forum 93

Newsletter of the Chair of Urban Water Systems Engineering

Annual Report of the Chair of Urban Water Systems Engineering

2022

Chair of Urban Water Systems Engineering

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Foreword

Dear Friends,

a year has passed, full of challenges we couldn't have imagined at the beginning of 2022, - a war at our footstep that doesn't seem to end soon, annulled human rights, extreme droughts and heat waves in Europe, natural gas shortage, an inflation with double digits, a shrinking multilateralism…despite many challenges we are grateful for a productive year at the chair and the fact that we can now meet our students again physically in the classroom.

In support of fighting the pandemic, several of our staff members were very busy like last year with monitoring corona biomarkers in wastewater. Finally, with the end of free testing and a declining willingness to take PCR tests, the decision makers realized the true value of wastewater epidemiology to get an objective reading on the infection situation at the population scale. New monitoring programs at the federal and state level were initiated this year and we could support these developments regarding sampling procedures, PCR analysis and data processing infrastructure in close exchange with municipalities, health authorities, the Robert-Koch-Institute and federal ministries.

This year, our staff was very active in publishing their findings in scientific publications and sharing them with the national and international scientific community during physical meetings and invited lectures.

We are very happy for Dr.-Ing. Pablo Vega, Dr. rer. nat. Susanne Minkus, Dr.-Ing. Christoph Schwaller and Mohammed Al-Azzawi for the successful completion of their doctorate degrees this year. A special honor goes to Dr.-Ing. Sema Karakurt-Fischer, who was awarded the 2021 Willy-Hager Award for the best dissertation. Congratulations once again!

In 2023, we are going to hold the 50th Wastewater Technology Seminar (ATS). We decided to celebrate this anniversary with a special event during a two day conference on July 5-6, 2023 to reflect on developments over five decades with highly accomplished leaders in the field. Based on lessons learned we will speak about trends and developments in the wastewater sector in the time ahead. Please join us during this event at the Science Congress Center of the Technical University of Munich at the Research Campus Garching in July of 2023. You can find more information regarding this event on our webiste at (https://www.cee.ed.tum.de/sww/foerderverein/ats/).

In our 'core business', the Chair again made significant contributions to the education of students in the Bachelor's programs in Environmental Engineering and Civil Engineering as well as in the Master's programs in Environmental Engineering, Civil Engineering and Sustainable Resource Management. In addition to a large number of lectures, exercises and lab-based courses, the staff of the chair supervised an impressive number of close to 100 master's theses, student research projects and bachelor's theses in total.

In addition to my duties as the head of the Chair, I am serving as the Academic Program Director for the Environmental Engineering program and its further development at TUM. I am also serving on the Strategic Board of the International Water Association (IWA) and I'm a member of the German Advisory Council on Global Change (WBGU). At the WBGU, we are currently preparing a new main report with a focus on 'Health and Environment' which will be delivered to the German Government in Spring of 2023 and made available to the public.

With this issue, I am very pleased to be able to present you with our Annual Report 2022 to give you a little insight into our activities. In 2022, new employees joined us, who introduce themselves to you in this annual report along with their other colleagues.

On behalf of my staff, I would like to thank you very much for your support and interest in our students and our work. In particular, we would like to thank you for the support of our association 'Friends of our Chair', which makes a very important contribution to the education of our graduate students and undergraduates by funding travel to conferences and research grants.

We would be very happy if we could provide these supports for our PhD students, graduates and undergraduates again this year through your donation.

We wish you a successful year and much pleasure in reading this report.

Yours,

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Research Center

The mission of the research center at the Chair of Urban Water Systems Engineering, directed by Prof. Brigitte Helmreich, is to provide support for process validations for both drinking water and wastewater treatment technologies at laboratory and pilot scale. In addition, we are conducting studies on new materials and processes and support research and development in close collaboration with industry partners, small and medium-sized enterprises, and public as well as regulatory agencies. The research center is comprised of a 400 m² pilot-scale facility and an adjacent research field, both with direct access to treated wastewater from the Garching Wastewater Treatment Plant (30,000 PE). This infrastructure enables us to conduct studies not only with drinking water but also to examine wastewater processes fed continuously with differently treated effluent qualities. For these studies, we can conduct experiments at laboratory and pilot scale with reactor volumes between 30 and 800 L in size. This provides opportunities to upscale and validate processes from laboratory to demonstration scale. Besides Zahn-Wellens-Tests to examine the biodegradability of wastewater samples (following DEV L 25), we also conduct activated sludge simulation tests (following DEV L 41).

Figure 1: Pilot-scale nanofiltration test skid (80 L/min).

Regarding advanced water treatment processes, the research center is equipped with test skids for chemical oxidation (ozone, UV irradiation with hydrogen peroxide, electrochemical oxidation) and membrane filtration (ultrafiltration, nanofiltration, reverse osmosis) (Figure 1).

In addition, the center is investigating and advancing treatment processes for urban stormwater and street run-off. For these investigations, we can utilize laboratory-scale test and soil column experiments of various sizes to examine the fate and transport of heavy metals and organic contaminants. Regarding urban run-off from copper roofs, a demonstration-scale test bed is available at the center, which is comprised of a large-scale copper roof and associated sampling and monitoring devices.

Physicochemical, Trace Compounds Analysis, and Microbiological Laboratories

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A central facility of the chair and the research center is the affiliated laboratory, with three areas of specialization: the physicochemical laboratory led by Dr. Susanne Petz, the trace compounds analysis unit led by Dr. Ignacio Sottorff and the microbiological laboratory led by Dr. Christian Wurzbacher.

The physicochemical laboratory is equipped with state-of-the-art analytical apparatus for the investigation of all relevant standard parameters in drinking and wastewater. Besides the characterization of water samples through sum parameters, such as COD and BOD (Figure 2), organic parameters can be further determined using 3-D fluorescence and UV spectroscopy and measured quantitatively with the TOC analyzer. For analysis of anions either photometric test methods or ion chromatography are available. Determination of metals is carried out using atomic absorption spectrometry.

Figure 2: Determination of single and sum parameters through cuvette tests using the HACH-photometer.

The analytical laboratory is specialized on the characterization and identification of organic molecules from aqueous samples with trace compounds analysis (target screening), including perfluorinated alkylic acids (PFAS), using chromatographic separation techniques coupled to highly sensitive mass spectrometric detection techniques (LC-MS/MS) (Figure 3). Volatile organic compounds, such as plasticizers or volatile fatty acids can be detected with the help of headspace-GC/FID as well as particles originating from micro plastics using a thermal desorption-pyrolysis-GC/MS, respectively.

Figure 3: LC-QTRAP-MS system by AB Sciex for trace analysis.

The microbiological laboratory uses conventional techniques to determine the fecal indicator germs relevant for hygienic water quality. For disinfection experiments, we offer biodosimetry and direct detection of damaged microorganisms. Bacterial cell counts and antibiotic resistance genes are additionally quantified molecularly (quantitative PCR) (Figure 4). High throughput sequencing technologies are used to characterize microbial communities.

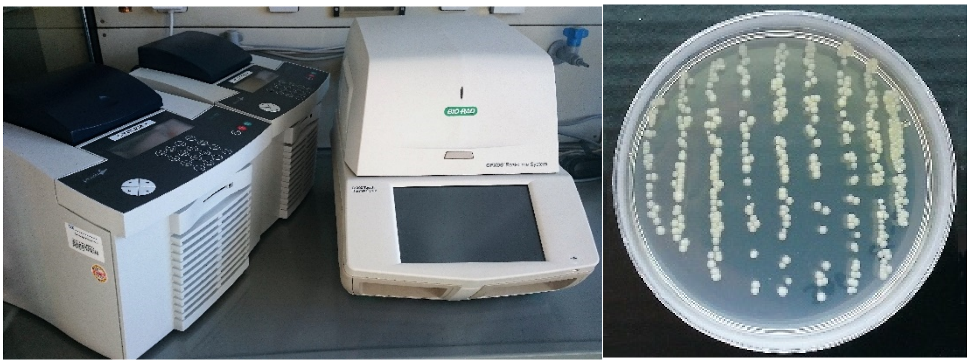

Figure 4: Left: PCR and qPCR system to amplify and quantify different genes of interest. Right: microbial cultures for experiments.

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Research Group Stormwater Harvesting and Drainage Systems

This year, the topic of "water-aware settlements" was again a priority in the drainage systems working group. Climate change poses major challenges for urban drainage due to the increasing frequency of extreme weather events such as heavy rain events and periods of drought. Therefore, adaptation strategies as a reaction to climate change impacts are becoming more and more important. It is important to integrate all actors of the grey, green and blue infrastructure into the planning right from the start when new planning or the densification of districts in settlements is taking place. At the same time, it must not be forgotten that pollutants must be removed from the stormwater runoff of urban areas in order to prevent them from entering groundwater and surface water.

Figure 5: Pilot tests on biodiversity in the project Multifunctional infiltration swales in residential areas; Excursion of the working group in July.

A new research project in 2022 deals with the topic of increasing energy efficiency through the climate-adapted, synergetic use of innovative energy and rainwater management for the ecoSquare urban district. Here, together with partners, we are developing a decentralized treatment system for rainwater runoff from various sealed areas (green roofs, facades, traffic routes) with the aim of water recycling for irrigation. Another new research project in 2022 on the subject of urban green infrastructure is embedded in a research training group of the German Research Foundation (DFG). The doctoral student works in a team with other doctoral students from other disciplines in order to scientifically elucidate the pollutant retention in the living soil zone of infiltration systems.

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Multifunctional Infiltration Swales in Residential Areas

Rapid urbanization is leading to high levels of densification in cities and new developments. The resulting increasing soil-sealing and reduction of inner-city green spaces inevitably leads to changes in the local water balance, intensification of effects such as the urban heat-island and a decline in biodiversity in residential areas. Globally observed climate changes, including more frequent extreme events such as heavy rainfall and periods of drought, intensify the negative effects of a lack of open spaces in cities. An important element in counteracting these effects can be green infiltration swales in residential areas. In this research project, this type of near-natural stormwater-management is to be extended by the aspect of multifunctionality.

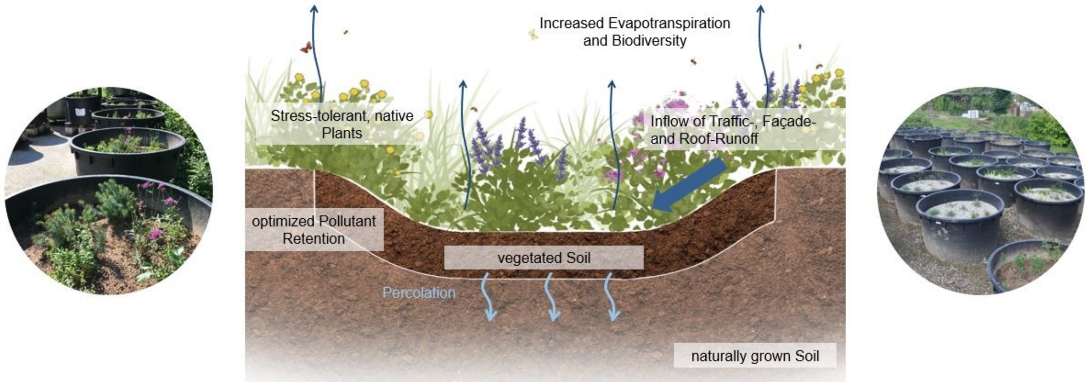

Figure 6: Schematic structure and effect of multifunctional infiltration swales.

FUNDING:

BAVARIAN ENVIRONMENT AGENCY
BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION

COLLABORATION:

WEIHENSTEPHAN-TRIESDORF UNIVERSITY OF APPLIED SCIENCES,
SOIL-INSTITUTE JOHANNES PRÜGL,
ENGINEERING OFFICE FOR SOIL AND VEGETATION TECHNOLOGY

The aim is not only the development of an improved infiltration system, but also an optimized plant- and animal-habitat (Figure 6). The research on adapted and suitable vegetation is carried out by employees of the HSWT. The Chair of Urban Water Systems Engineering (SWW) focuses on the development of a suitable and optimized vegetated topsoil by means of substrate amendment. In the first half of 2021, the laboratory experiments on the retention of pollutants through different substrates were mainly completed. In July 2021, semi-technical experiments were set up open air with vegetation at both the HSWT and the SWW to investigate the material load and operational stability (Figure 6). This experiments at the SWW focuses on drainage safety and the retention of heavy metals and biocides from traffic-area-, façade- and roof-surface-runoff. In April 2022, piloting of a multifunctional swale in Munich was implemented with the proven soil-substrate mixtures and different plants from the semi-technical experiments. Additional, stormwater tree pits in pilot scale with the same topsoil-substrate mixtures were set up in Pfaffenhofen a. d. Ilm. First results of the pilot scale plants will be expected at the end of 2023.

This research project forms the basis for a future guideline for operators and planners, from which the ecological and economic advantages, as well as the effort for maintenance, will become apparent.

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BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION

COLLABORATION:

INSTITUTE OF ENERGY AND SUSTAINABLE DESIGN AND BUILDING TUM, INSTITUTE FOR REAL ESTATE ECONOMICS

Accompanying Research "Climate-friendly Construction – Model Projects"

The consequences of anthropogenic climate change are also visible in Bavaria and, depending on the level of future global emissions, will have significant impacts in the coming decades. In the future, Bavaria will have to prepare for more frequent extreme weather events, such as intense and prolonged heat waves and dry phases, as well as longer-lasting rain events and heavy precipitation events. Accordingly, the urban environment, the construction and design of buildings and open spaces must already meet the changing external circumstances and rise to the challenges today.

An important component of climate-friendly building is on-site stormwater management. A water-sensitive settlement development aims to come as close as possible to the natural local water balance in order not to overload the municipal drainage systems, as they are not prepared for the impacts of climate change (e.g. flooding, combined sewer overflows during heavy rainfall).

