33. Doktoranden-Treffen der Hydrogeologie

Let’s talk about water

Freiberg, 13. – 16. Mai 2024

Organisation:

Die Doktoranden des Lehrstuhls für Hydrogeologie und Hydrochemie der TU Bergakademie Freiberg

Leonie Gabler, Clemens Hartmann, Lúcia Pedrosa, Sebastian Schramm, Rebecca Serbe, Faith Chebet Tumwet

Das 33. Doktorandentreffen der Hydrogeologie wurde in diesem Jahr vom Lehrstuhl für Hydrogeologie und Hydrochemie der TU Bergakademie Freiberg (TUBAF) veranstaltet. Vom 13. bis 16. Mai trafen sich 19 Promovierende aus Dresden, Tübingen und Freiberg an der TUBAF. Am Montagabend, den 13. Mai, hielt der Birdsall-Dreiss Dozent 2024 Ben Rostron eine Vorlesung über Lithium in Solen von Südwest-Saskatchewan (Kanada). Den offiziellen Auftakt des Treffens bildete die anschließende Ice-Breaker-Party, bei der sich die Promovierenden in lockerer Runde kennenlernen konnten.

Der Dienstagmorgen startete mit einem Keynote-Talk von Dr. Alireza Arab (TUBAF, Lehrstuhl für Hydrogeologie und Hydrochemie) über mögliche Höhen und Tiefen während einer Promotion. Dabei gab er hilfreiche Ratschläge zum erfolgreichen Abschluss. Anschließend stellten die Promovierenden bis zum Mittag ihre Forschungsthemen in 15-minütigen Vorträgen zur Diskussion. Am Nachmittag wurden bei frühsommerlichen Temperaturen die Obertagebauwerke der Unteren Revierwasser-laufanstalt Freiberg besucht. Dieses Wasserversorgungssystem entstand ab dem 16. Jahrhundert im Zuge des Silberbergbaus. Zum Tagesabschluss hielt Ben Rostron einen weiteren Vortrag über das erste untertägige CO_2-Speicherprojekt in Kanada.

Der Mittwoch begann mit einer Exkursion in das Forschungs- und Lehrbergwerk „Reiche Zeche“ der TUBAF: Neben einem kurzen Einblick in die Geschichte des Bergwerks stellten zwei Promovierende ihre Untergrundlabore in einer Tiefe von 150 m vor. Dabei präsentierten sie ihre Projekte zum Monitoring der Grubenwasserqualität und zur thermischen Energiespeicherung in stillgelegten Bergwerken. Nach dem Mittag gab Andre Uhlmann vom südwestsächsischen Gründungsnetzwerk SAXEED einen Einblick in den Weg von der Forschung in die Unternehmensgründung, gefolgt von weiteren Vorträgen der Promovierenden. Posterpräsentationen und Gelegenheiten zum Networking bildeten den Abschluss des Tages. Insgesamt stellten die Promovierenden ihre Forschungsthemen in elf Vorträgen und sechs Postern vor. Die Themen reichten dabei von Säulen- und Batchversuchen, über den Transport von Schadstoffen, die Herstellung eines Wasserfiltersystems, hin zu numerischen Modellierungen.

Am Donnerstagvormittag endete das 33. Doktorandentreffen mit einem Workshop unter dem Titel: „Navigating the doctoral Odyssey – Strategies for overcoming challenges and achieving success“, geleitet von Dr. Kristina Wopat (TUBAF, Graduierten- und Forschungsakademie).

Wir danken dem Verein der Freunde und Förderer der TU Bergakademie Freiberg, der Fachsektion Hydrogeologie in der DGGV (FH-DGGV) und der deutschen Sektion der International Association of Hydrogeologists (IAH-D) für die finanzielle Unterstützung, ohne die diese Veranstaltung nicht möglich gewesen wäre. Ebenso gilt ein Dank allen Teilnehmenden, welche das Treffen zu dem gemacht haben, was es ist: Ein Networking-Event für junge WissenschaftlerInnen der Hydrogeologie in Deutschland. Glück Auf!

