data acquisition and analysis, just to mention some problems. The Inn basin, which is spread over the territories of Switzerland, Italy, Austria and Germany, is a perfect example to identify the existing problems and to elaborate strategies to counteract them. Coordinated research projects were launched by The Environment Agency Austria, the Bavarian Environment Agency and the Germany Federal Environment Agency to examine the Inn-Salzach aiming on an operative tool to manage nutrient and pollutant flux. The research projects include work packages on data harmonization and acquisition as well as on the adaption of certain model approaches. To give some examples: A new and coordinated system of hydrological sub units was established and a new water model covering the whole investigation area (LARSIM-ME) was tested and implemented. Due to the alpine character of a considerable part of the catchment area, the quantification approaches for suspended solid input via erosion was adapted. To validate model results a surface water monitoring program is a vital part of the project. The program includes the investigation of water and sediment quality parameters. Monthly water samples were taken at ten different sites in the Inn catchment and analysed for seven heavy metals, 26 organic micro pollutants including pesticides, biocides, pharmaceuticals and polycyclic aromatic hydrocarbons (PAH). In addition, large volume samplers were installed at five of the ten sampling sites to collect flow-proportional composite samples in 1000 L sedimentation tanks which allow the analysis of solid and supernatant water separately. The large sample volumes ensure sufficient amounts of solids for a valid analysis of particle bound micro pollutants.
The contribution will present and discuss both the results of the model development and the monitoring program.

Mass balance of organic contaminants at the scale of the Seine River basin (FRANCE)

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The Seine River basin drains an area of 78 650 km² which accomodates 25% of the French population and 30% of its industry. Thus, it is highly impacted by anthropic activities. As such, the Seine River basin has been the place of numerous studies, mostly achieved within the PIREN-Seine research programme, aiming to quantify several groups of organic micropollutants in different environmental compartments and urban matrices. Among the monitored organic persistent pollutants, Polycyclic Aromatic Hydrocarbons (PAHs), Polybrominated Diphenyl Ethers (PBDEs), Polychlorinated Biphenyls (PCBs), Phthalates (PAEs) and Alkylphenols (APs) have been considered. These compounds originate from very contrasting sources in the environment. PAHs are mainly emitted during combustion processes such as household heating and road traffic. PBDEs were mainly used as flamme retardants in plastic and textile industries. Although PCBs are forbidden in France since 1987, they have been extensively used as electric insulators and they can still be found in the environment. Phthalates are still used nowadays as plasticizer. Finally, PFAs can be found in many daily consumers goods as waterproof textiles or non-stick coatings. Along with their diversified sources, differences in their physico-checimal properties strongly impact their environmental fate.

This study aims to establish mass balances at the Seine River basin scale for these 5 groups of organic compounds. Mass balances constitute efficient tools for understanding transfer pathways of pollutants in the environment. Databases collected by several research teams working on the Seine River basin were used for the calculations. Along with stocks in soils, most of major environmental fluxes were quantified including atmospheric fallout, erosion from soils, river exports and wastewater treatment plant discharges. A focus on urban mass balances was also carried out considering wastewater, runoff, and sewage discharges at the Paris City scale.

First results show very contrasting dynamics depending on organic contaminant groups. PAHs were found to be the most abundant compounds in the soils of the Seine basin. The other contaminant stocks were smaller (PAHs > PAEs > Aps > PCBs > PBDEs), likely due to differences in emission sources. In atmospheric fallout, Aps were found to be the most abundant compounds. AP, PAE and PAH atmospheric fallouts were homogeneous across the basin, but highest PBDE and PCB fluxes were measured on Paris City and on agricultural areas respectively. These results suggest that PBDEs present very specific sources and that agricultural soils may act as secondary sources for PCBs. The largest fluxes in the Seine River downstream Paris City were measured for APs and PAEs and reached about 10 $t.yr^{-1}$. The lowest fluxes were observed for PBDEs and PCBs (ca. 50 $kg.yr^{-1}$). Soil erosion seems to be a predominant contributor to PAH and PCB fluxes in the Seine River. For PAEs, wastewater treatment plant discharges appears as a significant contributor. Concerning PBDEs and APs, erosion and urban discharges were approximatively proportionnal to fluxes in the river. However, so far, some sources remain unidentified or poorly quantified and futher treatment of results is required.

Session 4: Modelling and Management

Spatial relationships between sources of micropollutants and drinking water supply in the Rhine basin – Misfit between physical affectedness and regulatory embeddedness

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The contamination of surface waters with micropollutants (MPs) like pesticides or pharmaceuticals from various sources is an important topic in many river basins. MPs may not only impair the ecological status of streams, but can also pose problems to drinking water providers relying on bank filtration, artificial groundwater recharge or lake water purification. Water suppliers are therefore directly affected by pollution originating from upstream areas. Due to the persistence of many MPs in the aquatic environment the sources of pollution may be situated well beyond the jurisdiction of actors responsible for water quality at the location of drinking water abstraction. Therefore misfits may exist between the spatial extent of the pollution problem and the spatial coverage of actor networks that should manage the problem. In this project we specifically address the question to which degree such a misfit exists for drinking water suppliers along the River Rhine. We focus specifically on agricultural herbicides, biocides from material protection on buildings and pharmaceuticals from households. We combine a spatially distributed mass flow analysis with a georeferenced analysis of actor networks in the water sector in the Rhine basin.

On the basis of GIS land use data (agricultural land, buildings and wastewater treatment plants), statistical use data for the selected chemicals were downscaled from national level to small catchments to identify the mass of specific chemicals potentially available for release to the aquatic system. The transfer to streams was simulated with a parsimonious mass flow model that was calibrated at a number of small catchments in Switzerland with adequate data on MP use in the catchments and corresponding load measurements in the streams. Losses of agricultural herbicides were modeled with empirical loss rates related to site-specific discharge, and biocide losses were related to precipitation. For pharmaceuticals, the release was related to human metabolism rates and elimination rates in WWTP. For the routing through the river network, different approaches including a spatially-distributed setup of the hydrological modeling software AQUASIM were used.

The model validation on independent data generally yielded satisfactory results but indicated that input uncertainty for the compounds might impose substantial limitations to the accuracy of model predictions. The application of the calibrated model to the entire Rhine basin down to the German-Dutch border yielded plausible results when compared to observed load and concentration data.

The resulting spatial information on the origin of MP discharge into the river network that may affect the drinking water supply in Basel and Düsseldorf was compared to their respective actor networks for identifying the potential spatial (mis)fit. The analysis demonstrated that these networks do not properly cover all relevant MP source areas. Specifically, they do not account for the transboundary character of the problem of MP pollutions of large streams. Future studies will investigate how such spatial misfit situations can be tackled from a water governance point of view.

Cross-border consequences and conflicts of interest in River Basin Management Planning: the case of the Tisza River (Ukraine, Romania, Hungary, Serbia)

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Similar to lake eutrophication, stream eutrophication is driven by enhanced nutrient loads. However, due to both the complex interactions between the different parts of river networks and the unidirectional transport, the relationship between local water quality and nutrient loads is much more complex in streams than in lakes. Higher influence of connectivity, flow conditions, travel time and other abiotic factors may often mask and even reverse the relationship between local water quality and nutrients. It is because of these manifold interactions that successful management of water quality problems must treat stream networks and their catchments as a single entity.

The Tisza River (in Hungarian; Tisa in Romanian and in Slovakian, Тиса in Ukrainian and Serbian, Theiß in German) is the longest tributary of the Danube and a major development axis in Central East Europe. In its upstream, Ukrainian section, the Tisza is a nutrient-poor river with low planktonic productivity. The hypertrophic Szamos River (in Hungarian; Someș in Romanian, Somesch in German) dramatically changes the trophic status of the twice larger Tisza. Water quality of the Szamos profoundly determines the ecological status of the next 500 km section of the Tisza due to the absence of other major eutrophic inflows. An analogous situation arises some 10 km upstream of the Hungarian-Serbian border, where the Maros River, the largest and most eutrophic tributary enters the Tisza. Thus, to improve the ecological status of the recipient river, nutrient and phytoplankton inputs from the Szamos and Maros rivers should be controlled. Although both the Tisza and its two large tributaries have international basins, the cross-border contexts are asymmetrical. The Tisza, downstream of the confluence of the Szamos passes Hungary and Serbia. The Szamos and Maros basins are principally in Romania, only their narrow lowermost river corridors are in Hungary. Therefore, management efforts of host countries driven by socio-economic rationality are focused to different target areas and the countries are reluctant to harmonize their management plans. Hungary and Serbia are primarily interested to improve trophic status of the Tisza River, while Romania strives to enhance sanitation in the heavily underdeveloped regions of the Szamos and Maros basins that could, in turn, worsen downstream water quality.