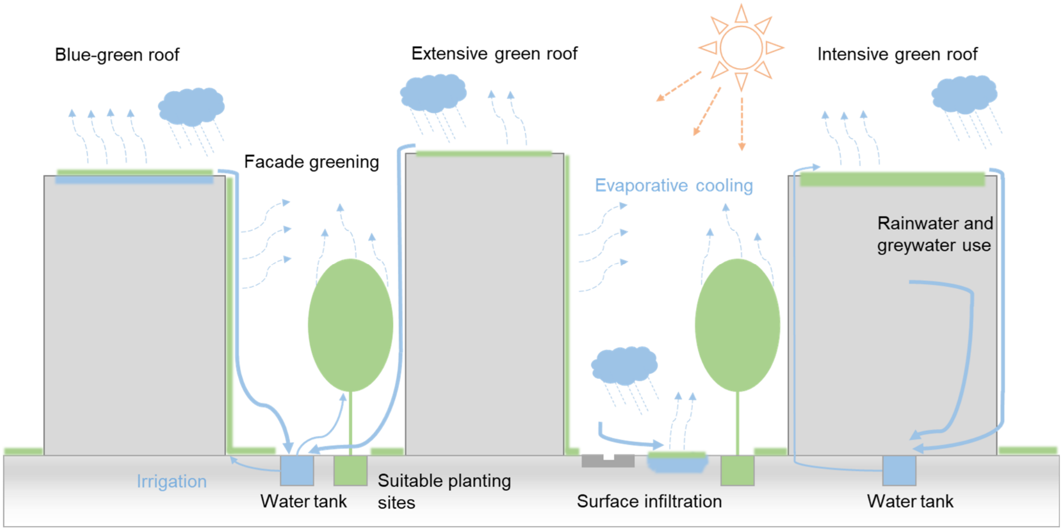

Figure 7: Correlations of green-grey-blue infrastructure.

Within the scope of the project, quantitative and qualitative aspects from a water management point of view are investigated for this purpose. For selected model projects, simulations of different climate scenarios (heavy rainfall to extreme dry periods) are carried out and used to evaluate the influence of blue-green measures on the adaptability to climate change.

The research project is a subproject of the Centre for Urban Ecology and Climate Adaptation (ZSK) and serves as scientific support for the implementation of ten model projects in Bavaria with regard to urban climate adaptation (adaptation) and climate protection (mitigation) in municipal housing construction. The aim is to demonstrate the feasibility of blue-green-grey climate adaptation measures in municipal housing, considering the long-term economic viability, which will have a positive impact in times of climate change and the associated increase in the number of extreme weather events.

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FEDERAL MINISTRY OF ECONOMIC AFFAIRS AND CLIMATE ACTION

COLLABORATION:

FRÄNKISCHE ROHRWERKE GEBR. KIRCHNER GMBH & CO. KG, OPTIGRÜN INTERNATIONAL AG

Decentralized Sustainable Urban Drainage Systems – Development of a Stormwater Treatment Train for Contaminants from Multiple Sources in Residential Areas

The densification of cities and an increasing amount of impervious surfaces support negative effects of global warming, such as the urban-heat-island-effect and an increase in urban runoff volume. Innovative rainwater management can decrease these effects. Large volume multi-use rainwater cisterns collect urban runoff from green-roofs, façades, and traffic surfaces within a residential area. The natural thermal energy from rainwater is fed into cold local heating networks. In combination with geothermal installations, the energy supply is high enough to meet energy demands for heating or cooling of a residential quarter throughout the year. The same runoff is used to irrigate the urban green spaces including green roofs. This supports the urban-water-cycle by on spot percolation and decreases the urban-heat-island-effect by evapotranspiration.

The urban runoff needs to be treated prior to its multi-purpose use. Therefore, the chair of Urban Water Systems Engineering (SWW) in cooperation with “FRÄNKISCHE Rohrwerke Gebr. Kirchner GmbH & Co. KG“, will develop a stormwater treatment train for simultaneous removal of contaminants from multiple sources in residential areas. Other techniques like direct infiltration into the ground (façade-runoff and some roof-runoff) or separate treatment of different runoffs require more space and multiple treatment systems for different contaminants. The aim of this project is to find a substrate mixture to treat traffic-, façade- and green-roof-runoff all at once. The focus is the simultaneous treatment of biocides, total suspended solids, heavy metals, nutrients as well as organic contaminants.

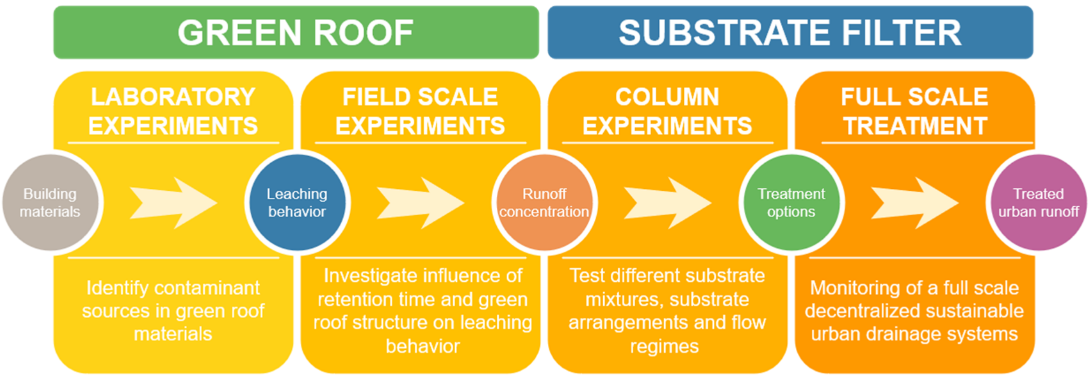
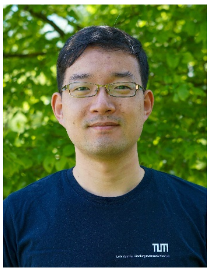


Figure 8: Project structure and sequential experimental setup description.

Recently biocides from facades and green roofs moved into the focus, as a potential threat for the environment. Especially, green roof related biocides are gaining interest in the scientific community, due to an increasing amount of green roofs in urban areas. The SWW In cooperation with the “Optigrün international AG” is investigating on the impact of retention time and green roof type on the leaching behavior of biocides. In a further experiment both partners will test the urban runoff treatment capabilities of different green roof systems.



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FUNDING:

CHINA SCHOLARSHIP COUNCIL

Quantifying the binding of different biocides and heavy metals to centrifugally fractionated DOM by dialysis equilibrium

In the urban area during the rain events, pollutants in building surfaces like heavy metals (Cu/Zn) and biocides appear in the rain water due to the flushing and leaching processes, and spreading around in the environment. Unfortunately, there does not have a high efficiency on-site treatment facility that can be used to mitigate the risks they posed to the ecosystem. Therefore, we carried out some studies aiming to understanding the interactions between heavy metals/biocides with DOM and providing knowledge in treatment system designing.

In previous study, heavy metals and biocides were proved can interact with the DOM. But that is a qualitative result. To describe the interactions precisely, dialysis equilibrium method is used in the study. Before starting the dialysis equilibrium, the used DOM was fractionated into different parts by centrifuge according to their molecular weight, as DOM is a complicated mixture, different molecular weight means different structure and binding ability to pollutants.

Quantification the binding of pollutants with fractionated DOM were carried out individually. Samples inside and outside the dialysis bag were collected. For heavy metals, they were analyzed by AAS after acid digestion removal the DOM. For biocides, they were analyzed by HPLC-MS. The influence from Cu on biocides binding with DOM was evaluated as well.

With these studies, pollutants binding with fractionated DOM are investigated compared.

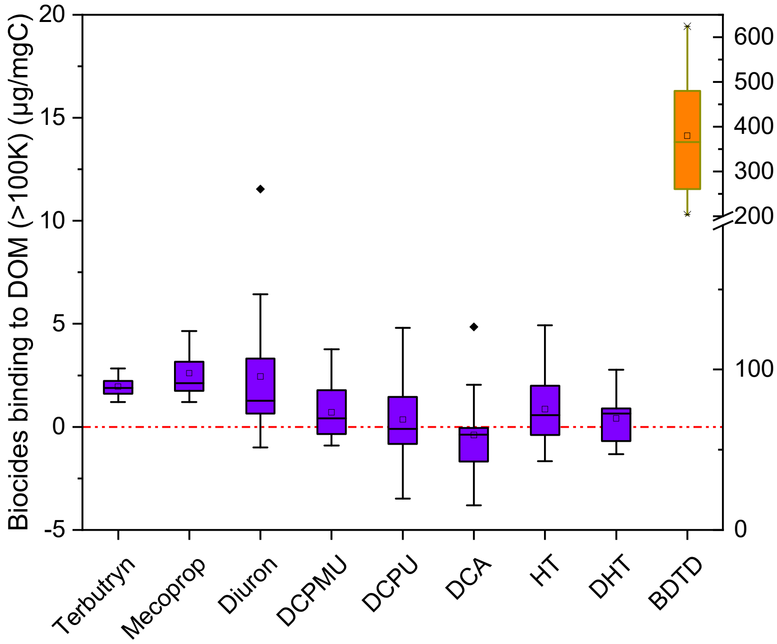

Figure 9: The amount of biocides/transformation products binding to the fractionated DOM (>100K), right Y axis is for BDTD.

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Funding:
Associations for Insulation System, Plasters and Mortars Germany

Collaboration:
Fraunhofer Institute for Building Physics

Development of a Model to Assess the Environmental Properties of Common Outdoor Plasters and Mortars

Building products such as plasters and mortars are largely used on the outside of the buildings (e.g. mineral and organically bound plasters on masonry, thermal insulation composite systems, masonry mortars and other substrates). When these products are used outside, they are exposed to precipitation and ambient air. The leaking of rainwater dissolves the ingredients from the plasters and mortars and releases them. Since not every substance has an environmentally hazardous potential, the release of substances from construction products in contact with rainwater does not necessarily imply a negative impact on the environment. However, the evaluation of the leaching behavior of plasters and mortars in the case of a rainy façade is not yet possible, as there is no transfer model to conclude from the results of leaching tests on the actual deterioration of soil and groundwater.

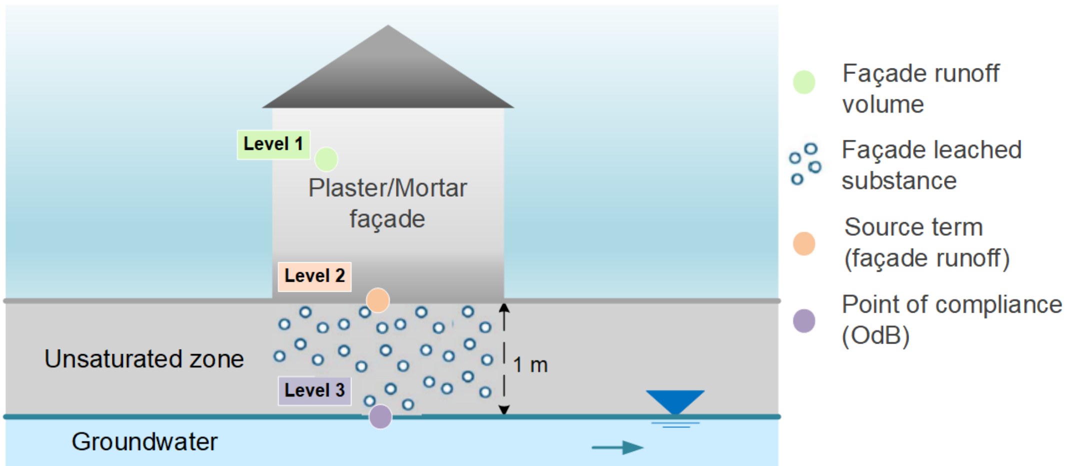

Figure 10: Source term of the leaching substances (façade runoff), unsaturated transport zone, and point of compliance (OdB), where the insignificance threshold value (GFS) acts as a target concentration. To achieve this overall objective, three specific sub-objectives are planned.

The main objective of the project in 2022 was to model the transport of four organic parent compounds (PCs) which are in façade runoff, namely carbendazim, diuron, octylisothiazolinone (OIT), and terbutryn, as well as 10 of their transformation products (TPs) within an unsaturated soil compartment (sandy or loamy/silty/clayey soil) until they reached a point of compliance (OdB). is to create a model that can describe the leaching mechanism of contaminants in a plaster and mortar facade during a random rainfall event. On this basis, an evaluation of the environmental characteristics should be carried out.

It was found that the model delivered concentrations of PCs at the OdB are, with exception of OIT, higher than the suggested value of 0.1 µg/L, independently if it is only sandy or loamy/silty/clayey soil according to the general conditions of the GRA. However, by including an appropriate topsoil layer with an organic content of 2% the concentrations of the PCs can be reduced significantly.

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FUNDING:

GERMAN RESEARCH FOUNDATION DFG

Implementing Biochar and Compost in Vegetated Infiltration Swales as Green Infrastructure for Stormwater Treatment

Urban stormwater is a significant pollutant source that impairs the quality of waterbodies and can affect human health and ecosystems. As climate change will increase the frequency and intensity of extreme heavy rainfall and flooding, mitigating pollution from urban runoff is crucial for urban sustainability and climate change adaptation. Implementing green infrastructure –such as vegetated infiltration swales or bioswales– for urban stormwater management is a meaningful strategy for addressing this challenge, as it can provide various ecosystem services. However, although conventional bioswales can effectively remove sediments and particulate-bound pollutants, they can fail to remove dissolved pollutants in a reliable manner.

This project aims to improve the dissolved pollutant removal in vegetated infiltration swales by studying the implementation of organic soil amendments, focusing on biochar and compost. These materials are easily available, have low production costs, promote a circular resource use, and can potentially remove a wide set of contaminants. Furthermore, they support other functions important for the sustainable operation of bioretention swales, such as nutrient provision for plant uptake and the maintenance of favorable conditions for microbiota development. This project intends to achieve a better understanding of pollutant removal mechanisms in bioswales while exploring the potential benefits of implementing biochar as an organic soil amendment in these systems.

Figure 11: Conceptual framework of implementing organic soil amendments in vegetated infiltration swales.