Die Promovierenden der TUBAF

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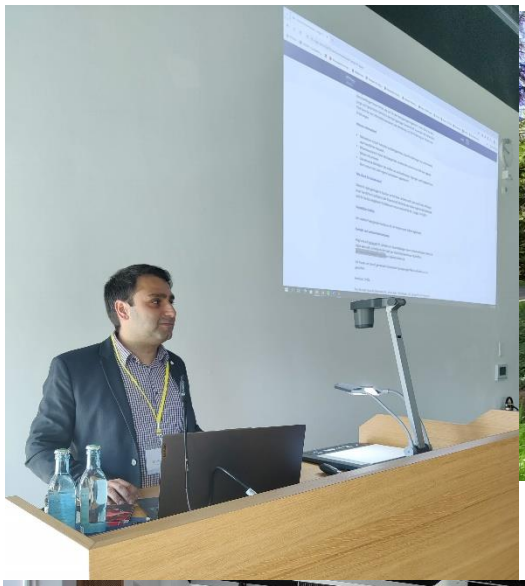

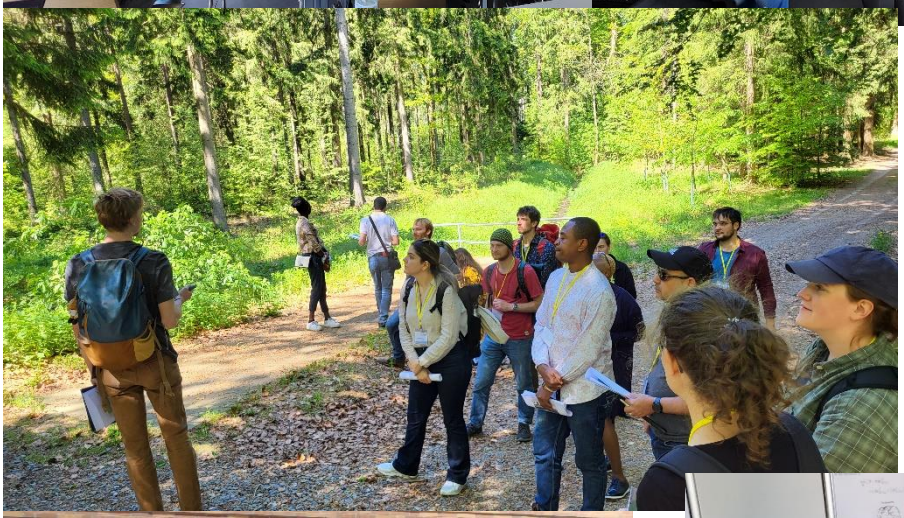


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Abstractverzeichnis

Extracting metal(loid)s of mining contaminated subaquatic sediments by precipitation water at the Hüttenteich, Saxony, Germany

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Significant amounts of sediments are stored in natural lakes and dams. In Erzgebirge, Germany, these sediments are usually contaminated by metal(loid)s due to high geogenic and montane background concentrations of their catchment. At the Hüttenteich, treatment strategies are needed to reduce the solid concentrations of the main constituents Al (maximum 30,400 mg/kg dry mass), Fe (26,100 mg/kg), Pb (2,400 mg/kg), Zn (1,700 mg/kg), Cu (158 mg/kg), As (135 mg/kg), Sn (66 mg/kg), Ag (26 mg/kg), Cd (18 mg/kg), Sb (8 mg/kg). As at least 50 % of the contaminants (As, Pb, Cd, Cu, Zn) are bound to non-residual phases, they are considered to be easily removable. Thus, aim of the laboratory study was to characterize the kinetics of dissolving metal(loid)s from subaquatic sediments in a natural environment such as on heaps. Therefore, unsaturated column tests were performed. Each consists of three leaching intervals of 12 to 24 h, which are gravitationally driven by natural precipitation water and alternate with drying intervals of 12 to 24 h. Time series of the metal(loid) concentrations in the percolate as well as the temporal change and the depth-dependent distribution of the solid concentrations within the sediment column were measured by ICP-OES. The results show lower post solid concentrations without clear depth dependence. The decrease depends less on the initial solid concentration rather than on the sediment and metal(loid) specific reactive transport conditions such as reactive surface area, reaction time, and time at which chemical equilibrium is reached. Most of the metal(loid) concentrations in the percolate are initialized by high values (first flush), followed by slightly decreasing rates. As, Ba, K, Li, and Cu show different patterns. The results contribute to understand the kinetics of dissolution and 1D-transport of metal(loid)s in sediments in the unsaturated zone. Dissolving metal(loid)s by precipitation water may be a promising treatment option for slightly contaminated sediments and soils.