To seek potential solutions to this deadlock, we developed a spatially distributed nutrient emission and algal growth model for the entire Szamos catchment. The model was used to draft packages of management measures that would satisfy objectives in each country involved. Four management packages were analyzed with altered landuse or cultivation patterns, and diverse infrastructural development options. Besides these, benchmark states were established to evaluate the relative benefits of management measures. The analysis suggests that a compromise solution exists. The heart of this solution is the upgrade of major wastewater treatment plants selected on the basis of their influence on water quality along the whole river network downstream of the point of sewage emission. Due to its hydromorphological characteristics, Szamos seems to be naturally more productive than the Tisza, but the present algal biomass could be reduced by 40%.

Estimating field-relevant degradation rates for emerging contaminants in the Danube Basin

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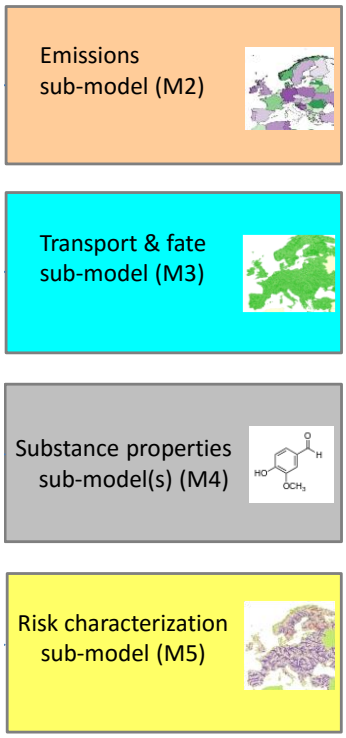
The project SOLUTIONS (7th Framework Programme for Research and Technological Development of the European Commission, Grant agreement no. 603437, 2013-2018) targets the management of present and future emerging pollutants in land and water resources (Brack et al, 2015).
Besides extensive research in the field and in the laboratory, SOLUTIONS will carry out "integrated modelling" on a pan-European scale. The integrated model consists of sub-models for simulation of emissions to water, soil and air, concentrations in water, sediment and biota, substance properties (e.g. partitioning, toxicity) and human health and ecological risk (see Figure).
The combined emissions (van de Meent et al, in preparation) and transport and fate sub-models (Lindim et al, 2016) are in the process of being validated in Case Studies. A key field dataset in this respect is the 3rd Joint Danube Survey (Liska et al, 2015), which provides measured concentrations of several hundreds of chemicals at 68 sites along the Danube and in the mouths of her main tributaries.
Initial simulations showed that the specification of field relevant biodegradation rate constants for emerging compound is a large challenge. Biodegradation rates in the field are known to be affected by various environmental factors and to be highly variable. In addition, for newly emerging compounds, we have to rely on QSARs to estimated biodegradation rates (Greskowiak et al, in preparation).
The comparison of simulation results to JDS data shows that often simulated longitudinal gradients differ strongly from measured gradients. Where observed longitudinal concentration gradients along the Danube main stream are weak, initially simulated gradients showed a strong decrease in a downstream direction. By sensitivity analysis we established that this could well be caused by an overestimation of (QSAR based) estimated biodegradation rates. Another theoretically possible cause would be an extremely strong increase of area specific emissions going in a downstream direction. We consider the latter explanation unlikely, because there are no plausible reasons to explain such an increase.
Following this conclusion, we used the transport and fate model to investigate which range of field-relevant degradation rates will result in realistic simulated spatial concentration gradients. Thanks to the unique data compiled under JDS3, we were able to establish such ranges for a wide spectrum of pollutants.
In the near future we will explore if we can use these insights to develop a methodology to establish field relevant degradation rates for emerging pollutants based on QSAR estimates, which can be used for integrated model simulations in cases where field information is not yet available.



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Session 5: Management

Numerical Modelling of Trace Substance Concentrations in the Ruhr River Catchment – A Tool for Operational Planning

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The pollution of surface water bodies by trace substances is one of the most discussed political and public topics in the field of water management and environmental protection in North Rhine-Westphalia. Wastewater treatment plants (WWTP) play a key-role in this context, as they are a primary intersection for the emission of trace substances into the aquatic environment. The Ruhrverband operates a total number of 66 WWTPs within the catchment basin of the river Ruhr. Therefore it is his task to develop a strategy to cope with the upcoming challenge of trace substances in the Ruhr.

As part of the monitoring program „Ruhrlängsuntersuchung“, established since several decades, the Ruhrverband measures the concentrations of a broad variety of substances along the Ruhr. Thirteen measurements with a total number of up to 650 parameters at 12 sampling points are part of this annual program. In addition several monitoring programs were conducted to quantify trace substances in the rivers Lenne, Baarbach, Volme and Rahmede, all discharging into the Ruhr. The effluent concentration of trace substances was also measured at several WWTP outlets. In combination with the results of a research project at Schwerte WWTP (Keysers et al., 2013) regarding treatment strategies and techniques, the Ruhrverband holds a considerable amount of data about the concentrations and loads of trace substances in the Ruhr river. Despite the considerable effort, this data is not sufficient to realize a comprehensive approach for a strategic planning process. Therefore, a close combination of monitoring and computational modelling is necessary.

The Ruhrverband chose the geo-referenced regional exposure assessment tool for European rivers (GREAT-ER) which has already been successfully applied (Kehrein et al., 2015) to estimate the concentrations of Diclofenac in the Ruhr and its tributaries. This software allows geo-referenced modelling of concentrations and loads by point source emissions in the river catchment.

For application by the Ruhrverband the river catchment was revised and updated by the Institute of Environmental Systems Research at Osnabrück University. The discharge values were re-calibrated to the median of natural discharge (Q_{183}). Based on the available set of data calibrated models for Diclofenac, Carbamazepin, Sotalol, Metoprol Sulfamethoxazol and 1H-Benzotriazol were created. As an example Figure 1 presents the simulated concentrations (dashed line) of Diclofenac along the Ruhr. In comparison the mean values of the monitoring points (2014-2016) are shown in relation to Q_{183} (triangles) and to the discharge at the moment of sampling (squares).

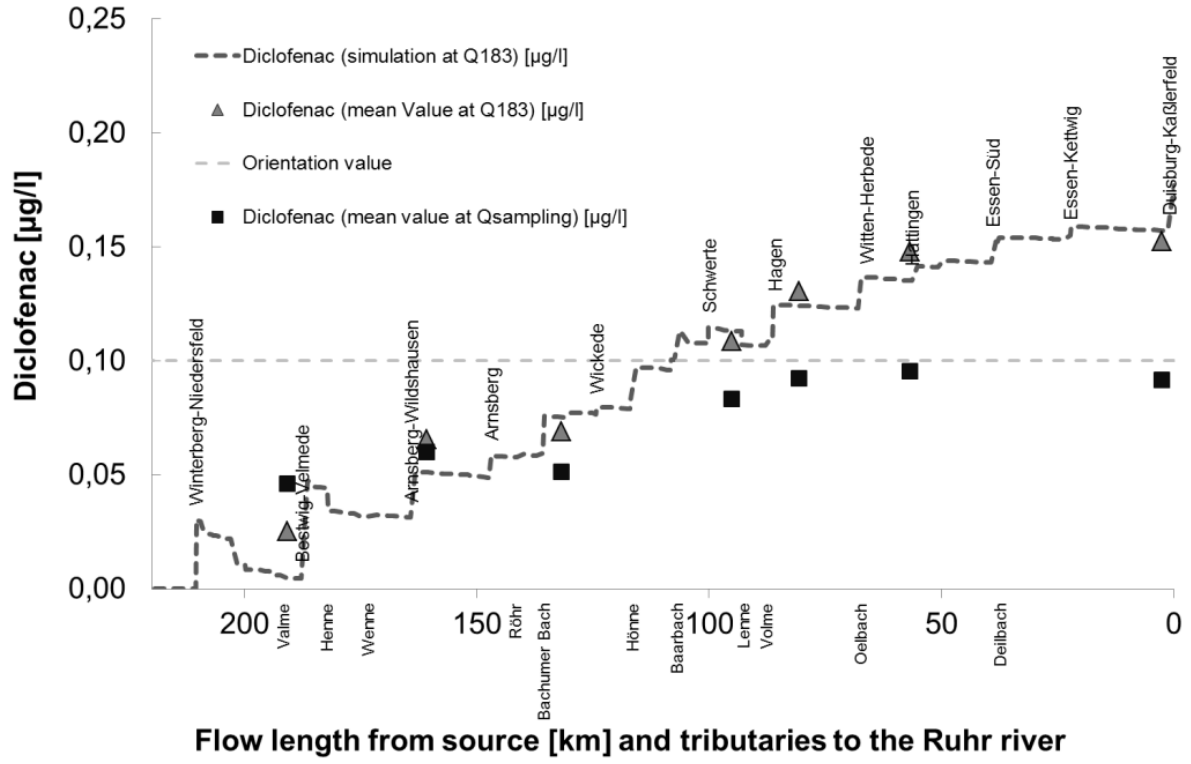

Figure 1. Concentration of Diclofeanc along the Ruhr at Q183

The simulation only refers to loads of point source emissions from WWTPs and effects of elimination in the longitudinal course of the river were not included to gain a worst case scenario of the occurring concentrations. The direct comparison of the simulated and measured values shows good correlation. Therefore, the model simulations appear suitable to estimate the concentrations for complimentary use with the monitoring data.