The project will involve laboratory and meso-scale experiments to test the removal of multiple dissolved pollutants (heavy metals, biocides and pesticides) in representative stormwater matrices in biochar- and compost-amended systems. The effect of combining low and high temperature pyrolyzed biochar to remove multiple contaminants with a higher efficiency and resilience to varying pollutant loads will also be evaluated. An assessment of increase in biodegradation of TOrCs will also be performed, as well as an evaluation of the effects of seasonal de-icing salts and different saturation conditions in bioswales.

This research is part of the interdisciplinary Research Training Group in Urban Green Infrastructure at the Technical University of Munich.

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Pilot Project Former Bayern Barracks: Development of Soils and Substrates Recycled from Secondary Raw Materials and Evaluation Regarding Water Storage Capacity, Pollutant Retention and Plant Compatibility

In the course of the site clearance at the former Bayern barracks the city of Munich plans to recycle approx. 200,000 tons of excavated soil and processed demolition waste as plant substrates in landscaping. To minimize disposal and transport costs, as well as disposal related externalized costs such as urban traffic load and CO_2 emissions, the city of Munich plans to utilize these materials on the spot.

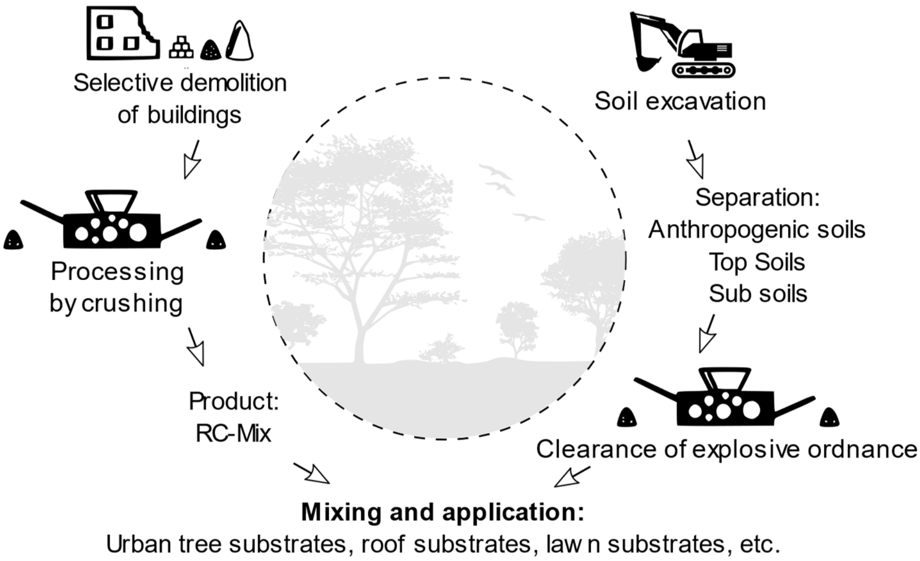

Figure 12: Process flow of secondary raw material extraction at the former Bayernkaserne Munich.

Funding:
City of Munich, Municipal Department

The aim of the pilot project is to assess the non-hazardous re-use of these secondary substrates within the newly arising city quarter 'Neufreimann' on the area of the former Bayern barracks. Also, potential benefits concerning water holding capacities will be investigated.

For this purpose, a field trial was established where different substrate mixtures will be investigated with regard to plant compatibility, soil water contents, emission of pollutants and retention of pollutants. Depending on the outcome, the recycling concept could be adopted for comparable building projects in Munich.

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Research Group Energy Efficient Wastewater Treatment

Wastewater treatment plants are currently still the largest consumers of municipal electricity, although there is actually more than enough energy in the wastewater than is required for its treatment. While the treatment of wastewater, taking into account the specified discharge limits, continues to be the top priority, the research group is looking for approaches to reduce the energy required for treatment on the one hand and recovering more energy from wastewater on the other hand, for example by generating biogas from the sewage sludge.

Since no new research project was initiated this year, I would like to take this opportunity to draw attention to our activities around the standardization of biochemical methane potential (BMP) tests, which are so important for anaerobic technology. These BMP tests often form the basis for many key decisions around digesters and biogas plants, such as their dimensioning or the evaluation of treatment processes. Although various guidelines for their implementation have been available for decades, unfortunately they are not conscientiously implemented either in practice or in science. Therefore, together with 40 other renowned international scientists, we published an easy-to-understand guideline in 2015, which is freely available (open access) and has meanwhile been successfully applied in more than 400 studies: https://doi.org/10.2166/wst.2016.336. Unfortunately, in an international interlaboratory comparison based on this guideline, it became apparent that the validation criteria laid down in it still need to be readjusted in order to ensure the necessary quality assurance of the results: https://doi.org/10.3390/w12061752. The necessary adjustments to the original guideline were summarized in another publication: https://doi.org/10.2166/wst.2020.569.

Although BMP testing is widely used, especially in science, the necessary knowledge in this regard is unfortunately often limited. Therefore, together with colleagues from the United States, Spain, Switzerland and Germany, we have launched a website where all relevant information about BMP testing is available and constantly updated: https://www.dbfz.de/bmp. In addition to general information, instructions on all common measurement methods and the associated calculations can be found there in various languages. The offer is complemented by the Biogas Package for the statistical software R developed by us, which is optionally also available as a web interface called Online Biogas App (OBA). The software offers a wide range of possibilities for planning experiments, conversion, standardization and data processing.

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FUNDING:
FACHAGENTUR NACHWACHSENDE ROHSTOFFE E. V.

COLLABORATION:
HEIDELBERG UNIVERSITY, BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE

ENCOVER: Energetic Utilization of CO_2 to Enhance the Methane Productivity and to Reduce the Residual Methane Potential

The most significant source of greenhouse gas emissions is the combustion of fossil fuels. In order to achieve the goal of greenhouse gas neutrality by 2050, energy supply in the future must increasingly be based on renewable energies. Biogas production has a key role to play here, since unlike most other forms of renewable energy, it can be stored. Unfortunately, a not inconsiderable proportion of the methane potential remains in the fermentation residue when renewable raw and residual materials are fermented. Studies have shown that an enrichment of the anaerobic degradation process with CO_2 can contribute to an increase in methane productivity under certain conditions, while at the same time increasing the resilience of the process.

The goal of the project is the energetic utilization of CO_2 to reduce the residual methane potential. In the process of biogas production, renewable raw materials and especially residual materials are used, whose behavior with CO_2 enrichment in anaerobic degradation has not yet been investigated. However, their use appears to be particularly promising, since in contrast to the substrate sewage sludge, which has been investigated in particular so far, a stimulation by a significantly better substrate conversion is considered to be probable.

Within the scope of the investigations, the CO_2 uptake potential and the additional CH4 production are to be quantified. By means of isotope analyses and microbiological investigations, the mechanisms and processes taking place are to be broken down and better understood. The investigations are carried out by means of batch experiments as well as continuously operated reactors on a pilot plant scale.

The reactors are currently fed with renewable raw materials in the form of corn silage. During CO_2 enrichment, one reactor is always gassed, while the second serves as a reference under otherwise identical conditions for control. Gassing of the reactors is semi-continuous. Finally, from the knowledge gained about the process control of CO2 enrichment of renewable raw materials, it is necessary to derive and present recommendations for the use of the effect for practical applications quantitatively in terms of CO_2 balance and economic efficiency.

Figure 13: Continuously operated reactors on a pilot plant scale.

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FUNDING:
EUROPEAN COMMISSION

COLLABORATION:
THE CATALAN INSTITUTE FOR WATER RESEARCH

Design of Hybrid Nano-engineered Bioprocesses for Wastewater Treatment

The project uses a nanomaterial to upgrade existing treatment technologies. Through graphene oxide (GO) addition into anaerobic wastewater treatment systems, the project aims to enhance the removal of organic micropollutants (OMPs), i.e., persistent pollutants with unknown long-term effects.

Although anaerobic treatments are preferred over aerobic due to the lower energy requirements and the possibility of producing energy in the form of biogas, they present some drawbacks. One is the slow ability to degrade organic materials, which makes the anaerobic systems, made of a complex and delicate mixture of microorganisms, incapable of dealing with the already recalcitrant OMPs. However, by adding the GO, the connection among microorganisms may be enhanced and the reaction times can be drastically shortened, allowing the removal of recalcitrant OMPs. Thus, this project studied the biogas production and the OMPs removal and transformation in anaerobic batch assays amended with GO.

As a prerequisite for improved degradation kinetics, GO must first be biologically reduced via microbial respiration. Results revealed that such GO's biological reduction occurred within one day. Notably, this is the first study demonstrating it using a real culture of an anaerobic digester rather than single or lab-cultivated microbial strains. However, the removal of the two antibiotics (sulfamethoxazole and trimethoprim), selected as model OMPs, occurred in a few days regardless of the presence of GO. Furthermore, GO presence had an inhibitive impact on the formation of sulfamethoxazole's transformation products and the biogas yield by up to 20%. Therefore, the expected improvement in OMPs transformation due to GO addition was not observed.

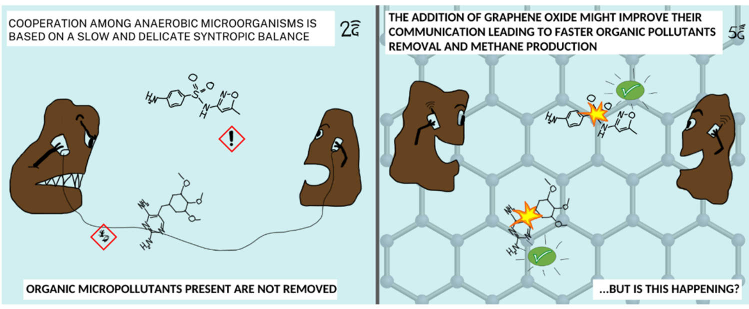

Figure 14: Effect of GO addition in batch experiments.

Nevertheless, in a long-term study, the modeling and statistical analyses revealed significant accelerations in organic material degradation using GO concentrations greater than 10 mg per gram of volatile solids (VS) (or biomass presence).

From an environmental significance point of view, the work provided compelling prospects for accelerating the removal of organic pollutants (even recalcitrant ones) and producing biogas in shortened times in long-term or continuous treatment set-up.

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Decentralized Biogas Generation

To meet the energy needs of the Global South, it is essential to rely on renewable energy sources while reducing the carbon footprint. Anaerobic digestion plays an important role in generating energy from various feedstocks and residues available in rural areas of the Global South. However, due to poor operating conditions, biogas plants are often operated at low efficiency. As a result, little biogas is produced and the digestate still contains a high proportion of organic material. One main reason for this is the lack of required expertise.

Within the framework of the TUM SEED (Sustainable Energy and Entrepreneurship) Center, so-called living labs have been established at various locations around the world. These are used to pass on scientific methods and findings to the local population in an illustrative way and to provide them with continuous support in the event of questions. This ensures that the respective technology and the associated know-how can also be used promisingly in the long term.

In October, I visited the living lab of the Pontificia Universidad Católica del Perú in Huyro near the world-famous Inca mountain fortress of Machu Picchu together with Dr. Konrad Koch. In addition to other technologies, such as the use of the hydraulic ram to pump water without electricity, we presented at the workshop, which lasted several days, the method we developed together with partners to determine the biogas yield with little technical effort. In addition to the usual equipment, such as bottles, septa and incubator, the method requires only a precise balance and syringes for volume determination. This allows the density and thus the composition of the biogas produced to be determined. Thus, the expected methane yield of any substrate can be determined with relatively little effort. Based on this, appropriate biogas plants can then be dimensioned and planned. In addition, the participants were provided with basic technical knowledge about the biogas process.

Funding:
German Academic Exchange Service

Collaboration:
TUM SEED Center

Figure 15: Workshop in the living lab of the Pontificia Universidad Católica del Perú in Huyro.

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FUNDING:

BAVARIAN MINISTRY OF ECONOMIC AFFAIRS REGIONAL DEVELOPMENT AND ENERGY

COLLABORATION:

BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE

Optimization of the Microbiological Methanation in an Anaerobic Thermophilic Trickle Bed Reactor and Demonstration of the Reactor Performance at Pilot-Scale

Renewable energies will become the most important energy source for the energy transition in Germany. Developing conversion and storage technologies is crucial in ensuring a sustainable energy supply. An approach for flexible and demand-oriented energy storage is the generation of methane (CH_4) from hydrogen (H_2) and carbon dioxide (CO_2) (power-to-methane). In this process, H_2 is produced from unused renewable electricity by means of electrolysis, and CO_2 from wastewater treatment plants, biogas plants, or industry can be used directly at the point of generation.

The conversion of H_2 and CO_2 to CH_4 under anaerobic conditions by methanogenic microorganisms is known as a sub-process from biogas plants or digesters at wastewater treatment plants. A particularly efficient reactor concept is the gas-filled trickle bed reactor, in which the microorganisms are immobilized on carrier materials. Carrier materials with a large surface area increase the contact area between the gas (H_2 and CO_2) and the microorganisms in the liquid phase.

Thermophilic anaerobic trickle bed reactors at lab-scale already demonstrated a high performance with a CH_4 production of 15.4 $m^3_{CH4}/(m^3_{reaction\ volume} \cdot d)$ at CH_4 concentrations in the product gas above 96%. This would allow direct injection of the biomethane into the natural gas network without the need for further gas purification.

Figure 16: Pilot-scale reactor at the wastewater treatment plant Garching.

With an active reaction volume of 0.8 m^3, the applicability of the reactor concept was demonstrated on a semi-industrial scale. This makes the pilot reactor at the wastewater treatment plant Garching (Figure 16) one of the largest anaerobic trickle bed reactors in the world. Biogas upgrading at the point of origin has a holistic potential as all resources required for the operation of the reactor can be found locally.

After inoculating the reactor with digested sludge, the reactor was operated with raw biogas as CO_2 source from the local digester for a total of 450 days. With a stable CH_4 production of 6 $m^3_{CH4}/(m^3_{reaction\ volume} \cdot d)$ at gas grid injection quality, which corresponds to a product gas flow of 17 $m^3_{CH4}/(m^3_{reaction\ volume} \cdot d)$, taking the inert CH_4 content in the biogas into account, the potential of the energy conversion technology was demonstrated.