Testfilter experiments for defining DOC biodegradation during RBF with focus on climate change effects

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Natural uranium content in groundwater of former uranium mine in Königstein (Saxony)

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In order to enable the remediation of the former uranium mine near Königstein, a background value for the uranium concentration in the groundwater from the time before mining must be determined.

The former uranium mine near Königstein is located in the 4th aquifer, which consists of Wurm sandstone and sandstones of the Oberhäslich Formation in the Upper Cenomanian of the Cretaceous period. Under the conditions prior to mining in 1967, it was a confined sandstone aquifer in which oxygenated water flowed into the pyrite-bearing sedimentary rocks from the side. In this way, a redox roll front formed in which uranium, a redox-sensitive element, accumulated. The aquifer is simplified as a one-dimensional flow path from oxidized conditions with high uranium solubility to reduced conditions with low uranium solubility.

Batch experiments are used to simulate the interaction of solids and water. With different shaking times of a sample from an oxigenated part of the study area, we can visualize the time series (1, 3, 9, 27 days) of different elements, including uranium. Two individual batches were analyzed for each time step. The elements were measured by ICP mass spectrometry, ICP optical emission spectrometry, ion chromatography and titration of HCO3-. Modeling was performed with PHREEQC and the PSI Nagra database from 2020.

The concentrations of Si, Ca, K, HCO_3^- and sulphate increased with the shaking time. The concentrations of aluminum, iron, manganese and uranium peaked after one or three days and then decreased. Modeling with PHREEQC revealed that uranyl carbonate (UO_2CO_3) was the most abundant uranium species in solution. The saturation indices (SI) of meta-autunite and meta-torbernite indicate saturation and are sufficient to explain the evolution of uranium concentration in solution. The SI of 2-line-ferrihydrite is also sufficient to explain the iron concentrations. In the case of manganese, all relevant minerals have a negative SI, suggesting that there are no precipitation or dissolution processes determining Mn. Further investigation of complex processes is required to gain a better understanding of uranium mobilization processes.

Session 2 – 14.05.2024

Influence of microplastic shape and roots of wheat (*Triticum aestivum*) on the infiltration of microplastics into the soil profile

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Microplastics continue to pose a significant challenge as pollutants within agricultural ecosystems. Their vertical movement and infiltration into the soil profile may be influenced by root growth, elongation, and expansion. Wheat plants (Triticum aestivum) cultivated in rhizotrons measuring 70 cm deep were studied to understand how they influence the vertical movement of two common types of microplastics: polyester fibres and polyvinyl chloride (PVC) fragments. Microplastic contamination of 0.24% w/w dry soil weight was homogeneously mixed within the top 20 cm of soil. The study found that polyester fibres exhibited strong adherence to plant roots, leading to their infiltration to depths of up to 50 cm. PVC fragments were detected even at depths of 70 cm, suggesting their ability to penetrate deeply into the soil profile. PVC fragments were found both in the presence and absence of wheat plants. The growth of wheat plants in the presence of microplastics resulted in increased root branching but decreased shoot biomass. This study demonstrates that microplastics can indeed move vertically in soil, with the depth of infiltration influenced by their shape. The movement was attributed to either the strong attachment of polyester fibres to plant roots or the infiltration of PVC fragments, possibly facilitated by preferential flow paths in soil pores and the fissures created by root elongation and water movement.

Studying pathogen transport through tracer tests with non-pathogenic bacteriophages in karst aquifers

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Karst aquifers are vulnerable to contaminations by solutes, such as pesticides or pharmaceuticals, as well as particles, such as bacteria or viruses. These contaminants can enter the aquifer through agricultural practices or waste water leakages. Due to the specific characteristics of karst aquifers that allow for rapid recharge and high groundwater flow velocities, contaminants can travel over long distances and reach springs at high concentrations within short time. This causes a threat especially to springs used for drinking water production, which often cannot be protected against these contamination events. Many laboratory experiments have been conducted to understand the transport and retention behavior of viruses but only little is known from large-scale field experiments, especially in karst aquifers where retention is usually considered to be low.