At the Ruhrverband, GREAT-ER was introduced to identify the key points of significant stress and to assess their impact on the aquatic ecosystem. Within a causality analysis GREAT-ER will be applied to estimate the effect of potential measures. Therefore GREAT-ER has the potential to become a useful tool for future operational planning.

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From end-of-pipe to control at source – Source control strategies in the water- and wastewater sector

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In Sweden, the water- and wastewater sector has developed strategies for reducing and controlling environmental pollution at source through a practice called *Uppströmsarbete* ('upstream work'). This practice was first initiated to increase the quality of sewage sludge. Even if the positive effects of 'upstream work', to a large extent, can be seen in the water as well, the practice is still often associated with sewage sludge quality. An expanded concept to incorporate source control efforts for the whole water cycle may lead to more holistically sound solutions. As many types of environmental pollution is of persistent character, the risk with non-holistic approaches is that the pollution might switch medium, such as that water treatment move pollution to sediment or soil. In this paper we investigate a range of upstream measures to hinder or reduce environmental pollution/environmental toxins in the water cycle and the cycle of nutrients. This means that strategies for wastewater, sewage sludge, stormwater and raw water for drinking water purposes are included. The main aim of the paper is to present an overview of the current source control practice in the water- and wastewater sector and discuss the potential for future developments of the practice. It is based on an inventory of methods and tools to facilitate source control in Sweden and internationally, and a survey and interview based investigation of the current source control practice and regulations that shape the practice in Sweden. The paper presents the results of the investigation of Swedish source control practice with a particular focus on the obstacles that currently hinder systematic and efficient source control and how the organisations tackle these problems. In a pre-study, there were indications that there are some technical, institutional and organisational difficulties regarding the work with source control measures in the sector, which is why this is a focus area. The paper also discusses potential further developments of source control measures as well as potential opportunities based on some examples of particular initiatives from Swedish municipalities.

The Role of Transnational Municipal Networks in Transboundary Water Governance

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The transboundary nature of stressors impacting shared water bodies has been traditionally recognized in agreements between nation states. Several developments have led to new layers of cross border environmental actors, including regional and city level interactions. This proliferation of non-state actors is witnessed in two large water bodies, the Baltic Sea and the North American Great Lakes. In both regions, transboundary water governance was led by nation states in agreements to improve heavily contaminated waters, the Helsinki Convention (1974) and the North American Great Lakes Water Quality Agreement (1972), respectively. Whilst there has been much research on transnational regional networks, especially in Europe, there has been less theoretical work done on transnational municipal transboundary water networks due to the delay of recognition of the legitimacy of these local government actors. This paper aims to examine the role of the transnational municipal networks in transboundary water governance by looking at the case studies of the Union of Baltic cities in the Baltic Sea region and the Great Lakes and St. Lawrence Cities Initiative in the North American Great Lakes Basin. It does this by assessing the role of these transnational municipal networks in bridging water governance gaps in these regions.

2. Poster presentations

Trans-boundary Water Management for Human Development: Case study of Ethiopia and Sudan in the Eastern Nile Basin

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This paper aimed at investigating the essence of the trans-boundary water management and its role in boosting the speed-up of the regional cooperation, and to identify the complications which may affect the water course riparian countries; Sudan and Ethiopia in the Eastern Nile Basin are taken as a case study. The paper also tries to find out the optimum means for an integrated method of the water resources so as to determine the role of the concerned authorities in strengthening the mechanisms of regional cooperation for the realization of the common vision.

The paper adopted an interdisciplinary approach due to the intricate and interrelated nature of the subject of the trans-boundary water management, in term of different disciplines, whereby assistance was sought of each of the historical, descriptive, analytical and case study methods. The paper also relied on exploration and identification of the requirements of each state separately; first of all on the national level and secondly, it proceeded forward with these needs and requirements by adding the regional dimension thereto so as to be able to know what is unacceptable to these states for their planning and implantation on the level of all riparian states. This, in addition to conducting of interviews with the experts and the persons working in the fields serving the trans-boundary water management, besides analysis of the available documents from the seminars and workshops, especially the series of the Nile conferences which were held in 2002, and other local, regional and international conferences and workshops.

The paper arrived to several findings and the main among them is that the most comprehensive and agreed upon vision of the riparian states in the trans-boundary water course for cooperation in the management of the common water course stem from special concerns of a paramount importance for the sake of confidence building. These concerns are attained through: preservation and maintenance of security in the common borders, sustainable development, irrigation of agricultural projects, hydro-electric generation of clean and environment maintaining energy, floods risk reduction, drought mitigation, commercial exchange, transportation and communication. As to the risks and negatives, the riparian states of the cross-border course, mainly Sudan and Ethiopia – in the case study – has agreed that the lack of a political will and inadequate finance for the planning and implementation of joint projects will strengthen and aggrandize the risks and negatives between the riparian states and this, in turn, will impede the economic and social integration and cooperation of the riparian states in the trans-boundary water course, including Sudan and Ethiopia, the case study.

The paper recommended the need for serious cooperation in the field of trans-boundary water management in the Nile Basin and the necessity and importance of adopting of the principle of the economic and social benefits exchange between the riparian states in the watercourse. This is in addition to the need to take in consideration the views of the beneficiaries, the stake-holders of the governmental authorities, the private sector and the civil society organizations.

Quantifying the Effect of Stream Restoration in the Coastal Plain of North Carolina

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North Carolina State University

In 2011 construction began on the U.S. Highway 70 Goldsboro Bypass (R-2554). Under Section 404 of the Clean Water Act (CWA) environmental mitigation was required. Mitigation was completed by restoring an agricultural canal to a Rosgen type E stream connected to a floodplain. Restoration projects in North America are on the rise as is the money spent to conduct these projects. Since 2000, roughly $15 billion have been spent on stream and river restoration in the United States without a consensus on the effect of the restorations. Lack of consensus is a result of an absence of monitoring in many projects and poor monitoring methods in those where monitoring took place. Fewer than 10% of projects conducted any kind of monitoring and for projects where monitoring was conducted, methods were poor. Current restoration monitoring relies on infrequent sampling, shown to have large cumulative uncertainty. The large uncertainties lead to imprecise conclusions. In order to reduce the cumulative error while monitoring, state-of-the-art S::CAN Spectro::lyser spectrophotometers will be used to monitor the restoration conducted as a result of the R-2554 construction. Three years of water quality and hydrology data were collected prior to restoration which will compared to the data collected after the restoration. Deploying in-situ spectrophotometer will allow for data to be collected at high frequency, 15-minute intervals, thereby increasing precision. By monitoring the restoration over multiple years, seasonal and long-term changes can be quantified as the restoration matures.

Tracing the origin of nutrients, pesticides and heavy metal loads in a river basin

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The Water Framework Directive (WFD) Explorer computes transport and decay of nutrient loads throughout a catchment (Roovaart et al, 2013; Burger et al, 2014). A typical WFD-Explorer schematization consists of a network of drainage basin and surface water nodes. Seasonal steady state simulations yield nutrient concentrations in each node as well as water fluxes between connected nodes (Roovaart et al, 2014). Recently, a new feature was implemented to trace emissions throughout the system. This makes it possible to determine the origin and he composition of the total load reaching a particular water body. The tool allows the user to define emission types and origin areas to be distinguished in the mass balance. Emission types indicate activity or process at the source of the emissions (e.g. WWTP's, industry, atmospheric deposition, agriculture, etc.) whereas the origin areas indicate the geographic origin of the emissions.

For each combination of substance, emission type and origin area, a unique tracer is created.