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FUNDING:

FACHAGENTUR NACHWACHSENDE ROHSTOFFE (FNR) E.V.

COLLABORATION:

ASSOCIATION FOR TECHNOLOGY AND CONSTRUCTION IN AGRICULTURE, INSTITUTE FOR SOIL AND ENVIRONMENT - LUFA NORD-WEST

Modelling the Degradation Kinetics of Substrates Rich in Lignocellulose for a Flexible Biogas Process in Practical Application

Biogas represents a considerable share of the renewable electrical and thermal net energy in Germany. Beyond that it can be stored in gas storages, or it can be supplied to the natural gas grid after conditioning. Because of its storage capacity, biogas is also well-suited to balance the fluctuating supply of other renewable energy sources. Besides that, the process of biogas formation itself can be made flexible, too. At the moment, the production of biogas is mainly based on energy crops. However, the substantial available potential of agricultural waste biomass is currently not full used.

Figure 17: Agricultural biogas plant.

In contrast to energy crops, agricultural waste biomass is generally characterized by a markedly higher content of lignocellulose. Lignocellulose is a complex component of biomass that can only be converted very slowly or partially in the biogas process due to its structure and composition. As a result, the biogas process reacts comparatively slowly to substrate additions and the biogas yield is reduced. In order to make the biogas production flexible and to be able to plan the biogas production, it is necessary to make predictions. These are to be made possible by means of a model that is capable of describing the degradation kinetics of agricultural residues.

In order to define this model, existing work will be followed up, in which a correlation between the composition of energy crops and their degradation kinetics as well as their specific methane potential could already be demonstrated. In this context, the effectiveness of different pre-treatment methods on the degradation kinetics and methane potential of agricultural residues will also be investigated. Furthermore, it is planned to develop an application based on the model in order to make the results usable in practice. This should enable operators of biogas plants to plan the use of agricultural residues for biogas production.

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ALEXANDER VON HUMBOLDT FOUNDATION

COLLABORATION:

UNIVERSITY OF QUEENSLAND, NORTHWESTERN UNIVERSITY

Towards Mainstream Anammox for Energy-Efficient Municipal Wastewater Treatment

Municipal wastewater treatment plants (WWTPs) receive increasing pressure because of the high energy consumption. To address this issue, various partial nitritation-based anammox (PN/A) processes were developed owing to their significant economic benefits, by which the operational costs could be cut by 85% compared to the currently employed nitrification/denitrification process. However, there are no successful engineering projects in treating low-strength municipal wastewater so far. The main bottleneck is the difficulty in effectively suppressing nitrite-oxidizing bacteria (NOB), which leads to insufficient nitrite to maintain anammox activity resulting in high effluent nitrate concentrations.

We proposed a novel *Sidestream Enhanced Mainstream Anammox* (SEMA) process for energy-efficient municipal wastewater treatment. As displayed in Figure 18, organics in raw wastewater are recovered in A-stage, its effluent is fed to PN/A reactor, and a small portion of A-stage effluent is introduced to sidestream nitritation reactor along with centrate to achieve an efficient nitrite production. These two streams are then transferred to downstream anammox reactor together with a small portion of raw wastewater providing organics to enhance denitrification for in-situ nitrate removal. Assuming the nitrogen load of sidestream wastewater is 20% of that in municipal wastewater and a nitrogen removal efficiency (NRE) of 60% is achieved in the PN/A unit, nitrogen mass balance analysis indicated a low effluent total nitrogen (TN) concentration of 5.1 mg N/L could be achieved.

Multiple benefits could be achieved by the SEMA process in terms of economy, effectiveness, and efficiency, and the long-term stability and a suitable effluent quality could be guaranteed with an easy control. It thus has a great potential in engineering application. In contrast to the generally accepted viewpoint that sidestream wastewater needs to be treated separately, the beneficial role of integrating sidestream treatment in facilitating mainstream anammox should be recognized. Technology feasibility and economic viability of the proposed SEMA process will be further verified.

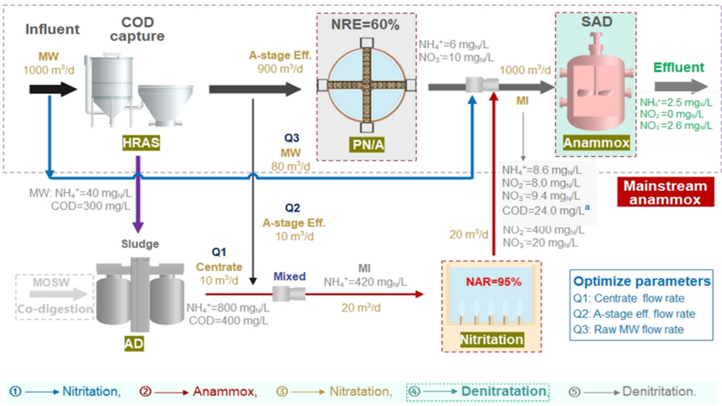

Figure 18: Schematic diagram of the proposed Sidestream Enhanced Mainstream Anammox (SEMA) process for energy-efficient municipal wastewater treatment.

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Research Group Advanced Water Treatment

Despite the high treatment efficiency of conventional wastewater treatment plants (WWTPs), concern is raised regarding the removal of emerging contaminants including

- trace organic chemicals at ng/L to µg/L level (e.g. pharmaceuticals, per- and polyfluorinated alkyl substances)
- pathogens (bacteria, viruses, protozoa)
- antibiotic-resistant bacteria and resistance genes
- nutrients at low concentration (P, N)

Discharge from WWTP poses potential risk to aquatic ecosystems and human health. The work of this research group focuses on the evaluation and optimization of advanced water treatment processes and concepts for mitigation of these emerging contaminants. We apply advanced water treatment to mitigate discharge into the aquatic environment but also develop and assess concepts for (indirect) potable and non-potable reuse.

An important aspect of the research group is also the transfer of research results from laboratory scale to pilot- and full-scale implementation. Particularly in the development of new oxidation processes, the step to practical application is often very slow despite extensive international research, which is often due to the lack of comparable and transferable laboratory results. In cooperation with partners from Germany and abroad, we develop recommendations for a more systematic and targeted investigation of the new advanced oxidation processes.

Figure 19: Bench-scale ozonation system.

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FUNDING:

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

TEL AVIV UNIVERSITY

In-situ Chemical Oxidation (ISCO) by Passive Dissolution of Ozone Gas using Gas-Permeable Membranes for Remediation of Petroleum-Contaminated Groundwater

Within this joint German-Israeli research cooperation, we aim to develop membrane-based ozonation for in-situ groundwater remediation. The diffusion-driven, bubble free gas exchange via membrane contactors is a promising technology for overcoming problems of conventional groundwater remediation approaches. It could potentially lead to a more homogeneous dissolved gas distribution and a more energy-efficient process. By installing membranes as permeable reactive barrier, we expect an effective removal of monocyclic, aromatic compounds (BTEX, Figure 20) from polluted groundwater.

Fundamental research on passive, bubble-free gas introduction at low flow velocities is first conducted in lab-scale reactors (Figure 21). The test of different membrane materials shall provide more insights into options and limitations of the proposed technology. In addition, the model substance benzoic acid is used to investigate removal with different subsequent porous media configurations. This provides new knowledge on the ozone distribution and the impact of reactive soil elements.

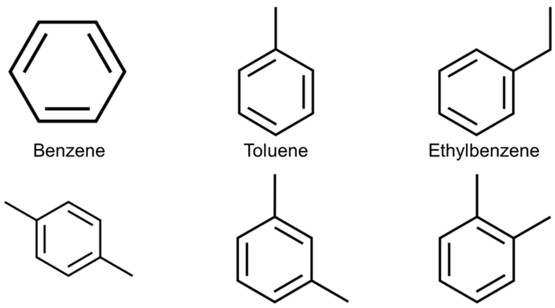

Figure 20: BTEX compounds.

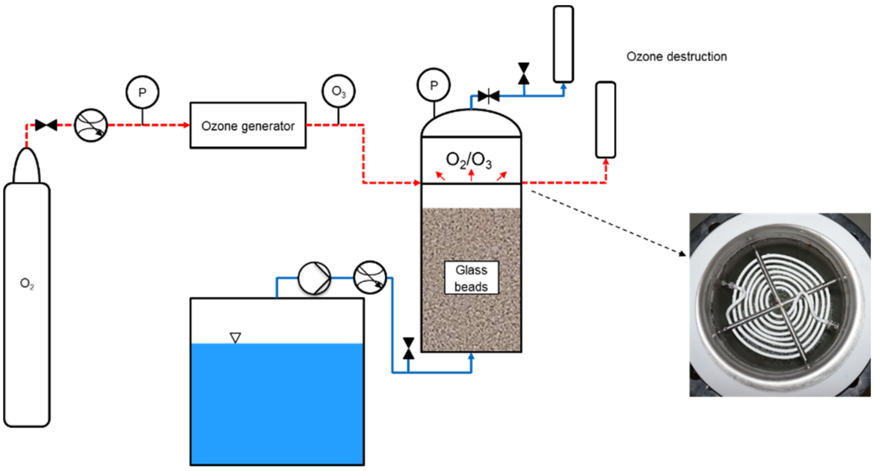

Figure 21: Experimental set-up to study in situ ozonation.

In a follow-up study, we focus on the transformation of BTEX in ozone-based treatment and subsequent biodegradation of the transformation products. This is done to isolate synergistic effects of ozone and hydroxyl radicals for contaminant removal.

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Functional Group Specific Reactivity, Transformation and Persistence of Contaminants of Emerging Concern (CECs) and their Transformation Products During Wastewater Ozonation

Chemical oxidation by ozone is an established technology for the efficient oxidation of contaminants of emerging concern (CECs) in water treatment. Its major disadvantage is the formation of ozonation products (OPs) that might have unknown and potentially detrimental effects in the environment and on human health. Currently, it is impossible to investigate each individual CEC, its reactivity towards ozone, its OPs and their biological stability and toxicity. Therefore, the generation of knowledge based on the systematic study of functional groups within CECs is a key factor to be able to understand the mechanism of reaction with ozone and its use. This information will allow the prediction of the interaction of ozone-CECs, which will improve our understanding of the formation and behavior of OPs.

The project aims are to i) generate transferable knowledge on the reaction pathways of chemicals containing specific functional groups by the treatment with ozone, ii) predict the formation of ozonation products (OPs) according to the chemical structure of the studied CECs, and iii) characterize the environmental behavior of OPs (i.e., persistence, and biological activity) depending on their chemical functionality.

To achieve our aims, we propose the use of heavy oxygen isotope (^{18}O) to produce a heavy ozone molecule, which can react with CECs and label their OPs. This labeling method will facilitate the detection, identification, and elucidation of the generated OPs through mass spectrometry.

To date, the labeling method was established with a modified ozonation system optimized for its operation with heavy oxygen ($^{18}O_2$). Furthermore, the validity of the labeling method was confirmed with an indicator compound (venlafaxine N-oxide) for determination of the $^{18}O/^{16}O$ ratio, and applied to label OPs from seven different compounds with N-and S- containing functional groups. Therefore, it is possible to identify OPs formed by oxygen transfer reaction, highlighting their reaction site and functional group availability of the parent compound. Finally, the concept is now applied to track and assess the stability of labeled OPs in biological treatment systems.

FUNDING:
GERMAN RESEARCH FOUNDATION DFG

COLLABORATION:
HELMHOLTZ CENTER FOR ENVIRONMENTAL RESEARCH

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Funding:
European Commission

Collaboration:
Catalysis Research Center at TUM, Friedrich-Schiller-University Jena, University of Santiago de Compostela

Development of Novel Materials and Systems for the Removal of Per- and Polyfluoroalkyl Substances (PFAS) from Water

Initiated under the Marie Curie International Training Network NOWELTIES, this project aims to develop methods and process optimizations for removing per- and polyfluoroalkyl substances (PFAS) from municipal and industrial wastewater. Based on a critical literature assessment, two promising treatment concepts have been identified, which will be investigated in this study.

Together with colleagues at the Friedrich-Schiller-University in Jena, we explored proven concepts of degradation through ultrasound cavitation and are determining the potential for optimization of these processes through a set of carefully designed experiments. The advantages of such a process are simplicity, robustness and no chemical input required. The goal is to reduce the high operational costs due to its energy demand by coupling with a pre-concentration step using nanofiltration or reverse osmosis membranes. As an end goal this project aims to design a system capable of efficiently and effectively treating industrial wastewater prior to release into recipient water systems.

In close collaboration with the Chair of Inorganic and Metal-Organic Chemistry, TU Munich we are also developing and testing the performance of metal-organic framework (MOF) materials primed to elicit extraordinary adsorption capability towards PFAS present in trace amounts in water sources. This is done through:

1. structural modifications of the materials both by changing the structural properties of the material surface (different functional groups, different properties and performance expected) and through introducing structural defects
2. Post-synthesis modification and composite material fabrication in order to maximize the potential of used materials

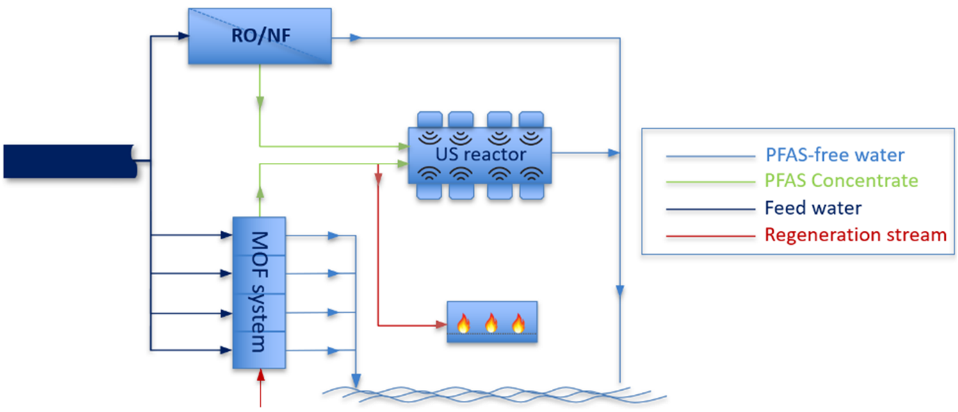

Figure 22: Schematic representation of the treatment concept for PFAS-polluted water.