Non-pathogenic bacteriophages MS2 and phiX174 were used in tracer experiments over distances between 3 and 9 km in the karst aquifer of the Gallusquelle spring (Swabian Alb). In all experiments, infectious bacteriophages were determined at the spring. Although their recovery was about 50 to 99 % lower compared to the conservative tracer uranine depending on boundary conditions, such as injection location, transport distance, and discharge, their arrival at the spring proves the high contamination risk of karst springs regarding viruses.

Developing A Sustainable And Cost-Effective Portable Diatomaceous Water Filtration Device Using Recycled Materials: A Solution For Safe Drinking Water For Artisanal Communities and Beyond

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Session 3 – 15.05.2024

Numerical modeling of the herbicides and metals under railway

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Railway systems are among the most important infrastructure for transportation of people and goods. However, their maintenance implies the use of contaminants such as herbicides and oil derivates that can spread underneath railway embankments. In order to inspect and evaluate the hazard risk, it is necessary to fully understand the dynamics of water flow through the embankment, unsaturated and saturated zone. Primarily, numerical experiments were performed to systematically investigate the influence of parameters on water content distribution and stream patterns. The parameters are hydraulic characteristics of the embankment and the subsurface, i.e., θ_r (saturated water content), θ_s (residual water content), α and n (empirical coefficients shaping the soil water retention function), and K_s (saturated hydraulic conductivity); recharge (effective precipitation), groundwater table levels, influence of a less permeable layer at multiple depths, and thickness of the embankment. The study identified groundwater levels and empirical coefficients (specially α) governing soil-water retention as the most sensitive parameters shaping water percolation fronts. Secondarily, follows the modelling of herbicides and metals for specific locations in Germany. A work in progress that will be shown and discussed at the conference.

Estimating hydrogeological parameters using data assimilation in real-time modelling

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Every hydrogeological model simplifies the system that it is representing. These simplifications arise in the form of the exclusion of 'irrelevant' processes, the parameterization of model features and boundary conditions and the choice of the model itself. Each simplification introduces a degree of error and uncertainty. In the case of model parameterization, not only the choice of parameters, but also their values are affected by uncertainty. Furthermore, information on model parameters (e.g. hydraulic conductivity) and measurements (e.g. hydraulic head data) is usually sparse, while most models require spatial information for their entire domain. Therefore, these parameters need to be calibrated, which is a computationally expensive procedure.

In the project GW4.0 (Groundwater 4.0, LURCH (Grundwasser nachhaltig bewirtschaften)), we are developing a real-time groundwater model, covering 480 km2 in the triassic landscape of south-west Germany. The model includes the quartary pore aquifer of the Neckar valley as well as the carstic system of the upper Muschelkalk and the Grabfeld- and Erfurt-formations of the Keuper. These systems differ strongly in terms of their hydrogeological attributes and in the availability of data concerning these attributes. In order to address this heterogeneity and uncertainty, we employ an ensemble approach. Within an ensemble of models, it is possible to represent the parameter uncertainty as a distribution, as every model is equipped and initialized with a set of parameters that stem from the uncertainty range of the parameters.

In the context of real-time modelling, real-time hydraulic head data will be used to perform data assimilation. While in classical data assimilation the observed state, i.e. hydraulic head, is corrected and updated within the domain, it is possible to use the correlation within the ensemble, as well as between the parameters and the model states to also estimate parameters. The technique employed in this project is the Ensemble-Kalman-Filter which approximates the parameter distributions, used in the standard Kalman filter, with the aforementioned ensemble. Thus, through the regular assimilation of hydraulic head data, the groundwater model ensemble stays up-to-date, while improving on the most plausible set of parameter combinations. This approach has been successfully implemented in a synthetic study and is in the process of implementation, through the construction of a real-time monitoring network, for the regional groundwater model of GW4.0. Conclusively this approach will be compared to classical calibration techniques like PEST.