Tracers have the same characteristics as the substance they represent and hence undergo the same decay processes in the model as the original substance. The tracer emissions are derived from the original substance emissions. As a result, the sum of all emissions of a given substance is equal to the total of all its tracer emissions. Hence, in each node, the sum of the computed tracer concentrations representing a same substance will equal the concentration of that substance. Dividing the tracer concentrations by their total (i.e. the substance concentration) yields the fraction of each tracer. Because each tracer corresponds to a single emission type from a specific origin area, the computed fractions represent the relative contribution of each emission type and area. Finally, the fractions can be multiplied by the total load to obtain absolute contributions in kg.

The method described above is easy to perform manually for small cases but quickly becomes unmanageable for larger applications. The workflow was therefore automated using the Python scripting capabilities of the Deltares Delta Shell framework hosting the WFD Explorer (Donchyts and Jagers, 2010). The result is an add-on toolbar in the WFD Explorer. The toolbar guides the user in defining origin areas, renaming and aggregating emission types, setting up simulations and generating graphs or .csv exports from the calculations.

In 2016 two pilots were performed with the tracer tool on a national and a regional scale. The tool is developed in collaboration with Waterboard Limburg. In a first pilot the origin and types of emissions of WFD substances including total nitrogen, total phosphorus, heavy metals and pesticides were analyzed (Figure 1.) (Roovaart et al, unpublished). The second pilot focusses on heavy metal concentrations in Dutch national waters exceed the WFD target values. Insight in the distribution and origin of heavy metals will support the implementation of appropriate mitigation measures (Figure 2) (Chrzanowski et al, unpublished).

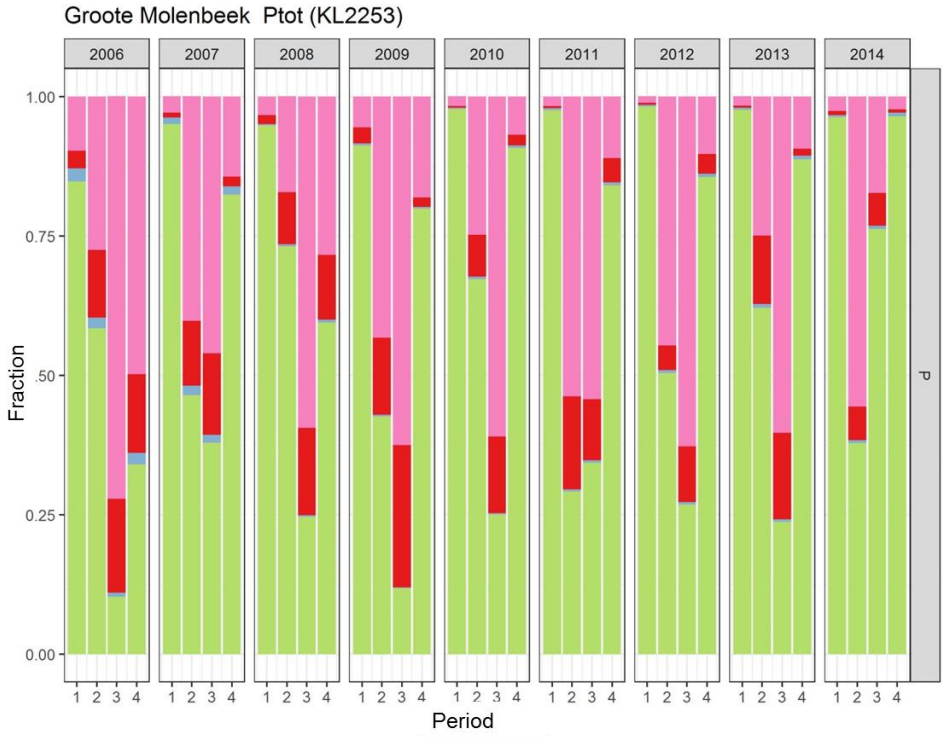

Figure 1. Application of the tracer tool in the Southern Dutch stream Groote Molenbeek for total phosphorus for the years 2006 until 2014 per quarter and the relative contribution of different emission types and origins (red: WWTP, green: Agriculture, pink: Belgium, blue: Other).

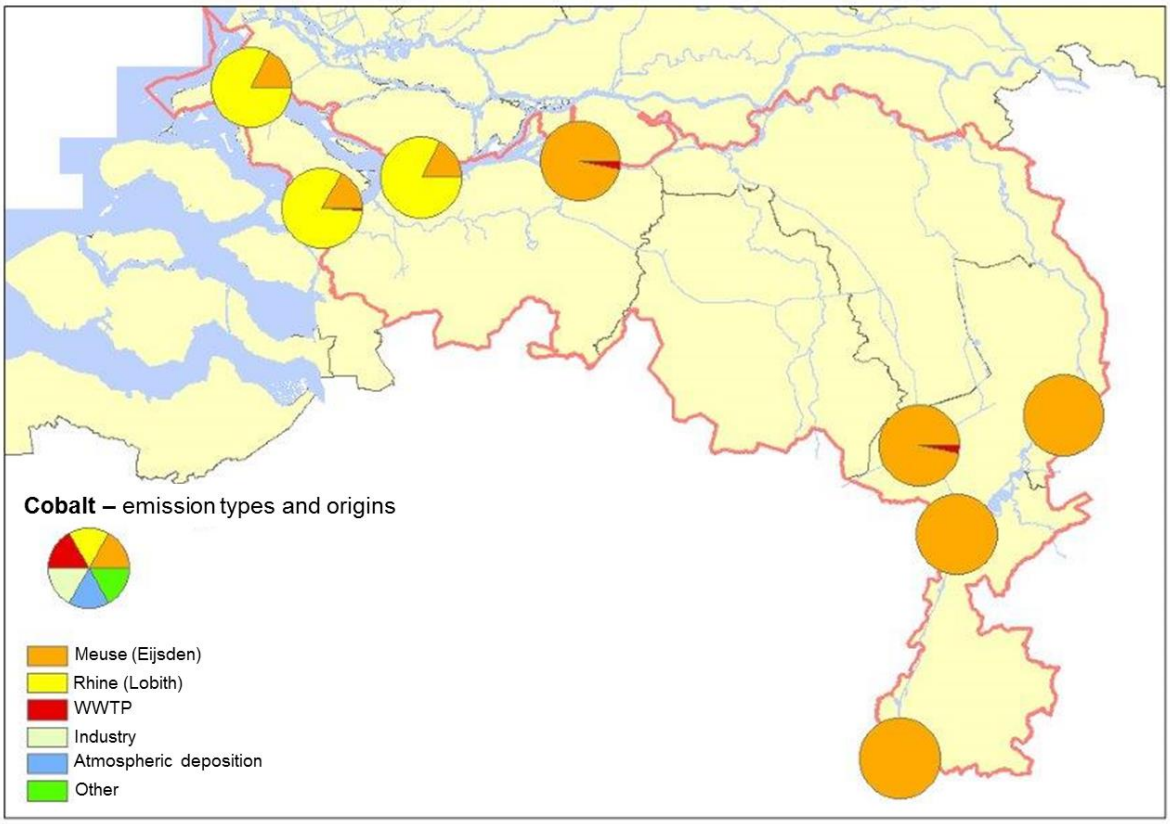

Figure *2* For several Dutch national water bodies with WFD monitoring locations the contribution of different emission types for cobalt is given.

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Harmonization of complex input data – lessons learned in the transboundary Inn catchment

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A comprehensible water management at (sub)basin level regarding chemical pollution of rivers, requires a wide variety of data (data on emissions, geodata, land use data, etc.). Data requirements for a sound water quality assessment highly depends on the spatial and temporal scale but even on the methodological approaches used for an assessment of substance specific impacts at the basin level. Broad approaches on large scale can be handled on base of large scale data sources, bearing in mind, that conclusions drawn from this exercise should have an adequate level of abstraction. Consequently, such approaches provide an overview of spatial differences and a first general designation of catchments with potential risks and highlight the needs to have a closer look on water quality issues. If, in a second step, catchment related investigations are aimed at i.) a regionalized characterization and quantification of sources and pathways (source/pathway analyses) ii.) the definition of programs of measures and iii.) the quantification of their effect to reduce substance specific emissions (management of material flow) in river basins, it is obvious that methodological requirements and data needs will increase significantly. However, often methods and data for river basin management issues are available on the level of administrative borders, like political municipalities, federal states or provinces and countries, which from an administrative point of view is reasonable. As international river basins do not stop at administrative borders and in order to generate transnational input data sets with comparable and consistent data quality, it is essential to harmonize data generation and data processing methods. Hence, beside the quality of approaches and availability of required input data the harmonization of different methods and complex input data sets significantly influences the quality and consistency of the results.