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Elucidation of Metabolic Strategies for the Degradation of Trace Organic Chemicals Under Oligotrophic and Oxic Conditions

NOWELTIES is a Horizon 2020 Marie Sklodowska-Curie Innovative Training Network composed of 14 individual research projects. The common objective for all projects is to develop innovative water treatment technologies. Within this project, we aim to elucidate pathways in the metabolism of TOrCs.

We developed a retentostat system (Figure 23) to study the bacterial metabolism of TOrCs under stable oxic and oligotrophic conditions. Aniline, histidine, and di-sodium succinate were selected as the unique carbon source to adapt bacteria from activated sludge.

Figure 23: Current experimental setup able to run 10 experiments in parallel.

FUNDING:

EUROPEAN COMMISSION

In 7 days of exposure experiments, most substances showed similar behavior among all the microbial communities (Figure 24). No effects were observed for recalcitrant compounds, such as carbamazepine, either for substances reported as removed, such as metoprolol or gabapentin. Sulfamethoxazole and atenolol were transformed by all microbial communities.

COLLABORATION:

THE CATALAN INSTITUTE FOR WATER RESEARCH

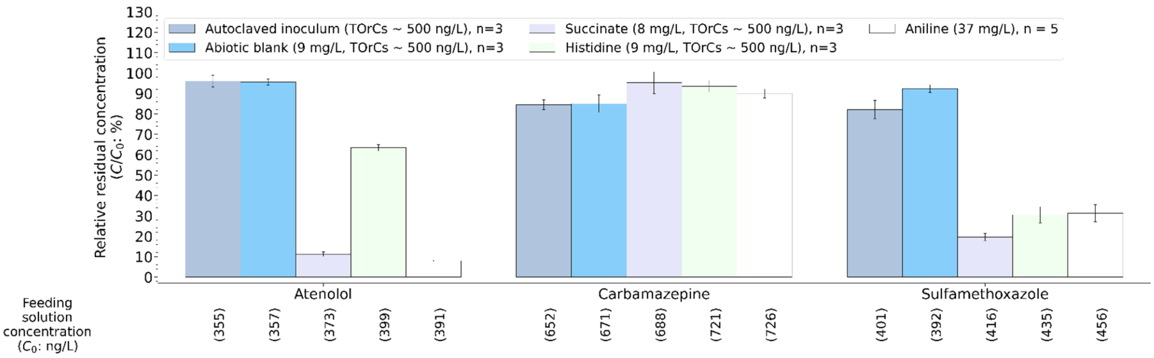

Figure 24: Relative residual concentration (C/C_0) of selected TOrCs after treatment with different microbial communities, and abiotic blanks.

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Elimination of Trace Organic Compounds (TOrCs) at Small-Scale Wastewater Treatment Plants: Using the Example of the Irschenberg Treatment Plant (<10.000 p.e.)

As part of a planned amendment to the wastewater treatment act (AbwAG), an additional treatment stage for further wastewater treatment is currently being discussed in Germany. This is intended to reduce water pollution with TOrCs. Trace substances such as pharmaceuticals, pesticides and corrosion inhibitors enter waterbodies because they cannot be entirely removed by conventional wastewater treatment plants (WWTPs). As a result, adverse effects occur in aquatic organisms, among others. Up to now, processes for the removal of TOrCs have mainly proven successful in medium to large WWTPs. However, TOrCs removal can also be considered for smaller WWTPs in the range of 2,000 – 10,000 p.e., as they often discharge into small and sensitive water bodies.

This project, funded by the LfU, aims to develop and test cost-effective and low-maintenance solutions for the removal of TOrCs at small scale WWTPs. The Irschenberg WWTPs (7,000 p.e.) was selected as a case study for the implementation of the project. As part of the new construction of the WWTP, it is to be equipped with secondary treatment in a vertical filter (VFCW). For the elimination of TOrCs, it is planned to equip the filter with a mixture of sand and granular activated carbon.

FUNDING:

BAVARIAN ENVIRONMENTAL PROTECTION OFFICE

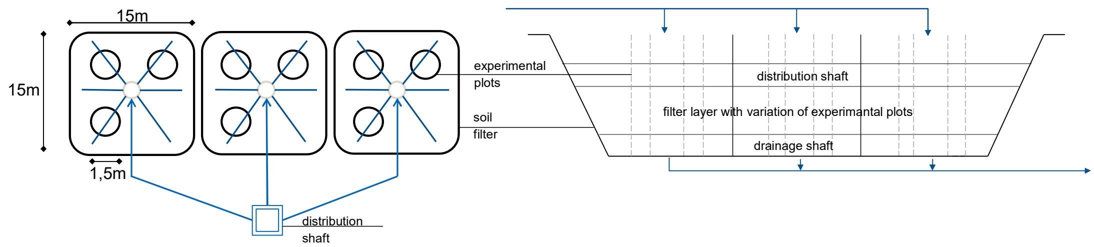

Figure 25: Soil filter top view and cross section

COLLABORATION:

For the large-scale test at the wastewater treatment plant, the conceptual design of the soil filter will be determined at the beginning of the project in order to be able to prepare the planning draft for the construction and equipment. For the simulation of the soil filters, lysimeters are used at the technical center of the chair at TUM. Here, variables such as the loading regime, the saturation state or the hydraulic residence time and their effects on the elimination performance in the filter can be investigated.

Figure 26: Lysimeter

In the further course of the project, investigations will be carried out into alternative concepts for further TOrCs removal at small WWTPs. Furthermore, a cost-benefit analysis of the different process variants will be carried out. After the construction of the new WWTP, the operation of the Irschenberg WWTP will be scientifically monitored in order to assess the reliability and performance of the soil filter. Finally, the transferability of the results to other WWTPs in Bavaria will be examined.

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FUNDING:

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

CENTER FOR BUILDING MATERIALS AND MATERIAL TESTING TUM

Research on Treatment Mechanisms of Cementitious Materials in the Treatment of Wastewater from the Textile Industry

Textile wastewater has a variety of compositions and, in addition to dyes, also contains electrolytes, softeners and dispersing agents, which are usually added in the form of dye salts. Textile wastewater therefore poses a challenge for wastewater treatment. Azo dyes in particular are difficult to remove with conventional wastewater treatment (mechanical-physical and biological) due to their chemically complex structures in combination with dyeing salts. These treatment methods quickly reach their application limits when it comes to wastewater from textiles or they are too energy-intensive, expensive and demanding for use in poorer regions. However, textile factories are mainly located in poor regions of the world, especially centers of the textile industry in South Asia and India, such as Bangladesh, Gujarat and Balotra. Inexpensive treatment methods are therefore important for the feasibility of an adequate treatment of textile wastewater to protect water bodies. Adsorption methods are the most promising for a low-cost solution.

Figure 27: Hardened cement granulates before (left) and after (right) exposure to Reactive Blue 19.

The aim of the research project is the fundamental investigation of the surface interactions of hydrated cement phases with relevant dyes from the textile industry and the development of a cost-effective adsorption filter.

Adsorbents based on hardened cement paste containing ground granulated blast furnace slag are manufactured and ground to various grain sizes, and therefore different surface areas, which adsorb the dyes and coloring salts. The discoloration processes identified on the hardened cement paste surfaces are examined more closely in order to gain a better understanding of the underlying mechanisms. It will be clarified whether the discoloration is due to pure adsorption processes on the surface of the hardened cement paste or whether degradation or metabolism processes also play a role. For this purpose, a detailed analysis forms the basis for clarifying the processes.

The research project (research group Helmreich) is being carried out together with the Centre for Building Materials and Material Testing (cbm) at the Technical University of Munich.

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Research Group Water Reclamation and Reuse

According to an estimate by the World Resources Institute, a quarter of the world's population lives in regions with acute and extreme water scarcity. The situation is expected to worsen worldwide in the coming decades. In particular, rapid population growth, increasing urbanization, advancing industrialization and agricultural activities, exacerbated by the effects of climate change, are putting enormous strain on our global water resources.

Water reclamation and reuse can efficiently and sustainably overcome water resource problems by creating new sources of high-quality local water supply, partially replacing already scarce freshwater resources. In particular, stormwater and the reuse of (municipal) reclaimed water and its reuse can effectively mitigate the challenges associated with increasing water use conflicts. In May 2020, the EU published for the first time a new regulation on minimum requirements for water reuse for agricultural irrigation. This legislation must be implemented by the EU member states into national law by June 2023. Due to this development, but especially due to the noticeable consequences of climate change, there is now also a great need for action for water reuse in Germany. Building on a feasibility study in Lower Franconia, we started the new joint project 'Reclaimed Water' in 2021 funded by the Federal Ministry of Education and Research (BMBF), which develops concepts for safe water reuse for urban and agricultural irrigation on a demonstration scale. In addition, water reuse can also serve to augment groundwater supplies. Also funded by the BMBF, we launched the new project TrinkWave Transfer' in close collaboration with the Berlin Water Works to investigate alternative concepts at a former water works site in Berlin.

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FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

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Nutzwasser: Reclaimed Water as Alternative Water Resource for Urban and Agricultural Irrigation

The area around the city of Schweinfurt is a region with traditionally pronounced water scarcity, in which water use conflicts are increasingly occurring due to the effects of climate change. Therefore, the so-called "Nutzwasserprojekt" was initiated in this region. The aim of the "Nutzwasserprojekt" is to develop practical management strategies for water reuse for urban and agricultural irrigation and to optimize them within the framework of relevant demonstrations with industry partners in such a way that implementation in other target regions is accelerated.

The 3-year research project is divided into different work packages:

- Elaboration of the prerequisites for a **legal implementation** for the application of reclaimed water
- Establishing **water quality requirements** for different irrigation practices
- Development of digital approaches for the automated determination and of the **irrigation demand**
- Implementation of **innovative multi-barrier treatment technologies** for the efficient removal of microbiological and chemical contaminants
- Development of an automated, **needs-based provision of reclaimed water**
- Conception of **adapted operator models**
- Embedding the project in an interactive **stakeholder process** and
- Establishment of an innovative **public relations platform**

Link to the project website: https://www.nutzwasser.org/public/index.html

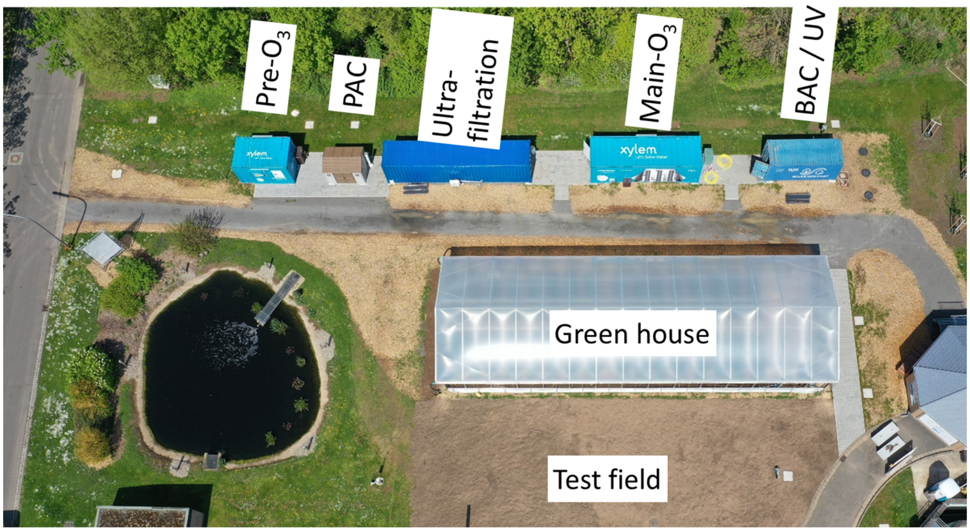

Figure 28: Aerial view of the demonstration systems on the premises of the Schweinfurt municipal drainage system.

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FUNDING:

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COLLABORATION:

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Nutzwasser: An Alternative Water Resource for Non-Potable Applications Using Hybrid Membrane-Ozonation System

The world population is continuously increasing, but the natural resources are staying constant and, so far, are not sustainably used by communities. Water is one of the most vulnerable resources in terms of quality and quantity. Therefore, providing alternative solutions for using safe fresh water for each application (such as irrigation and industrial applications) is crucial for tackling these challenges. The potential of increasing water reuse facilities even in European countries like Germany that have not experienced water scarcity yet is increasing.

In water reuse applications, no single treatment process can remove all contaminations from influent water alone; therefore, in the Nutzwasser project, a highly flexible multibarrier water treatment system is developed to ensure safe water quality for urban and agricultural irrigation purposes. Each barrier of the system is responsible for different targets, such as microbial and chemical contaminants in the influent of water reclamation system (WWTP effluent). The Nutzwasser treatment train includes ceramic ultrafiltration (UF), an oxidation step (ozonation), a biological activated carbon filter, and a final UV disinfection unit. Performance monitoring is done by real-time online sensors plus weekly lab analyses. The role of ceramic UF regarding removing pathogens and the effect of UF membrane before the downstream treatment systems (ozonation and BAC filter) have been already investigated.

Operational stability of UF membrane performance and trace organic compounds (TOrCs) removal are additional objectives of this study. The considered pre-treatment steps for ceramic UF membrane in the Nutzwasser project comprise the dosing of powdered activated carbon (PAC) and ozonation prior to UF membranes.

Figure 29: Second barrier in the Nutzwasser treatment train (ozonation).