Accelerating Groundwater Model Inversion: A Multilevel Approach to GLUE

M. Rudolph, T. Wöhling, T. Wagener, A. Hartmann

Session 4 – 15.05.2024

Hydrogeological Assessment of the Siguatepeque Aquifer, Honduras

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Sustainable groundwater management is based on hydrogeological information that is usually nonexistent, outdated, or incomplete in developing countries like Honduras. Such is the case of the Siguatepeque aquifer, where technical information to support decision-making is lacking and adequate management strategies are not implemented, jeopardizing the sustainability of the aquifer which is currently the most important source for water supply; situation that is being faced by many other important cities in Honduras and the Central American region.

A conceptual model has been defined for the Siguatepeque aquifer, along with hydrogeological units and parameters. A complete well inventory was mapped and based on previous data, it was possible to perform a historical analysis of groundwater levels. Aquifer recharge was calculated through a soil water balance and total well extraction was estimated. A multicriteria analysis based on remote sensing and geographic information systems was performed to determine potential groundwater recharge zones (PGRZ).

The aquifer (228 km^2) is classified as semiconfned with intermediate to low yield for groundwater supply. Average recharge was calculated as 10.7 million m^3/year and average extraction of 506 wells was estimated as 4.5 million m^3/year, representing 41.7% of average recharge. Analysis of historical data shows a decrease of groundwater levels especially in the urban area, where almost 80% of the wells are located, indicating this area may be facing overexploitation and counter measures should be implemented to avoid further aquifer depletion. Regarding PGRZ, 28% of the total area was found to have a good recharge potential, 40% medium and 32% low. Field validation shows an accuracy of 83%. A special zoning of areas with good recharge potential is presented to facilitate interpretation. This information is now being used to build a hydrogeological model and support decision-making regarding the design and implementation of strategies for groundwater conservation and the sustainable management of the Siguatepeque aquifer.

Assessment of Biosurfactant-Enhanced Remediation Effect on the Rate of Clean-up of Oil-contaminated Groundwater

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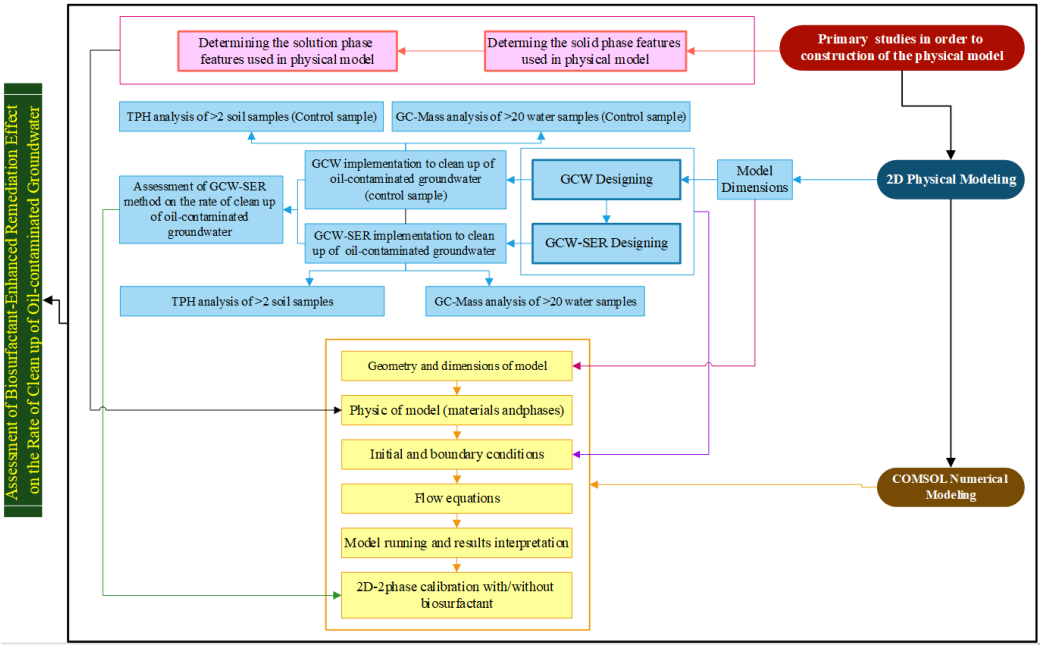
One of the problems associated with groundwater quality, especially in the capital of Iran, Tehran, is the effect of human hydrocarbon resources due to oil refining activities; So, we try to study the methods and rate of clean-up of oil-contaminated groundwater based on Groundwater Circulation Wells (GCW) combined with Surfactant Enhanced Remediation (SER) using a 2D physical model and COMSOL numerical modeling. So, I have applied for a research visiting period at Freiberg University regarding my thesis entitled "Assessment of Biosurfactant-Enhanced Remediation Effect on the Rate of Clean-up of Oil-contaminated Groundwater Using a 2D Physical Model".