The Inn basin, situated in the territories of Switzerland, Italy, Austria and Germany, is a suitable example for identifying problems regarding differences in data availability and data quality and for elaborating strategies to counteract them. A coordinated research project was launched by the Germany Federal Environment Agency, the Bavarian Environment Agency and the Environment Agency Austria to examine the Inn-Salzach catchment aiming on the development of an Emission Model (MoRE) to manage nutrient and pollutant fluxes.

The contribution will present and discuss the consequences of a hypothetic use of non-harmonized detailed input data from Bavaria and Austria in a transboundary approach. Furthermore, on behalf of three data sets (landuse map; soil loss quantification; calculation of nutrient surpluses) different requirements, barriers and approaches for data harmonization are discussed.

Investigation of Land Use Effects by Using a Hydrodynamic Model for Ankara Stream Watershed

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Water resources, their protection and regulation are essential to meet drinking water demand and to prevent hazards, e.g. flood events. Therefore, exploring and evaluating the results of human activities with direct influence on water resources and hazardous events is of concern for researchers in the hydrology area. Especially, new developments interfering with the amount of drinking water and hazard risk are major interests as these strongly depend on the increase in population which in turn is influential for water resources. As a result of urbanization, changes in concentration time, amount of infiltrated water, and overflow rates are expected to occur. Therefore, the impact of urbanization on water resources and hazards should be investigated to avoid present and future problems such as floods, droughts, and pollution. In this study, Ankara Stream Watershed located in Ankara is selected as the study site. Ankara Stream Watershed has 7,140 km^2 of drainage area and the stream length is 140 km. It flows through the residential areas and into Sakarya River. The watershed contains forest, agricultural, residential, and industrial regions. Moreover, there is a tendency of increase in the residential area due to the great potential of population growth. Ankara Stream Watershed has experienced a land use/cover change especially during the last two decades and these changes are expected to continue in the future because of population affecting land use dynamics.

The aim of this study is to investigate the impact of land use change on surface runoff and flood events in Ankara Stream Watershed by employing a hydrodynamic model according to the various land use scenarios. For this purpose, first, a hydrodynamic model based on Environmental Protection Agency Storm Water Management Model (EPA SWMM) was developed for the watershed. EPA SWMM is a dynamic simulation model for the surface runoff developing on a watershed during a rainfall event and it calculates the quantity and quality of surface runoff on each subcatchment, i.e. the flow rate, depth and concentration in each conduit and junction. Next, we simulated the flow developed on the watershed under typical rainfall events with the hydrodynamic model. Finally, we selected several land use types and investigated their influence on runoff and flood occurrence by means of different scenarios, e.g. high urbanization, low forest and agricultural area, and vice versa. Thus, we observed the possible effects of human activities on surface runoff and flood risk in Ankara Stream Watershed.

Flood Modelling of Ayamama River Basin in Istanbul, Turkey

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Flooding is one of the most common natural disasters. Especially in highly urbanized regions, flood causes serious loss of life and property. In order to prevent these losses, reasons that cause flooding, should be examined thoroughly. For this purpose, hydrological models should be developed in order to simulate and forecast the flood events. One of the recent flood events occured in Turkey in September 9, 2009 in the Ayamama River Basin. During this flood event, 31 persons died and 50 persons injured. This disaster was also a huge blow on the economy due to the damage in buildings and infrastructures. In order to prevent these type of events in the future, the hydrological behavior of Ayamama River and the basin feeding the river should be investigated in order to better understand the causes of the flood. In this study, hydrologic and hydraulic models for the Ayamama River Basin are developed and flood analyses are conducted using these models. For this purpose, two different computer programs called EPA SWMM (Environmental Protection Agency Storm Water Management Model) and WMS (Watershed Modeling System) are used and flood analyses are performed with both programs under different scenarios. The results of models are compared with observations done during the site visit. Finally, results obtained by these two models are compared.

Assessment of nutrient retention in Hungarian rivers based on long term monitoring data

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Diffuse source nutrient emissions are of primary concern in river basin management as the control and management of point source emissions has developed in recent decades. Assessing the emissions in basin scales is a difficult task due to the difficulties of measurements of the nutrients along the diffuse pathways. The methods of emission estimates have been developed around modelling approaches of different kinds, depending on the spatial and temporal scales of the problem and the availability of the environmental data necessary for such a study. Whatever modelling approach is selected, the control and validation of the modelling calculations can only be done at the monitoring stations, where frequent water quality and discharge measurements are available. To make connection between the emission estimates and the measured loads at the monitoring stations, the nutrient retention of the water bodies are necessary to be known. The retention can be estimated in several ways including detailed water quality models for the water bodies but also using simple empirical relationships, such as the well known Vollenweider model for phosphorus retention in lakes. Another experimental relationship have been used in the MONERIS model, which is also a well known and widely used, robust model for basin scale nutrient emissions. In the current study the monitoring data for Hungarian river network is analysed following a simple methodology: adjacent monitoring points are selected based on the principle that both have measured nutrient concentration data in the same time period and either have very small change in water discharge between them or if a tributary river channel is delivering significant loads between them, than the tributary and the main points all have known discharge and concentration values, therefore the change of the nutrient loads can be estimated between the upper and lower points. Following the method described in the MONERIS model manual, the retention is than compared with the hydraulic loads (HL) of the river sections. The results indicate that retention values are slightly higher in Hungary than calculated by the original model equations for total nitrogen (TN) but the TN-HL relationship is very similar in its shape. For total phosphorus (TP) however, the picture is unclear, the yearly average data shows signs of a major internal load in many river sections. To investigate this further, a more thorough analysis of the monitoring data is carried out on a year by year time scale to see the change of trends in the loading between monitoring points along time.

Processing statistical parameters of concentration along a river network

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Water quality models have been under constant development in the last decades. It is a tendency to build robust deterministic models characterized by high data demand in order to get knowledge on non-monitored elements of the stream network. However, based on simple descriptions of the water quality processes many statistical parameters of the concentration time series can be extended to arbitrary point of the stream network. This paper proposes a method for the extension of statistical parameters of concentration along a river network.
The proposed method is based on the extension of the idea of linearisation. Investigating a single river reach, supposing a simple in-stream process (e.g. 1st order decay), the downstream mean, standard deviation and correlation values can be calculated via Taylor-series approximation. Also, approximations can be given for values below a confluence of two rivers, if upstream values are known.

The proposed method is tested against:

1. Synthetically generated flow and water quality data, where parameters of the data generation are derived based on long-time measurement data.
2. Measured upstream data, and elements of the downstream data series that are calculated one by one based on simple equations describing the in-stream processes.

In the 1st test, upstream daily discharge, BOD concentration and water temperature values were generated synthetically. Statistics of a hypothetical downstream point were calculated (supposing realistic river geometry) in two ways.

1. The downstream concentration was calculated on a daily basis assuming 1st order decay. Statistical values were calculated from the daily downstream concentration data series for each year ("*daily*").
2. With Taylor-series approximation ("*approximated*").

The approximated statistics showed promising agreement with values calcualted on a daily basis. Approximated mean values of the downstream concentration had an error of -10 … 1% relative to the mean calculated on a daily basis. Approximated standard deviation of the downstream concentration had an error of -8 … 9% relative to the standard deviation calculated on a daily basis. The relative error exceeded 5% only in 4% of the cases. As for the correlation between discharge and downstream concentration, the difference between approximated values and values calculated on a daily basis ranged -0.04 … 0.21. It exceeded 0.05 in only 6% of the cases. Concerning the correlation between temperature and downstream concentration, the difference between approximated and calculated values ranged between -0.10 … 0.11. The difference exceeded 0.05 only in 3% of the cases.
Investigating a confluence of two rivers with synthetically generated realistic data, the most statistical properties downstream to the confluence could be approximated with very little error relative to the ones calculated on a daily basis.

The random amplified polymorphic DNA (RAPD) assay in assessment of genotoxic potential: the Sava River case study

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The Sava River is the major drainage basin of Southeastern Europe and the largest tributary to the Danube River [1]. With a population of about 8.2 million and poor legislation regarding the discharge of wastewaters in the countries of the region, the anthropogenic pressure in the basin is more than obvious. Genotoxic stressors are a group which has drawn increasing attention lately due to the possible adverse effect which they might have on the quality of the ecosystem [2]. The effects of the DNA alterations can be dramatic in means of drop of survival and fertility but can also lead to changes in the genetic code and become one of the primary drivers of genetic diversity among the populations [3].