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FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

BERLINER WASSERBETRIEBE, BRANDT GERDES SITZMANN UMWELTPLANUNG GMBH, CARL VON OSSIETZKY UNIVERSITY OF OLDENBURG

Development and Optimization of an Innovative Treatment Approach for Indirect Potable Reuse in Urban Water Cycles

During the TrinkWave joint project, which was completed and funded until 2020 by the BMBF (Federal Ministry of Research and Education), new multi-barrier treatment processes for water reuse based on sequential managed aquifer recharge technology (SMART) were developed. The aim was to assess multidisciplinary monitoring approaches for innovative process combinations of water reuse to augment drinking water supplies.

The subsequent joint project TrinkWave Transfer (funded by the BMBF), is now testing the large-scale implementation of the SMART process in collaboration with the Berliner Wasserbetriebe, the University of Oldenburg and BGS Umwelt GmbH. This is taking place at the former Berlin-Johannisthal waterworks site, where the process will be demonstrated in its optimized form with integrated high-infiltration trench technology and active hydrological control in the subsurface. The knowledge gained from the previous project and from the SMART*plus* technical pilot system will be incorporated into the planning and implementation.

In addition to the scientific support of the field study in Berlin, the investigation and further development of the SMART*plus* system takes place at the TUM in Garching. With the SMART*plus* pilot plant at the TUM, it is possible to analyze the efficiency of the reduction (biotransformation) of anthropogenic trace substances at pilot-scale. Aiming for further characterization and optimization as well as improved hydraulic conditions, the integration of further barriers for the establishment of a multi-barrier system will be investigated. The focus is also to enhance an adequate process monitoring system at the pilot-scale plant at TUM. With the help of intensified measurement data acquisition, the use of machine learning approaches for improved and automated control of the SMART*plus* system in real-time will be investigated.

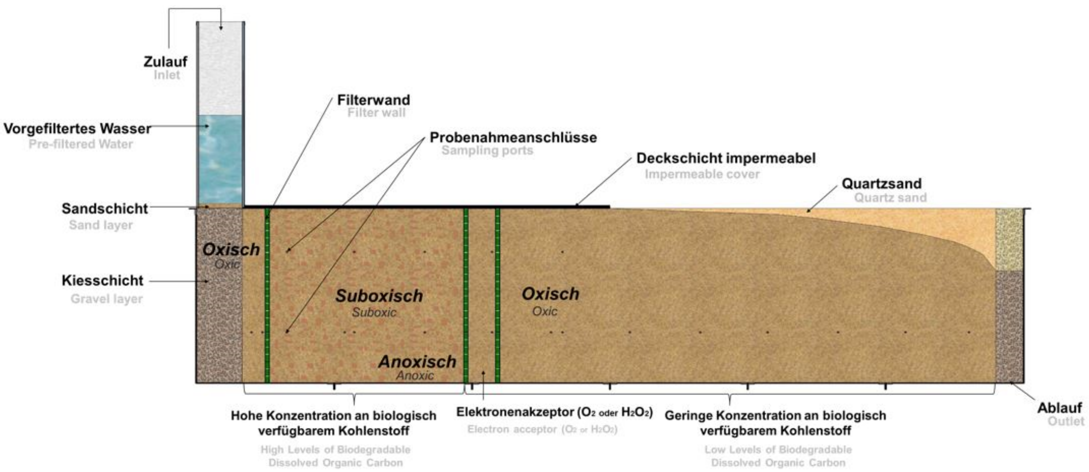

Figure 30: Schematic of the SMARTplus pilot-scale test facility at TUM (adapted from Karakurt-Fischer et al., 2020).

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Research Group Urban Water-Energy-Food (WEF) Nexus

With ongoing economic growth, urbanization and industrialization, demand for natural resources such as water, energy and food continue to rise worldwide, especially in cities. The result is serious environmental challenges and climate change. Integrated urban planning to leverage on potential synergies of climate change mitigation and adaptation approaches and measures urgently needs to be developed and implemented by 2030 to avoid disastrous climatic change.

The Water-Energy-Food (WEF) Nexus approach is one integrated urban planning way for cities to devise more sustainable development pathways. The approach advocates that supplying water to cities takes much energy, and that much water is also needed to produce energy and food. Planning these three sectors in an integrated manner can support water, energy and food security and achievement of the United Nations Sustainable Development Goals (SDGs). Water reclamation with integrated resource recovery is a key synergy opportunity for the operationalization of the WEF Nexus approach. However, so far, few examples exist where this has been implemented at urban scales. More case study development and pilot projects are urgently needed in order to test the viability of this approach. Further, such development needs to be embedded from the outset in a participatory multi-stakeholder process.

Figure 31: WEF NEXUS approach.

Within the TUM Nexus Lab initiative (Nexus@TUM) founded by Dr. Gondhalekar in 2021, the Urban WEF Nexus Research Group uses the Nexus approach as an integrated urban planning framework to analyze the interactions between the sectors water, energy and food, as well as other related sectors such as mobility, solid waste, health and ecosystem services, and devises alternative future urban development scenarios to support the development of pilot projects at urban scales. Nexus@TUM aims to build on an environmental engineering perspective by integrating all three pillars of sustainability and connecting these to social, institutional, legal, political, and economic aspects, in an equal manner. Nexus@TUM further acknowledges that the issue at hand pertains equally to contexts in developing as in developed economies. The research group works in several case study locations including Germany, Ghana, India, and Niger.

Figure 32: Series of international Urban WEF Nexus workshops.

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WEF Nexus Pilot Project in Reto Dosso, Niger: Sustainable Water Supply with Analysis of Water Reclamation and Integrated Resource Recovery Potential as Part of a Climate Adaptation Strategy

This project is part of a larger cooperation project funded by the German Federal Ministry for Education and Research (BMBF, 2020-2023) titled "Science meets school – renewable energy powered water-food-economy Nexus for improvement of living conditions in the Dosso Region in Niger".

The aim of the Nexus Group project part is, to initiate a Nexus dialogue, build and strengthen academic networks on the topic, and to develop and implement a Nexus pilot project as part of a climate change adaptation strategy with sustainable water supply (drinking as well as other uses) coupled with an analysis of the potentials of water reclamation and integrated resource recovery as a key Nexus opportunity. This study is undertaken using a typical case study, a secondary school campus in a village in the Dosso Region of Niger. Using geographic information systems (GIS) the project will develop and visualize alternative development scenarios with suitable technology options as a basis for a participatory multi-stakeholder discussion in order to secure from the project outset the co-design/-creation process of the pilot project together with the local community, thereby enabling co-ownership. In parallel, the project aims to conduct capacity building locally to anchor sustainable use of water as part of a climate change adaptation approach in the region.

Figure 33: Dar es Salaam, Reto Dosso region, Niger.

By supplying drinking water and water for various other uses in a 'fit-for-purpose' sustainably, e.g. for agricultural irrigation or aquifer recharge, the project aims to create a revenue stream at a model scale that in turn aims to enable a public-private-people organized operation. The potential of resource recovery through biogas and organic fertilizer generation is also analysed. The hypothesis is that such an innovative framework can be the foundation of an innovative decision-making and socio-economic governance model, that can contribute to more sustainable development of cities under climate change impacts as well as to achieve the UN SDGS, especially SDG6 Water und SDG2 Food Security. Further, the project aims to gain insights into the key enabling factors for operationalizing the Nexus approach and in particular water reclamation with resource recovery through the implementation of the pilot project, thereby generating results transferable to other regions. The pilot project is being developed and implemented as a lighthouse project for climate change adaptation, and will generate results with very high relevance for the built environment and cities in the region and worldwide.

Press release: https://www.th-koeln.de/hochschule/solaranlage-fuer-die-lokale-wirtschaft_76314.php

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Nexus City: Enhancing Water, Energy and Food Security Through the Nexus Approach in Cities in India

Cities in developing and increasingly also in developed economies are already facing serious water-related development challenges. These are expected to intensify with climate change-related water uncertainty and scarcity, augmenting already existing and potential public health risk.

The WEF Nexus research group has been working in Leh Town, the capital of Ladakh, a semi-arid high-altitude region in the Indian Himalayas, for close to a decade. The project aim is to develop a WEF Nexus pilot project as a lighthouse project for water reclamation with integrated resource recovery in mountain regions in the region. Leh, with ca. 60,000 inhabitants and situated at the Indus River has expanded very rapidly in recent decades due to growth of the tourism industry. As a result, the town faces serious water-related development challenges. Currently, a centralized sewage system, which is very water and energy intensive, is being constructed. The project develops new knowledge about climate change mitigation and adaptation opportunities of the local water supply and wastewater management systems. Based on this, the project makes policy recommendations advocating decentralized urban water reclamation and reuse for water and energy conservation, as well as recovery of energy and nutrients, to support water, energy and food security as part of a climate change resilience strategy. This approach is being expanded by the Nexus group to other cities in India.

For more information on the WEF Nexus approach as it is being applied in the Urban WEF Nexus Research Group, please view the Nexus documentary film (2015): "If not now, when? Planning for the urban Water-Energy-Food Nexus" Duration: 18 minutes Link: https://vimeo.com/142941443

Figure 34: Leh, Indian Himalaya

The Nexus group works in Leh in close collaboration with His Holiness Chetsang Rinpoche, Venerable Sanghasena of Mahabodi Centre, the Ladakh Ecological Development Group (LEDeG), Bremen Overseas Development Cooperation (BORDA), Himalayan Institute of Alternatives (HIAL), Water Foundation, Water Solutions Lab of Future Earth, and others. This project has been funded by the European Commission and German Research Foundation (DFG) (2011-15), TUM Global Incentive Fund (2017-18), Bavarian State Ministry of Environment and Consumer Protection (2018-19), and German Federal Ministry for Education and Research (BMBF, 2018-2022).

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SEED-Himalaya: Sustainable Energies, Entrepreneurship and Development in rural Kashmir

This project is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK, 2022-2025) under the International Climate Initiative (IKI) Programme.

The livelihood of the rural population in Jammu and Kashmir is particularly threatened by climate change due to the negative impact of varied rainfall patterns and more frequent extreme weather events on local agriculture in combination with unreliable energy supply. This leads to economic stress, poverty, and limited employment opportunities, in particular for the youth.

SEED Himalaya aims to support the remote Himalayan community of Jabri in its transformation into an environmentally resilient and economically empowered community. This is to be achieved through community-based, decentralized energy supply as well as local value creation in agriculture. The inclusive bottom-up development plan, covering both green infrastructure as well as socio-economic structures, is tailored to the local resources, capacities, and needs. This ensures the sustainability of the project and enables the replication of its approach in other Himalayan communities.

Figure 35: Waterwheel in Jabri, Kashmir.

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Research Group Membrane Filtration

Membrane processes play a central role while establishing closed water cycles, for the reuse of municipal wastewater as well as in seawater desalination. The research of the Membrane Filtration group at the chair currently focuses on the suppression of biofouling by integrating UV-LEDs into membrane modules, the combination of powdered activated carbon and ozone with ceramic ultrafiltration membranes, the retention of microbial and chemical contaminants in high-pressure membranes, as well as fouling mitigation strategies by alternative membrane surface patterns.

Since the end of 2018, we have been working in a BMBF project on the question of how far unwanted biofouling on the membrane, which affects the energetic efficiency of the membrane process, can be reduced. By using UV-C LEDs, we are developing UV-membrane hybrid processes in which targeted UV pre-treatment delays the formation of biofouling and, at the same time, UV-induced effects in microorganisms to positively influence the properties of the formed biofilm in terms of its permeability and cleanability.

The coupling of powdered activated carbon with ultrafiltration membranes results in high efficiencies for the retention of microbial contaminants but also organic trace substances. In this context, the mechanisms of retention of antibiotic resistance carriers need to be clarified in more detail in order to ensure high effluent quality. Furthermore, the formation of cover layers has to be optimized in such a way that operational advantages result. These water qualities would allow reuse for urban and agricultural irrigation as well as artificial groundwater recharge.

In 2022, we have launched the new project FreeSpace in collaboration with the University of Duisburg-Essen funded by the German Research Foundation (DFG) to investigate membrane fouling mitigation strategies by employing modified membrane surface patterns and new spacer configurations.

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FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

UV-EL GMBH, DELTA UMWELT-TECHNIK GMBH

Development of a UV Irradiation System to Increase the Resource Efficiency of Water Treatment by Reverse Osmosis Membranes

As part of a collaborative BMBF research project, we aim to develop an innovative UV irradiation system that is based on pulsed UVC-LEDs to mitigate biofouling in reverse osmosis (RO) membrane processes by UV pre-treatment. UVC-LEDs have many advantages over conventional mercury vapor lamps, which makes them environmentally friendly and, due to their size, they can potentially be integrated into the pressure vessel of RO membrane systems as an in-situ treatment.

The membrane filtration research group investigates the efficiency of the novel UVC-LED system in lab- and pilot-scale experiments. Accelerated biofouling experiments are conducted by additionally dosing nutrients to the feed water. A pre-defined biofouling protocol allows conducting biofouling experiments with and without UV pre-treatment in a well-defined and reproducible manner.

The UVC-LED system will be characterized with regard to its UV fluence by using actinometry and biodosimetry. A further research focus of this collaborative project is to evaluate the efficiency of the innovative UVC-LED system on the basis of typical membrane module performance parameters, such as permeability decline and feed channel pressure drop (FCPD) increase (Figure 36). The built biofilms are extracted and analyzed for various parameters including ATP content, extracellular polymeric substance composition and microbial diversity. Further the removal of the formed biofilms is investigated.

When applying an intermittent current as power supply, UVC-LEDs can generate pulsed irradiation. Through fundamental investigations, we plan to determine the inactivation efficiency and mitigating effects on biofouling of pulsed UVC irradiation at various duty cycles and fluence rates.