Biosurfactants are surface-acting agents that can improve surface–surface interactions by forming micelles produced by the natural source of origin. The main goal of the current project is the laboratory study and computer modeling of the effect of biosurfactant on increasing the cleaning rate and reducing oil contamination of groundwater Using a Physical Model; this goal can be divided into:

- Effect of biosurfactant on increasing the cleaning rate
- Effect of Combination of SER and GCW on increasing the cleaning rate

The details of research method presented in the below chart:



Development of low-cost pollutant removal adsorptive technics for industrial effluents

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Heavy metal ion pollution due to the discharge of industry wastewater is attracting increasing attention around the world. Presence of heavy metals in wastewater has toxic effects on the receiving environment and human health. Among the polluting metal ions, Cr(VI) and Cd(II) is the most hazardous in the aquatic environment. To respond to the pollution problem of heavy metal ions, various technologies have been developed. Among these different technologies, adsorption is recognized as a well-suited method for the removal of heavy metal ions due to its ease of use and low operating costs. Different adsorbents (zeolites, peats, bentonite, volcanic rock, and diatomite) are suitable for the removal of heavy metals are investigated to determine their adsorption potential. Substantial diatomite and volcanic rock deposits are present in different parts of Ethiopia. Due to its favourable physical, chemical and microstructural properties, low-cost and abundant availability, diatomite is a promising natural sorption material for waste water treatment in this country. However, only few studies have been conducted using diatomite and volcanic rock as an adsorbent media so far. Therefore, the main objective this study is to investigate the potential of locally abundant low-cost adsorbents (Diatomite and volcanic rock) for the removal of heavy metals (Cr(VI) and Cd(II)) from wastewater under batch adsorptive and column experimental designs. The diatomite was characterized by XRD, FTIR, SEM, XRF, and surface area as BET to characterize its morphology and structural and physicochemical properties. Various influencing factors (contact time, pH, initial concentration, and adsorbent dosage) were systematically studied in the batch adsorption experiments. The best sorption conditions for Cr(VI) removal by natural diatomite were found to be at a pH of 2, contact time of 240 minutes, and 0.4 g adsorbent dose. Under these conditions, the adsorbent removes about 69 % of Cr(VI) from an aqueous solution having 10 mg/L initial Cr(VI) concentration at a temperature of 303 K. Moreover, the maximum adsorption capacity achieved at a higher concentration of Cr(VI) of 100 mg l-1 is 2.261 mg g-1. Results indicated that the Cr(VI) sorption of the studied diatomite fits well with kinetic data according to the pseudo-second-order model and external diffusion model. The obtained results follow the Langmuir isotherm model, and even better the Freundlich isotherm model. The Langmuir maximum adsorption capacity (qm) of the

Ethiopian diatomite for Cr(VI) sorption was found to be 2.768 mg g-1. Therefore, we conclude that diatomite can be used as an effective low-cost adsorbent for Cr(VI) removal from wastewater.

Water and Solute Fluxes and their Structural Controls at Margins of Floodplain Aquifers

Konstantin Drach, Mauricio Arboleda-Zapata, Carsten Leven, Olaf A. Cirpka, Peter Dietrich

Floodplains and their margins are important hydrological elements because they connect rivers to their catchments. Due to the heterogeneous sedimentary architecture, preferential flow paths and other high-permeability structural elements connect while low-permeability elements separate surface and subsurface flow paths. This significantly impacts the hydrogeological functioning of a catchment and the solute-turnover processes therein. Previous work has made significant progress in investigating and understanding the internal structure of highly stratified floodplain aquifers. The question remains how floodplains are coupled to other catchment elements at their margins. This project aims to improve the understanding of how important the contributions of individual margins are to the overall water and solute turnover within the floodplain. Of particular interest are the magnitudes and dynamics of fluxes of (1) subsurface contributions from surrounding hillslopes, (2) groundwater contributions from tributary valleys (3) local groundwater recharge from the vadose zone, (4) surface-water contributions from leaky drainage channels within the floodplain, (5) surface-water contributions from the main river, and (6) contributions from other aquifer stories within the bedrock.