The comet assay (single cell gel electrophoresis) is widely used for the evaluation of DNA-damaging effects in genotoxicity testing and population monitoring. It can be modified to enable the detection of specific classes of DNA damage, like oxidative damage (Fpg-modified comet assay). In the last decade, random amplified polymorphic DNA (RAPD) assay, a simple, fast, sensitive, and straightforward PCR-based method, has been used to detect genotoxic-induced DNA damage and mutations in different organisms, including fish. In the field of ecotoxicology, most RAPD studies describe the RAPD changes as differences in band intensity as well as gain/loss of stable bands.

In this study we have carried out a genotoxicological survey along the upper course of the Sava River. The specimens of chub (*Squalius cephalus*) were collected in August and September 2015 at seven sites (Litija-I, Vrhovo-II, Čatež-III, Zagreb-IV, Jasenovac-V, S. Brod-VI, Županja-VII) along the river. Blood was collected directly from the heart with 3 mL syringes. One drop of blood of each specimen was diluted 20x in 4°C cooled medium and immediately frozen in liquid nitrogen prior to the application of the comet assay and Fpg-modified comet assay analysis. Approximately 500 mg of muscle tissue was excised from each specimen and immediately frozen in liquid nitrogen upon RAPD analyses. The genomic DNAs from four individuals from each site were blended to suppress the intra-populational genetic polymorphism potentially revealed by RAPD. In our analysis 6 different primers were used.

Based on the results of the alkaline comet assay we have observed separation of the sites in Slovenia from the sites in Croatia. Increase of DNA damage was observed at sites situated downstream of the site Čatež and DNA damage reached the highest values in specimens collected at the site Jasenovac. The results of Fpg-modified assay showed a lack of correlation between the Net-contribution of 8-oxo-G sites and values obtained in the alkaline comet assay suggesting that the oxidative stress is not a major inductor of DNA damage in this case. Thus, it should be emphasized that the highest level of oxidative damage was also observed at the site Jasenovac. RAPD profiles evidenced substantial differences between examined sites. It was interesting that like the comet assay, RAPD band analysis

also singled out sites Zagreb and/or Jasenovac (5 out of 6 primers). Site Jasenovac (V) was excluded as the site with the highest net contribution of oxidative damage and the highest level of DNA damage detected by the comet assay but also as the site which was most frequently separated by others in clustering within the RAPD analysis. Based on the previous studies [3-5] occurrence of DNA damage such as single and double breaks as well as oxidized bases can lead to loss or appearance of bands in RAPD analysis, so it is reasonable to speculate the influence of DNA damage in overall change in bands. Besides the possible impact of the DNA damage in pattern of RAPD fingerprint is also the influence of other population of chub from the Bosna River (right tributary of this site), which could have changed genetic structure.

Nevertheless, one of the downsides of these kinds of studies is that RAPD detects both genetic variability and DNA damage, and it is very difficult to differentiate the real contribution of DNA damage. However, according to previous research [6] using both approaches would be advantageous. At the population level, concurrent responses between changes in population genetic structure and elevated levels of DNA damage may provide evidence that the population genetic changes are influenced by the exposure to genotoxic chemicals [3, 6].

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Heavy metal transport in the river Elbe: A model-based assessment of extreme events

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Historically, the river Elbe has been one of the most polluted rivers in Europe. Over centuries, human settlement, agriculture, mining and industrial production contributed large amounts of anthropogenic contaminants to the river. In the 1990s, the discontinuation of many industrial sites, the establishment of sewage treatment plants and a better management of old mining sites resulted in an improved water quality. However, compared to other large Middle-European rivers, pollution levels of the river Elbe still remain high; heavy metals, such as mercury, cadmium and lead are still of major concern. Particularly during flood events, diffuse sources contribute significantly to the heavy metal load. Flow-limited zones play a major part in the transport of particle-bound contaminants. But there is still a gap in the understanding of how groyne fields, back waters, harbours, and floodplains act as sinks and/or sources of pollutants.

Hydrodynamic-numerical models can assist in assessing suspended sediment and contaminant transport. A modelling study was conducted to quantify heavy metal loads during extreme flow events. Two different flow events of the German stretch of the non-tidal Elbe River were considered: the 2013 flood, and the 2015 low flow. The objective of this study was to test the following assumptions: (1) During low flow events heavy metal loads are dominated by point sources; (2) During flood events in the lower part of the Middle-Elbe remobilised contaminated historical sediments from flow-limited zones contribute significantly to the heavy metal load.

We applied two different numerical models to address the varying flow conditions and associated processes. The model QSIM is a one-dimensional water quality model with a fast processing time but limited representation of exchange processes with flow-limited zones. It was used to simulate the 2015 low-flow event between Schmilka and Geesthacht (Elbe km 3.9 to 585.9) when flow-limited zones had a rather negligible effect on total contaminant loads. For the 2013 flood the Delft3D Flexible Mesh model was used and coupled with the water quality and sediment transport model DELWAQ. This high resolution two-dimensional model has a cell size of 25 m and covers the part of the Elbe reach from Wittenberge to Geesthacht (Elbe km 451.1 to 585.9). Preliminary results of the modelling will be presented and discussed.

Assessing uncertainties in hydrological modelling of discharge and nitrate-nitrogen under future climate change conditions for Austrian catchments

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To make informed decisions about adapting to climate change, water resource managers, policy-makers and decision makers require knowledge on how much uncertainty can be attributed to a hydrological prediction. There is an obligation and a necessity to identify, isolate and analyse the different sources of uncertainty within a modelling chain. The objective of the project "Uncertainty Assessment of Water Flow and Nutrient Loads under Future Climate Change Conditions (UnLoadC^3)" is to examine the impacts of uncertainty inherent in data and modelling on the simulations of discharge and nitrate nitrogen (NO_3^--N) loads within two selected river catchments in Austria.
The UnLoadC^3 project evaluates the sensitivities of simulated variables (discharge and NO_3^--N) with respect to:

- hydrological models (a complex versus a simple structure);
- the complexity of the set-up of the hydrological model;
- the calibration parameter sets that fit given objective criteria;
- the point-sources stemming from urban wastewater treatment plants;
- future land use change scenarios;
- a suite of future climate change simulations.

The hydrological model Soil and Water Assessment Tool (SWAT; Arnold et al., 1998) was applied to the Schwechat and Raab catchments to simulate discharge and NO_3^--N. The SWAT model is a semi-distributed, process based, continuous model that operates on a daily time step and has over 100 parameters than can be calibrated. The SWAT model was calibrated for both catchments with historic climate, land use and water quality data for the time period 1971-2000.
A simpler model, MONERIS (Behrendt et al., 2007) was set up for the Schwechat catchment to also examine simulated outputs of discharge and NO_3^--N under historic conditions (1971-2000). The MONERIS model is a conceptual, nutrient-balance model that uses an empirical approach to calculate N-emissions and has about 20 parameters. The MONERIS simulated variables were compared with the SWAT simulated variables to determine if model complexity has a significant influence on simulated outputs of discharge and NO_3^--N.
Furthermore, an ensemble of climate projections from EURO-CORDEX (at 12 km grid) was used for the climate change simulations in SWAT for two future time periods (2021-2050 and 2071-2100). These ensembles are driven by two RCPs (RCP4.5 and RCP8.5) used within the Fifth Assessment Report of the IPCC. To provide climate change projections for the required impact scales, statistical downscaling techniques to a 1 km grid, as well as bias correction methods for temperature and precipitation were applied. Each climate simulation was input, one at a time, into the SWAT model from which future climate variables were read to drive the hydrological processes.

For the Raab catchment, the effect of the required input data into the SWAT model on simulated variables were examined. First, the input soil information was varied to determine an optimum aggregation in SWAT. The initial data was obtained from SoilGrids (Hengl et al., 2017) at 1 km spatial resolution that was used for the SWAT model calibration. Subsequently, different aggregation methods of the soil classes using machine learning techniques were carried out to provide various levels of detail in the soil information at 250 m spatial resolution. The optimum aggregation map based on specific criteria was selected and used in all further analysis. To further investigate the influence of the input data, two future land use change scenarios of different complexities were developed based on changing agricultural land use (Mehdi et al., 2016). The scenarios were applied to the SWAT model, one at a time, in lieu of the historic land use map. In addition, the urban wastewater treatment plant effluent discharges were increased incrementally for the future to develop several cases of point-source pollution loads for the Raab. Finally, the dominant sources of model uncertainty were pinpointed using a modified STARVARS (Razavi and Gupta, 2016) global sensitivity analysis framework. Thereby, the sensitivity of the SWAT model set-up, the calibration parameter sets, as well as the changing anthropogenic factors in the Raab catchment (i.e. land use, point source loads and climate) were evaluated for their simulated impacts on discharge and NO_3^--N at the daily time step (Figure 1).