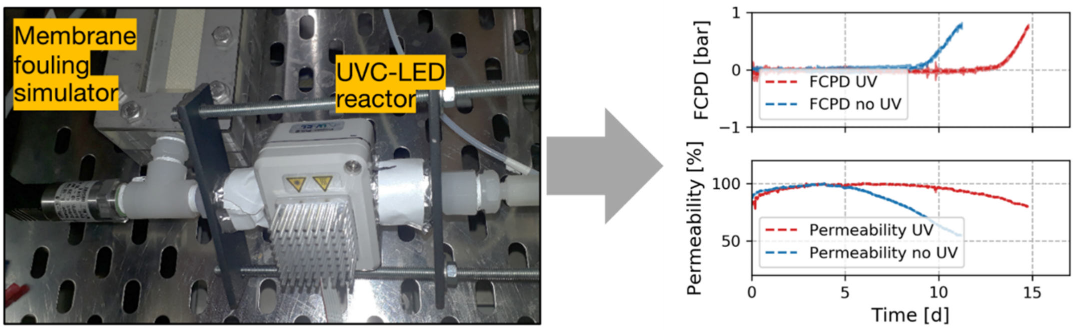

Figure 36: UVC-LED reactor attached to a membrane fouling simulator and the effects of UV pre-treatment on the feed channel pressure drop (FCPD) increase and permeability decline (Sperle et al.,Membranes 2020, 10, 415).

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Optimizing the removal efficiency of antibiotic-resistant bacteria and antibiotic resistance genes by microfiltration and ultrafiltration in municipal wastewater treatment plants

Antibiotic resistance is not only a threat to human health in clinical settings, but also a challenge to the environment in terms of the spread of antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARG) in aquatic environments. Antibiotics are used to treat bacterial infections in human and veterinary medicine worldwide. In aquaculture, antibiotics are used as growth promoters. Since humans and animals cannot completely metabolize antibiotics, large quantities of antibiotics and antibiotic-resistant bacteria enter the so-called urban water cycle (wastewater, sewage sludge, slurry, surface water, drinking water) via excreta.

The spread of antibiotic resistance was studied in the BMBF HyReKa research project from 2016 to 2019. The aim of the project was to analyze antimicrobial-resistant bacterial pathogens in clinical, agricultural and municipal wastewater and to assess their biological or hygienic-medical relevance and significance for drinking water in raw water.

Conventional wastewater treatment plants reduce ARB and ARG by 2 to 3 log levels. When surface waters are used as bathing water or drinking water or for irrigation in agriculture, the treatment capacity of a conventional wastewater treatment plant is not sufficient.

The aim of the project in wastewater treatment was to investigate more advanced treatment processes of ozonation, UV irradiation and membrane filtration to reduce ARB and ARG.

The most efficient technology for ARB and ARG reduction was membrane filtration. Further experiments with membrane filtration included studies of the removal efficiency of ARB and ARG after water backwashing and after chemical backwashing. In addition, recontamination and antibiotic resistance development in the filtrate of membrane filtration were investigated.

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Freespace: Fundamental Research to Exploit Hydrodynamic Effects to Reduce Membrane Fouling by Introducing Special Arrangements of Novel Feed Spacer Geometries in Combination with Non-Regular Membrane Surface-Pattern

In this DFG-funded research project, we aim to investigate synergistic influences of membrane surface patterning and feed spacer geometry on fluid dynamics and particle deposition mechanisms in the feed channel at certain operating conditions. This research will promote our understanding of fundamental design criteria that determine the overall module performance. With this understanding, special arrangements of feed spacer and surface pattern geometries will be designed. This novel development concept is believed to allow for higher process efficiency, longer module lifespan, and less energy consumption.

Biofouling, the accumulation of microorganisms and subsequent biofilm growth on the membrane, is of particular concern in Nanofiltration and Reverse Osmosis systems. Therefore, in order to understand the spatial and temporal evolution of biofouling on surface-patterned membranes, we perform accelerated biofouling experiments with semi-synthetic feed water. A pre-defined protocol allows conducting biofouling experiments in a well-defined and reproducible manner.

In parallel to this experimental approach, we create a CFD model of the fluid dynamics in the feed channel with surface-patterned membranes. CT scans of feed spacers assure an accurate representation of their geometry. With this CFD model, we plan to investigate the macro-scale flow in the whole feed channel as well as the micro-scale flow in direct vicinity of the membrane surface patterns.

FUNDING:
GERMAN RESEARCH FOUNDATION
DFG

COLLABORATION:
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Research Group Microbial Systems

The Emmy-Noether Junior Research Group Microbial Systems focuses on the investigation of microbial processes in aquatic and technical systems ranging from biological wastewater treatment to surface water ecosystems. Microorganisms are tiny, yet crucial organism that cycle our planets resources and keep our biosphere balanced, and thus provide vital ecosystem services. We are interested in the microbiomes of engineered and natural water treatment. Therefore, our overall aim is to develop tools that specifically measure and qualitatively assess microbes and their functions in water systems. We perform hypothesis driven and descriptive research that allows to link microbes to ecosystem services.

Our research hereby focus on the interaction and diversity of organisms within microbial biofilms with a focus on fungi and their function. Fungi produce very efficient exoenzymes that can transform difficult-to-degrade organic substances. Of particular interest are the largely unexplored aquatic fungi and their diverse functions in the environment. Further research is concerned with the characterization of the taxonomic and functional diversity of microbial communities with specific functions, e.g. with regard to microbial degradation or antibiotic resistance genes in the water cycle. Here, we focus on diverse biomarkers. Most recently, we have examined the potential of biomarkers in wastewater by quantifying biomarkers from the SARS-CoV-2 virus. This can be used to monitor the pandemic in the population and report it back to public health officials.

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Wastewater Biomarker CoV2: Wastewater Epidemiology Using the Example of a SARS-CoV-2 Biomarker for the Estimation of COVID-19 Infections on the Population Scale

Wastewater-based epidemiology (WBE) is gaining popularity as a diagnostic method to estimate drug and medication use for entire sewersheds. SARS-CoV-2 can also be used as a biomarker in the context of wastewater diagnostics, on the one hand to detect a change in the infection pattern at an early stage and on the other hand to better elucidate the number of unreported COVID-19 cases at the population scale. For this purpose, the amount of virus in wastewater must be reliably analyzed and detected. The detection of SARS-CoV-2 is based on different PCR analyses with previously prepared wastewater samples (see work flow in Figure 37). In this regard, there is a need for research to harmonize methods for enveloped viruses such as SARS-CoV-2, on the optimization of the treatment procedures for the detection of the amount of virus in raw wastewater, and on the active integration into the corona infection management of the health authorities.

For the correct estimates of virus concentration in the wastewater, it is also very important to consider other factors, such as population density, the size and coverage of the sewer system, the volume of wastewater generated, degree of extraneous water, and substance-specific variables such as excretion rates, as well as the fate and transport of SARS-CoV-2 in the sewer network. To reduce the uncertainty of the wastewater-based monitoring, these factors must be considered when estimating the incidence of infection. The results from this project can be used to develop a novel SARS-CoV-2 biomarker concept that will serve as an early warning system and can also be used to estimate the spread of infection directly by authorities. Such a concept may be extended to an estimation of the incidence of infection by other viruses or its early detection or tracking.

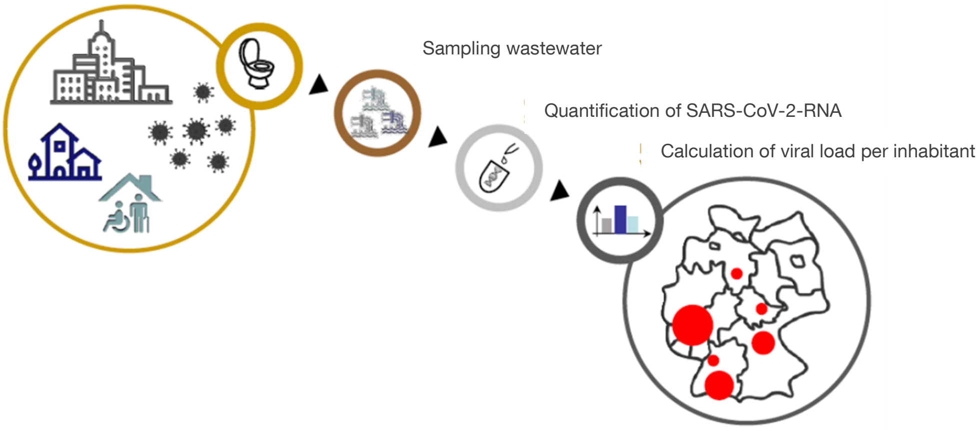

Figure 37: Concept of wastewater monitoring of SARS-CoV-2. Image: Claudia Stange, Johannes Ho. Collaboration with TZW Karlsruhe. Funded by BMBF.

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DVGW-TECHNOLOGIE-ZENTRUM WASSER

Wastewater Biomarker CoV2: Wastewater Epidemiology Using the Example of a SARS-CoV-2 Biomarker for the Estimation of COVID-19 Infections on the Population-Scale

SARS-CoV-2 biomarkers can be used as an additional metric for pandemic management in the context of wastewater-based epidemiology. This requires reliable detection of the number of biomarkers in the wastewater, which starts with studying the effects of transport in the sewer system and subsequently taking representative samples.

Sewer system: The transport of SARS-CoV-2 biomarkers in sewers results in biochemical changes which can negatively affect its detection rates in municipal wastewater. In cooperation with the Münchner Stadtentwässerung, we plan measurements in the approx. 9 km long sewer section between the two Munich sewage treatment plants Gut Großlappen and Gut Marienhof and in a shorter sewer section of approx. 300 m in the Munich district of Hasenbergl. Thereby, we will investigate the influence of various factors such as residence time, temperature, pH, and redox ratios on the degradation of SARS-CoV-2 biomarkers in the sewer system.

Diurnal variations: Due to the characteristic excretion behavior, the occurrence of SARS-CoV-2 biomarkers in wastewater is subject to diurnal variations. The diurnal succession pattern is assumed to be related to the amount of population served. To investigate this, we sampled 7 communities with populations ranging from 1.1 million to 8100 connected residents over 48 hours. We analyzed the samples for 4 SARS-CoV-2 biomarkers and other surrogate parameters (PMMoV, flow, ammonium, TOC, el. conductivity, and various trace compounds). Preliminary results show different diurnal patterns of biomarker concentrations for the different communities, as shown in Figure 38.

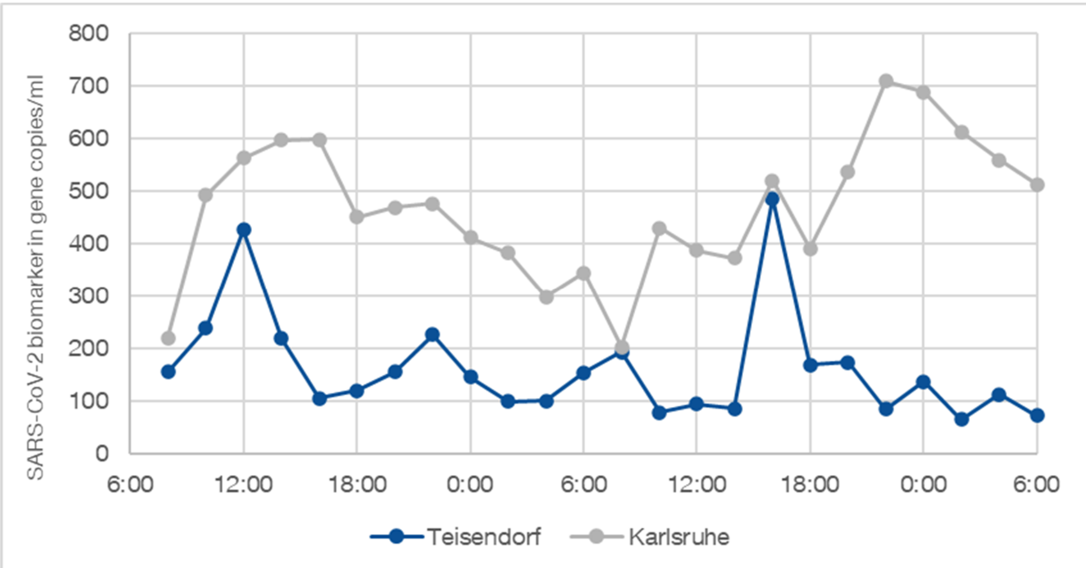
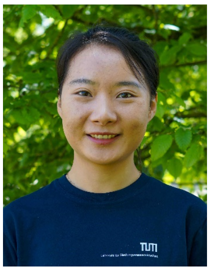


Figure 38: Diurnal variations of SARS-CoV-2 biomarkers in Teisendorf and Karlsruhe, Germany.



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Removal of Trace Organic Compounds by Functional Microbial Model Communities

Trace organic compounds (TOrCs) such as pharmaceuticals, personal care products, pesticides, has become emerging concerns in aquatic environment. These anthropogenic and xenobiotic compounds are frequently detected in surface water, ground water and even drinking water at the concentration ranging from few ng·L^{-1} to several µg·L^{-1}. Biological treatment is a promising technology as microbial communities bear a high potential to eliminate TOrCs via enzymatic degradation processes. However, the complexity of microbial interactions based on numerous species in realistic environment impedes the exploration of TOrCs biotransformation mechanisms, making it remain elusive to date. The aim of this study is to uncover the TOrCs biotransformation "black box" by simplified "model communities". Model communities with reduced complexity, either due to low species richness or dominance by one or a few populations, have been commonly used to overcome the challenge. A model community is defined as a closed assembly of microorganisms that represents or mimics the systemic behavior of ecological communities under controlled conditions.

Model communities were derived from natural environment including sediment core (Osterseen, Bavaria), technical sand (lab-scale biofiltration column, Garching), tap water (Garching) and soil (Garching). These inoculum were pre-adapted to a high concentration of mixed TOrCs for six months. Afterwards, we used dilution-to-extinction method to dilute both pre-adapted and non-adapted inoculum in 96 deep well plates for model communities. Communities which can grow up successfully were selected to identify taxonomy, which was achieved by 16S Nanopore sequencing. Model communities with different diversity were used to conduct biotransformation experiment to find links between TOrCs removal and diversity or taxa. In future work, metagenome sequencing and bioinformatics analysis will be applied to investigate the functional genes and enzymes in TOrCs biotransformation process as well as the microbial interactions in model communities.