As an exemplary model site we select the Ammer valley within the Neckar catchment in Southwest Germany, which is a representative for a mid-section floodplain aquifer in a temperate climate setting in Central Europe. All structural elements listed above are present at its margins and are subject to this project.

For the identification and characterization of different margins we will use a combination of hydraulic and geophysical investigations which will be advanced and employed at hydrogeologically relevant subsurface structural features. This will allow us to assess their geometric and hydraulic properties, their connection to the floodplain and the associated water and solute fluxes. We are advancing the methods of diffusivity tests and multi-well pumping tests in order to further constrain large scale aquifer properties and to test hydraulic connectivity to adjacent hillslope structures.

The results of these investigations will inform a numerical subsurface flow model of the relevant catchment section. Hypotheses about the hydrogeological functioning of different catchment elements will be tested by comparing different realistic model variants. Modeling the site will allow an integrated understanding of the system and the formulation of general hypotheses about its functioning, which may be transferable to comparable floodplain margins of other catchments.

Seasonal controlled dynamics on the fate of selected trace organic compounds and inorganic parameters

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Over few decades, there has been a significant upsurge in the global detection of contaminants of emergent concern, such as trace organic compounds (TROCs), in groundwater systems. This has led to an increased focus on knowing the precise transport, behavior, and distribution of these compounds. This strategy is relevant for maintaining the quality of drinking water, accurately assessing risks, and creating sustainable management plans. The purpose of this project is to evaluate the biochemical conditions on the spatial and temporal signatures of selected TROCs and inorganics, namely acesulfame, sucrose, amidotrizoic acid, carbamazepine, phenazone, diclofenac, sulfamethoxazole, chloridazon, dichlormethan, and atrazin, chlorid, sulphate, nitrate and phosphate, with a focus on two sites of River Rhine. These parameters were measured for this purpose for a period of two years in the surface water and groundwater monitoring. We use MODFLOW-PTH3D on one section of the bank filtration site to develop a 2D reactive transport model on the ORTI3D interface, and SPRING 6 simulation software on the other section. To represent the seasonal driven attenuation and transport dynamics, the observed temporal changes in the breakthrough curve of TROCs will be simulated. The research will provide a vital procedure for effective risk assessment and groundwater management for waterworks. More also it unravels the impact of seasonally controlled dynamics on the fate of selected TROCs in surface water infiltrating into the aquifer.

Understanding underground - dissolution and precipitation within carbonate aquifers under varying thermal conditions for aquifer thermal energy storage (ATES) systems

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Recently, aquifer thermal energy storage (ATES) systems gained increasing attention as a suitable storage method for local and temporary surplus thermal energy in aquifers. The success of ATES depends on aquifer properties like hydraulic permeability, thermal conductivity, and porosity. During ATES operation, variations in pressure and temperature above and below the surface can induce clogging and scaling processes, potentially leading to operational and maintenance issues or failures.

The "UnClog-ATES" research project investigates clogging and scaling processes from an interdisciplinary perspective encompassing microbiology, geology, hydrogeology, and geochemistry, with a focus on carbonate aquifers. The project aims to identify key influencing factors specific to carbonate aquifers and subsequently develop countermeasures, such as scaling inhibitors or the addition of CO_2.

ATES conditions are systematically simulated to investigate pressure, temperature, hydraulic, and chemical composition effects. Initial 0-D batch reactor tests allow for variations in hydrochemical environments and rock compositions. Two ATES-representative carbonate rocks are utilized: a) Jurassic limestone from Upper Malm, Germany ("Treuchtlinger Marmor"; primarily calcite), representing the Malm formation; and b) marble from Hammerunterwiesenthal, Germany ("Erzgebirgsmarmor"; containing calcite and dolomite). Water samples from the same Erzgebirge marble quarry serve as the fluid. Batch and flow tests are conducted over cycles, mimicking ATES temperatures ranging from 5 °C to 60 °C.