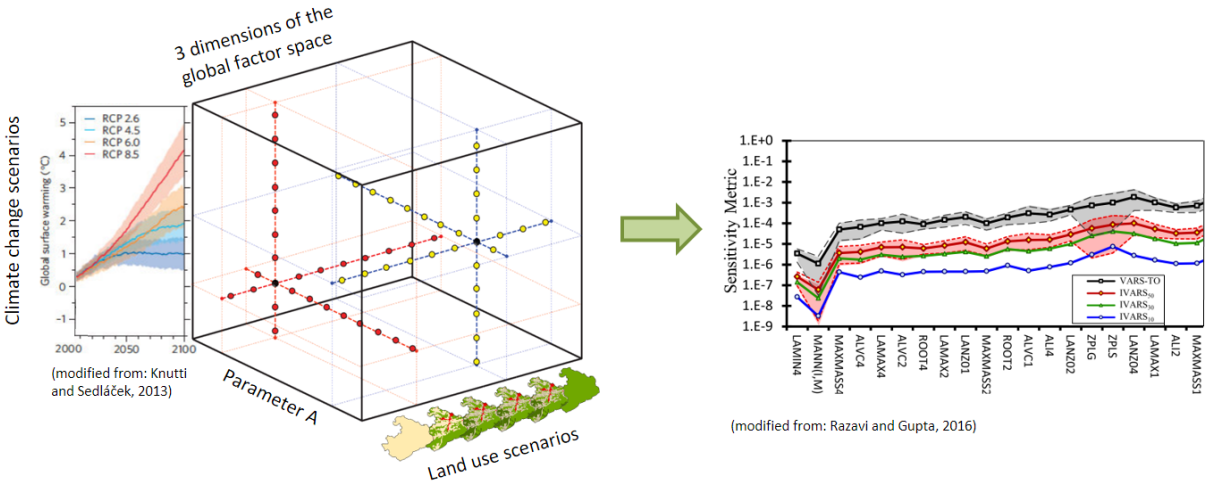

Figure 1. Global sensitivity analysis using a modified STARVARS approach of factors influencing the SWAT simulated variables

This framework provides valuable information on the contributions of uncertainty during a hydrological modelling process that uses future scenarios (i.e. climate change simulations or land use change scenarios) or that examines parameter values and model structure influences on the simulated outputs. When the dominant sources of uncertainty are identified, these can be further examined to reduce the causes of uncertainty. Furthermore, those inputs, parameters and factors that do not contribute significantly to the modelled output uncertainty do not need to have resources and effort spent on fine-tuning them.

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Monitoring of Biocides in German Sewage Treatment Plant Effluents

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Due to a widespread use, biocidal active substances and their transformation products are expected to be found in the environment. Projections show that there will be an increase of biocide entries in the environment, mainly in urban areas due to an increased use of e.g. disinfectants and especially masonry preservatives.

Biocidal substances enter the environment through numerous entry pathways. One main entry path is through sewage treatment plants (STP). Therefore, the German Environment Agency (UBA) initiated a project where the effluent of at least 30 STPs from all over Germany will be investigated over a period of one year. Additionally, selected samples from influents as well as from sewage sludges will be in the focus. Using an in-house prioritization concept for biocides a list, ranking substances that enter the environment through the STP-pathway was generated. The list was judged by experts and finally for this project more than 20 biocidal active substances or transformation products were chosen for analysis.

This project will provide better knowledge about the fate and behavior of biocides entering the environment through STPs. It will gives us a time dependent picture of the environmental pollution by biocides in Germany through urban STPs and also shows us possible fields of action for regulatory purposes.

Flood risk map as a tool for preventing material damage: case study of the Bistrita River (Romania)

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The most intense floods occurred in Romania in the Siret River basin, more precisely, the Bistrita River Basin. Although, the hydrotechnical development is very well equipped and often very effective within the Bistrita River basin, however, floods do occur and may affect numerous localities. To minimize the risk of flooding, especially in areas that are not yet inhabited, it is therefore, necessary to urgently draw up risk maps. In order to create these study maps on floodability, the completion of some time consuming and expensive stages are required. It was not until the year 2015, that some hydrological risk maps were completed for the most important flooded areas on the territory of Romania. In the present study, floodability maps were drawn up for different probabilities and with a high degree of accuracy with the help of the ISIS (Integrated Spectographic Innovative Software) modelling program, which was used as a system for modelling specialized issues of flood risk management. The hydraulic modelling uses the ISIS software products to control the hydrodynamics. The hydraulic models play the role of transposing the liquid flows from the key point sections into levels corresponding to different values of probability, in order to obtain the required limits of flooding. To create the model with a reduced degree of error, topographical measurements were effectuated in the sectors, most frequently affected by floods. In the year 2015, the topographical surface was scanned using the LIDAR (Light Detection and Ranging) system. The accuracy is very good at centimeter level and therefore, the maps created in this program have maximum efficiency. The largest areas of land affected by flooding are found in the lower sector of the Bistrita River, especially on the common floodplain with the Siret River.

Micropollutants in German Municipal Wastewater Treatment Plants – a nation-wide monitoring campaign

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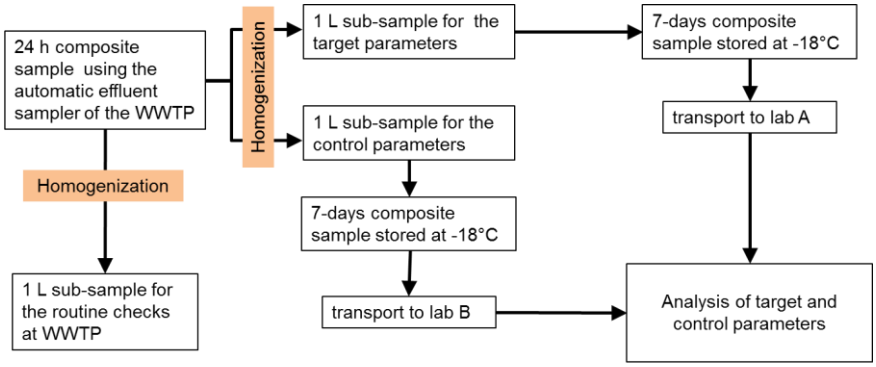
The European Union (EU) has defined environmental quality standards (EQSs) for priority and priority hazardous substances (PS) as well as several other pollutants in surface waters. It is a joint task of water scientists across the EU to establish the current concentration levels in surface waters, determine to what extent they comply with the prescribed standards, and take appropriate measures. For the proper implementation of measures, we need to know the main source of pollution. A major pathway for PS emissions into surface waters is the municipal wastewater system (treatment plants, storm water and combined sewer overflows) as a significant portion of PS emissions comes from point sources.

In order to determine the level of adherence to compliance standards, 49 municipal wastewater treatment plants (WWTP) in Germany has to be monitored over 12 months in rain and dry weather in the influent, effluent, and sludge. Using three WWTPs in the south of Germany as a basis, over the past years we developed an innovative sampling method which is now to be applied a larger scale.

Focusing on the effluent sampling, we have determined that the sampling should follow the established routine at the WWTP producing first one liter of daily composite samples, from which a part is frozen to compile a seven-day composite sample. The aim is to take a flow proportional to a seven-day composite sample. The necessary vessels for the sampler procedure should be made of stainless steel or glass. Stainless steel vessels have proven to be the best compromise, both in terms of ease of use (cleaning, stability) and keeping the samples intact.

The sub-samples for the analyses of both the target PS and the control substances are then immediately frozen (-18° C) in the stainless steel vessel. Seven consecutive 24-hour samples are combined in a deep fryer to form the seven-day composite sample. After seven days, the resulting sample is transported to the laboratory in a frozen state. The sample requires again a thorough homogenization after thawing in a refrigerator at 4° C. Thawing takes about 24 hours.

Figure 1 shows a schematic representation of the sampling procedure.



Note: If the analyses of the target and control parameters are performed in the same lab one 7 day composite sample might be sufficient. The water volume needed has to be coordinated with the lab personnel.

Figure 1: Scheme of sampling procedure

The sampling method described is well-suited to considerably reduce fluctuations in the generated results. This is an enormous advantage if the numbers of samples to be analyzed are limited. However, there is a risk of minor quantification for all substances which are volatile (e.g. Hg, Cd, volatile halogenated hydrocarbons, small PAHs) or readily degradable. Over-quantification may be a problem for DEHP or Bisphenol A because of the use of plastic materials in the lab and in the sampling devices.

Assessment of potential availability of particulate phosphorus from soil erosion in rivers

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Particular Phosphorus emitted via erosion may be dissolved by chemical, biological and physical processes in waters, become plant available and then contribute to eutrophication. The amount of phosphorus that - depending on physical/chemical boundary conditions on river water and sediment - potentially is dissolved in the river system depends on the chemical bonds of phosphorous in the particulate matter. In order to assess the potential relevance of particulate phosphorus for eutrophication in rivers and receiving lakes and seas, better knowledge on chemical bonds and on solution behaviour of particular phosphorus (PP) of eroded material is required. To gain information about chemical bounds and the availability of SRP of eroded soils and suspended solids we analyzed suspended solids from mountain and agricultural catchments and eroded soil samples from agricultural fields. Samples were collected along the Inn river basin in Austria and Germany.

The analyzes were performed according to phosphorus fractionation by Psenner et al. (1984). The method is based on a chemical leaching process, whereby acid and alkaline solvents are added on a particular sequence. Phosphorus bonds are divided into the labile phosphorus (extraction by NH_4Cl), the reductive soluble phosphorus (reduction by $NaHCO_3$ $Na_2S_2O_4$), iron- and aluminumoxide-bound phosphorus and poly-phosphorus of humic substances (extraction by NaOH), calcium bound phosphorus as apatite (extraction by HCL) and refractory phosphorus. In each fraction, SRP and total phosphorus content (TP) are determined except the refractory fraction in which only the TP content is analyzed. The plausibility check of results from fractionation is carried out by comparing the summed up TP contents of the fractions with a TP analyzes of the whole sample.

The TP-content of eroded arable soils varies between 0,8 to 1,1g/kg dry matter (DM). In respect to its chemical bounds it can be subdivided in three part of almost the same share: plant available phosphorus (NH_4Cl- and $NaHCO_3$ $Na_2S_2O_4$-SRP) is about 35%, poorly soluble or not soluble phosphorus (HCl- and residual SRP) is about 30% and the NaOH-fraction whose solubility is lying in between is about 35 % of the total TP content. Samples of suspended solids from catchments dominated by arable land use show a similar distribution, which indicates, that eroded arable soils are an important factor of transported suspended matter in waters. In contrast TP content of suspended solids samples from catchments dominated by forests and mountains varies between 0,5 to 0,7g/kg DM, whereas the percentage share of not soluble or poorly soluble phosphorus (refractory and HCl-SRP) is about 90 % of the total TP content.

All in all the investigations support the hypothesis that particulate phosphorus from alpine regions dominated by forests and mountains will hardly contribute to eutrophication of rivers and standing waters even after long retention times. On the contrary, particulate phosphorus from agricultural soil erosion may contribute to algae grow in receiving water bodies at a significant share of 50 % and more depending on retention time and physical/chemical boundary conditions.

Annual Fluxes and Risk Assessment of Emerging Contaminants from a Scottish Priority Catchment to the Estuary and North Sea

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Emerging contaminants (ECs) such as endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs) attracted global concern during the last decades due to their potential adverse effects on humans and ecosystems. This work is the first study to investigate 11 ECs including 5 EDCs and 6 PPCPs over 1 year (monthly monitoring) in a Scottish priority catchment currently undergoing regulatory monitoring (River Ugie, Scotland). Within this regulatory framework, spot and passive sampling strategies were undertaken to understand these compounds spatiotemporal occurrence, mass loads and ecological risks. All the target chemicals were detected in water by both sampling techniques. Overall, the total concentration in water ranged from 0.40 to 60.96 ng/l (mean: 9.90 ng/l) and 0.24 to 361.2 ng/l (mean: 51.16 ng/l) for EDCs and PPCPs, respectively. Ibuprofen and Carbamazepine were observed to be the dominant contaminants in the River Ugie (Ibuprofen: maximum: 91.46 ng/l, mean: 13.06 ng/l; Carbamazepine: maximum: 192.7 ng/l, mean: 11.23 ng/l). The total annual fluxes of 5 EDCs transported to the Ugie Estuary and North Sea were estimated to be 873 g and 646 g based on the spot and passive sampling data, respectively. While they were 4636 g and 4517 g for 6 PPCPs by spot and passive sampling, respectively. The overall comparison of the two sampling strategies supported the hypothesis that passive sampling tends to integrate the contaminants over a period of exposure and allows quantification of contamination at low concentration. The spatiotemporal trend suggested that living beings activities and medication usages were the primary source of the contaminants. The risk assessment showed that BPA posed the higher ecological risks with 21.5% of spot samples resulting in a Risk Quotient greater than 1. This suggests that mitigation measures might need to be taken to reduce the input of emerging contaminants into the river and its adjacent estuary and sea.

From Emission Modeling to Water Quality Modeling – New Developments for MoRE

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For effective river basin management and protection of freshwater resources the identification of emission pathways, spatial patterns and data on water quality are of crucial importance. Hence, the use of emission and water quality models has increased rapidly because models provide important possibilities to assess both the current situation and future developments. In the context of the Water Framework Directive the open-source instrument MoRE (Modeling of Regionalized Emissions) has been developed as a reporting tool for the German Environment Agency. It is based on the pathway-oriented MONERIS approach (Modeling Nutrient Emissions in River Systems) and can be used to model annual substance emissions to surface waters on a catchment scale. In three complementary research projects MoRE was extended to model river concentrations and in-stream processes to enable user to evaluate the effect of substance emissions and compare these with environmental quality standards. Using the Nidda catchment in Hesse as an example, we present the technical implementation regarding spatial basis and higher temporal resolution, the calculation approaches and first results.

The water quality module in MoRE is based on a river network which consists of nodes at important points, such as river junctions, point sources, dams or monitoring stations, and river segments connecting the nodes. Diffuse substance emissions calculated for analytical units (sub-catchments) can be assigned to river segments while calculated point source emissions enter surface waters at nodes. In-stream processes along the water segments are accounted for using simple approaches such as first-order decay or lumped first-order rates. Additionally, concentrations can be modelled using different scenarios based on a variety of input data. To improve the merit of model results a temporal resolution ranging from day to year can be chosen.

In the project NiddaMan we use MoRE to model emissions in the Nidda Catchment in Hesse (approx. 2,000 km²) at a higher spatial and temporal resolution than currently used in other MoRE applications. The results will be integrated into the newly developed water quality model using selected areas. In close cooperation with the project partners the modeled concentrations can be used to derive qualitative statements concerning the risk potential for biota in particular water segments within the catchment area.

While the Nidda catchment is considerably small and located entirely within one federal state, modeling water quality in large, transboundary river basins poses an even greater challenge than emission modelling. Since substance concentrations are passed on according to the runoff-routing and may cross borders several times harmonized input data (e.g. suitable river network) are an essential requirement.

3. Sponsor presentation

Ganges, reaching new shores in river monitoring

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Due to fast population growth, migration and industrialization, the pollution of the Ganges has become a major issue for India and one of the biggest environmental challenges on earth. Therefore, the "National Mission for Clean Ganga" was born in 2011 by the Indian government, to fight the pollution and try to revive the river and its surroundings.

A 5 year water quality data supply contract was signed by s::can Messtechnik GmbH and the Central Pollution Control Board (CPCB), the government authority in charge. On March 11th, 36 s::can monitoring stations went online. This water quality network was designed, installed and now is operated by s::can in close co-operation with a local partner. The measuring stations continuously send real time water quality data, on hourly basis to the CPCB in New Delhi. This project is the initial phase of an even larger program to acquire reliable water quality data along the Ganges, and other Indian rivers. It will be a reference for other global water monitoring networks.

In contrast to a classical service provider, s::can is not working as a system integrator. The new concept of "data as a service" was established within the contract between s::can and the CPCB. The service provider is compensated for the delivered data, under the condition that the network is online and transmits a certain amount of parameters of each single station, as criteria of a functional monitoring grid. Hourly data evaluation, by an independent consultant, guarantees the CPCB that conditions are fulfilled.

Compared to classical discrete measurements, the online strategy of using UV/Vis spectrometry and ion sensitive electrodes for organic carbon and nitrogen compounds, combined with traditional parameters like pH, dissolved oxygen and electrical conductivity allows a profound view of the water quality. This new customized project induced s::can to explore new avenues in working with high-end telemetry- and cloud solutions guaranteeing reliable operation under inhospitable environmental conditions. In the course of the project, the development of visualization- and asset management tools makes control and operational logistics more comfortable.

The collected information will strengthen the regulation and oversight of the river's pollution load by helping planners to better understand the origins of pollution, as well as to assess the impact of treatment on the water's quality.