Comprehensive hydrochemical and geochemical analyses are performed before, during, and after the experiments to monitor alterations in hydrochemical conditions. Initial results from batch experiments (shaking of the two carbonate rock types with carbonate water for approximately 30 days at 5 °C, 40 °C, and 60 °C) demonstrate distinct dissolution behaviors for each rock type. The Treuchtlinger Marmor (primarily calcite) exhibited increasing calcium concentrations at 5 °C and 40 °C over time, and a decrease at 60 °C. Magnesium concentrations decreased over time. Conversely, using Erzgebirgsmarmor (calcite + dolomite) led to decreased calcium concentrations and increased

magnesium concentrations over time. This indicates a dissolution of dolomite and a precipitation of calcite, which is a typical behavior for an incongruent dissolution process. Batch experiments with fluid alone, simulating various ATES heating and cooling cycles, showed reduced calcium concentrations after subsequent heating cycles, indicating a higher risk of precipitation following multiple thermal cycles.

In parallel with experimental work, hydrochemical modeling is employed to quantify processes and estimate experimental parameters a priori. Initial simulations using PHREEQC suggest an equilibrium state between the rock and fluid materials at 15 °C, followed by calcite precipitation upon stepwise heating. Further simulations indicate that this precipitation could potentially be mitigated by adding a specific amount of dissolved CO_2.

UnClog-ATES intends to contribute to optimizing the prediction accuracy of hydrogeochemical reactions and to the creation of methods both for estimating the clogging potential and for developing and testing possible countermeasures.

Fallstudie: Klimaangepasste Grundwasserbewirtschaftung im Oberen Gäu und im Neckartal bei Tübingen

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The impact of climate change on day-to-day life is already noticeable in many sectors. In some regions in Germany, the use of drinking water is restricted during the summer months to adapt the consumption to the declining availability. The long term adaptation of groundwater usage to the changing circumstances requires reliable predictions of the future development of water demand and availability. By simulating different water demand and climate scenarios, it becomes possible to estimate the water availability of the future and evaluate the implementation of different water management strategies such as managed aquifer recharge, seasonal accumulation and usage of bank filtrate.

The project GW4.0, within the BMBF funding "LURCH "for sustainable groundwater management, examines the regional joint and karstic aquifers of the upper Muschelkalk and the lower Keuper layers as well as the local quaternary valley fillings constituting porous aquifers, aiming to evaluate the impact of current trends observed in the development of climate, population, and economy as well as its implications (e.g. increase in irrigation agriculture, sealing of land etc.). Due to the intense usage of these aquifers, a solid foundation of information exists, including water level measurements, pumping tests, tracer tests, and mapped karstic features. The core of the calculation of the future scenarios is the regional finite differences groundwater model developed in MODFLOW-6 covering approximately 480 km^2.

We aim to quantify the impact due to changes in external boundary conditions caused by climate change, increase in population, development of economy and agriculture, and their implications such as sealing of surfaces, increased water demand, etc. The focus is on different time scales, short-term/seasonal forecasts are intended to enable short-term adaptions in water management strategies. Long-term/far future forecasts for the near (2050) and far (2100) future are designed to give estimates of the availability of groundwater, and the robustness of the present infrastructure and management strategies.

With the implementation of a real-time monitoring network and regular data assimilation the groundwater model capable of reflecting the current status of the groundwater levels. By developing a user interface the model acts as a tool for responsible authorities and water suppliers to gain a first estimate of the impact of actions affecting the groundwater bodies such as water extraction or construction measures in the aquifer. The flexible model architecture allows for the testing of different water management strategies or the implementation of additional wells.

Utilisation of underground resources: investigation of old mines for water and energy storage solutions

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The reuse and conversion of underground structures with regard to water storage options for industrial water use and flood protection offers an opportunity to mitigate the damaging consequences of extreme hydrological events and make landscapes more resilient to climate change. As part of the planned project, the “Reiche Zeche” research and training mine is to be investigated for the use of underground cavities as multifunctional storage facilities for energy and water. The applied simulation and forecasting tools for underground water and energy storage are intended to contribute to an improved understanding of the surface-underground-mine system and thus create the prerequisites for risk and utilisation management of underground cavities in mining regions against the background of climate change.