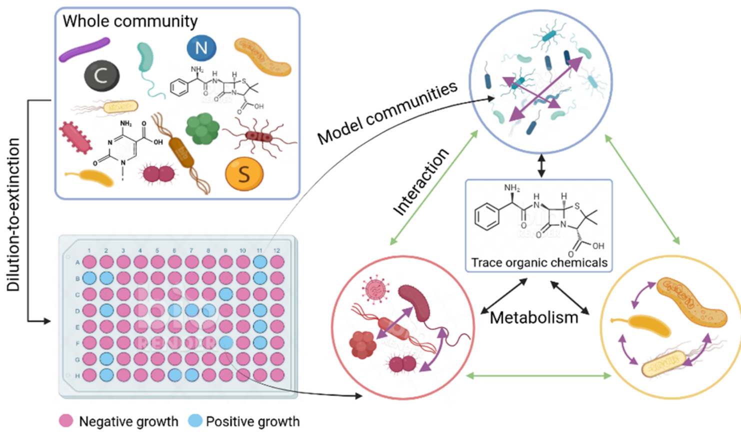

Figure 39: Scheme of TOrCs biotransformation by microbial model communities.

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COLLABORATION:
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Retrieving the Fungal Dark Matter in Diverse Aquatic Habitats Using Advanced Microscopic and Molecular Methods

Fungi play key roles in organic matter degradation and nutrient cycling, and their diversity is estimated between 2.2 and 3.8 million species. However, much of this is still unknown so far with only ~149 000 formally described fungal species. This disparity between known and unknown fungi is even more pronounced in aquatic habitats. Mycologists have applied culture-independent next-generation sequencing technologies to bridge this gap between known and unknown fungi. Nevertheless, these efforts turned out to be not enough to populate the Fungal Tree of Life (FToL) with newly described fungal species.

Therefore, being part of the Microbial System Research Group, we have successfully established a workflow that combines laser microdissection of fungal single cells with whole genome amplification and long-read sequencing. We have tested different aquatic habitats for hunting of specific fungal groups with success, e.g., aquatic hyphomycetes (known for leaf litter degradation) and chytrids (parasitic fungi). We have achieved a success rate of 59% for fugal short ITS region amplification and 24% for longer ribosomal region (5kb) of fungal rDNA. This workflow has enabled us to identify the taxonomic and phylogenic placement of an unknown fungal species within a timeframe of 1 week (Figure 40).

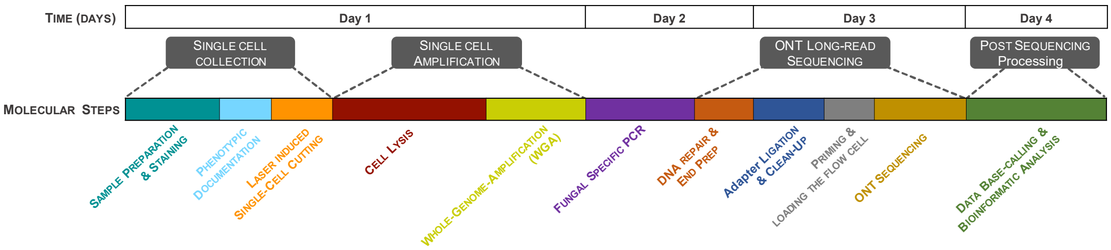

Figure 40: Workflow steps and estimated timeframe for identification of unknown aquatic fungal specimen using microscopic and molecular methods.

Moreover, we have expanded the application of our workflow to the aquatic habitats of the Arctic regions of the Northern Canada and the extreme water bodies of Iceland. During summer 2022, we have carried out sampling visits to the Arctic field sites of Northern Canada to sample permafrost thaw ponds of different ages (Figure 41a) and the glacial lakes and thermal hot springs of Iceland (Figure 41b). The samples will be processed and will help to tap the unknown fungal lineages from such environments which are critical to study from the perspective of global warming and extremophilic mycology.

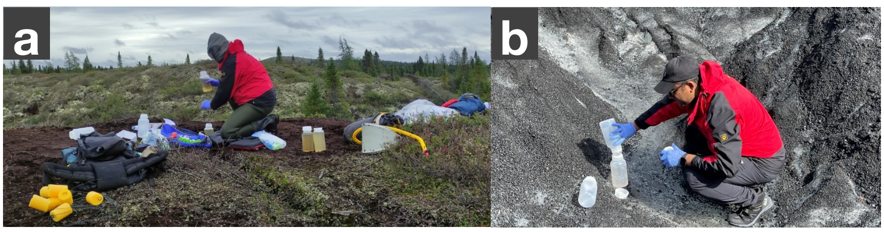

Figure 41: (a) On-site water filtration in Northern Canadian permafrost field site. Water collection from glacial lakes in Iceland (b).

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GERMAN RESEARCH FOUNDATION

COLLABORATION:

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Function of Aquatic Fungi in Biofilms of Water Treatment Systems

Fungi are known to be dominant in terrestrial systems performing biological breakdown of organic carbon which is crucial for the carbon cycle. However, their role in the aquatic environment is largely uninvestigated. Different environmental and diversity studies show their presence in a brought spectrum of aquatic habitats and highlight the lack of knowledge of this kingdom. In the last years even a whole new phylum, the Cryptomycota, was discovered and proven to be present in almost every water sample taken.

Especially in engineered biological systems, it is crucial to consider the fungal kingdom during investigations to understand and optimize the work with the whole microbial community. The superordinate objective of this research is to gain insight into and a better understanding of the fungal community in WWTPs in general with a focus on Cryptomycota. To enable this, existing molecular biological methods need to be adjusted and optimized for the use of fungi. Tackling this task this project aims to provide feasible primers for qPCR and a reliable and specific protocol. After achieving those the microbial community in down-flow hanging sponge (DHS) reactors is used as a model community to get insight into the interaction network between fungi and other microorganisms that treat wastewater. Following the influence on carbon degradation by comparing metatranscriptomic analysis of differently treated DHS reactors is studied.

A suitable qPCR system to quantify Cryptomycota was successfully implemented as well as an overview of the microbial community inside of the reactor systems was attained.

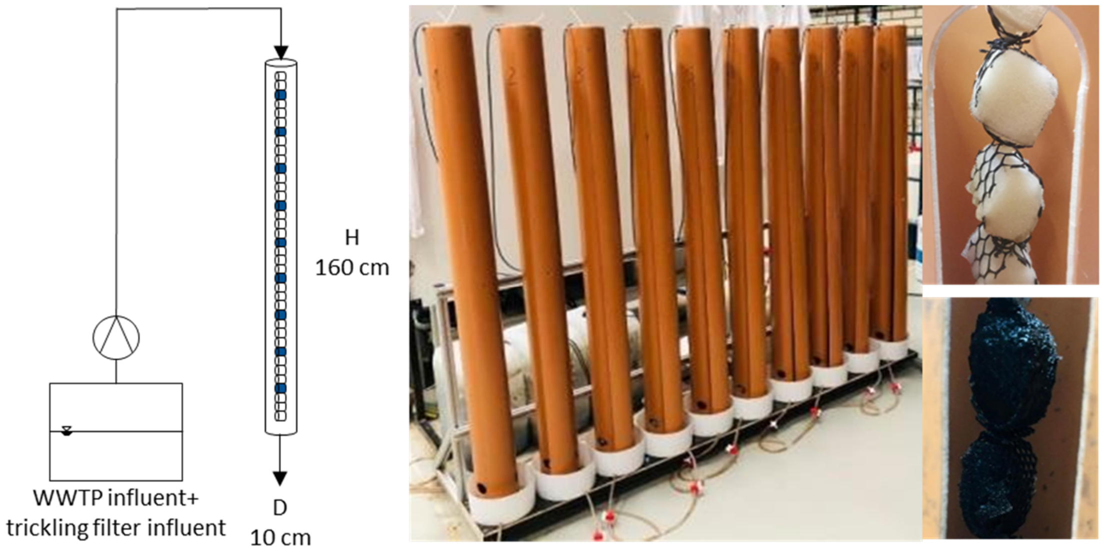

Figure 42: DHS reactor sketch and picture of whole experimental setup and clean as well as overgrown polyurethane sponge filling material.

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Funding:

German Agency for International Cooperation GmbH

Collaboration:

Robert Koch Institute, The Sanitary-Epidemiological Welfare And Public Health Service Of The Republic Of Uzbekistan

Feasibility Study: Implementation of a Wastewater Surveillance System for COVID-19 in Tashkent, Uzbekistan

The value of wastewater-based epidemiology has been recognized by local, regional, and national governments across the globe due to the pandemic. Wastewater-based epidemiology is known to be affordable and provides infection trends without depending on data from clinical PCR testing. This approach enables epidemiologists to monitor appearances of new pathogens or resurgence of diseases like polio. As a consequence, developed countries continue to expand the extent and depths of analyses through wastewater sampling. However, some countries do not yet have the resources and expertise to implement a wastewater surveillance system for disease awareness. This collaborative project aims to determine the feasibility of expanding wastewater-based epidemiology in the city of Tashkent, Uzbekistan.

The city of Tashkent comprises of over 2 million inhabitants and tracking the spread of diseases across communities is a difficult task for the authorities. The project aims to establish a pipeline for wastewater-based epidemiology by transferring the knowledge from TU Munich's expertise to the health officials and epidemiologists in Uzbekistan. Through providing the necessary equipment, training, and direct supervision for initial data processing, we aim to provide a feasible approach for a wastewater surveillance system which could be expandable onto other cities and/or regions of Uzbekistan.

Figure 43: A primary clarifier in a wastewater treatment plant in Tashkent, Uzbekistan.

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Research Group Trace Organic Compounds in the Environment

A broad range of compounds is introduced into the environment due to the modern human lifestyle, some of which show high biological activity. These organic trace compounds (TOrCs) contain classes of (crude-)oil, pesticides, and industrial chemicals, as well as household chemicals and pharmaceuticals (pain killers, antibiotics, x-ray contrast media, etc.). Though normally only traces (< µg/L) of these compounds are found in the environment, the high biological activity of the compounds could lead to harmful effects on humans and other organisms.

Hence, the focus of this research group is to develop new methods to detect TOrCs in the environment, as well as detecting the alteration of TOrCs by natural and oxidative processes. The main interest here is the evaluation of water treatment processes and the determination of the condition of the aquatic environment.

An outline of the aims of the working group:

- Broadening of the target screening for the monitoring of TOrCs in (waste-) water treatment
- Elucidate natural and oxidative degradation processes and identify the resulting degradation products
- Develop new methods to determine sorption behavior of TOrCs onto microplastic particles
- Validation of a sample preparation method for the assessment of microplastic in the environment
- Establishing a target method for perfluorinated alkyl substances (PFAS) in water treatment systems

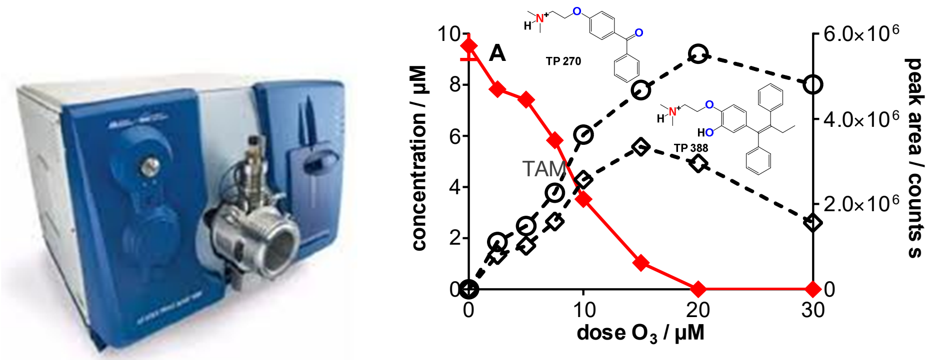

Figure 44: Left: AB Sciex QTRAP 5500 mass spectrometer for the identification of transformation products. Right: Example for the formation of transformation products during ozonation.

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UNTIL 03/2022

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FUNDING:
BAVARIAN RESEARCH FOUNDATION

COLLABORATION:
INSTITUTE FOR ENERGY AND ENVIRONMENTAL TECHNOLOGY E.V.

Sample Preparation Methods for Micro- & Submicroplastics in Environmental Matrices: Validation and Field Study

There is an urgent need to reliably quantify and qualify microplastics in the various environmental matrices. However, such a task involves distinguishing microplastic particles from natural particles such as sand, plant and animal debris. Even with the employment of spectroscopic identification methods like Fourier-Transformation Infrared spectroscopy (FTIR) and Raman spectroscopy, the interference caused by the natural particles can significantly impede the detection of microplastics. Hence, microplastics need to be separated from their natural matrices. Organics have a similar density to microplastics and need to be removed via chemical digestion methods, such as oxidation, alkali, acids, and enzymatic reactions. These reactions may inadvertently alter the microplastics being investigated.

The goal of this study was to optimize and validate a standardized sample preparation method to remove organic matter from wastewater samples, without altering the microplastics. This was tested on several microplastics (PS, PE, PP, PET, PVC, PA and PLA) by first optimizing and validating the sample preparation methods for larger microplastics fragments (80 – 330 µm) and then re-validating the two resulting methods (Hydrogen peroxide and Fenton protocols) for smaller microplastic fragments (< 10 µm).

Fenton reaction was further utilized during a field sampling campaign in cooperation with the Institut für Energie- und Umwelttechnik (IUTA), where effluents of wastewater treatment plants (WWTPs) were sampled to determine the microplastic retention efficiency of a tertiary sand filter. The sampling system consisted of a sealed system made entirely out of metal to avoid plastic contamination. The system consisted of a high-volume pump and three modular cartridges, where a set of steel mesh candle filters (100 µm, 50 µm, 10 µm) were placed in a cascade. Additionally, the effluent of the 10 µm filter was also sampled in order to account for smaller particles (< 10 µm). Sampled volumes were 5000 - 7000 Liters for 100 µm & 50 µm filters, 200 Liters for 10 µm filter, as well as 2.5 Liters for the fraction < 10 µm.

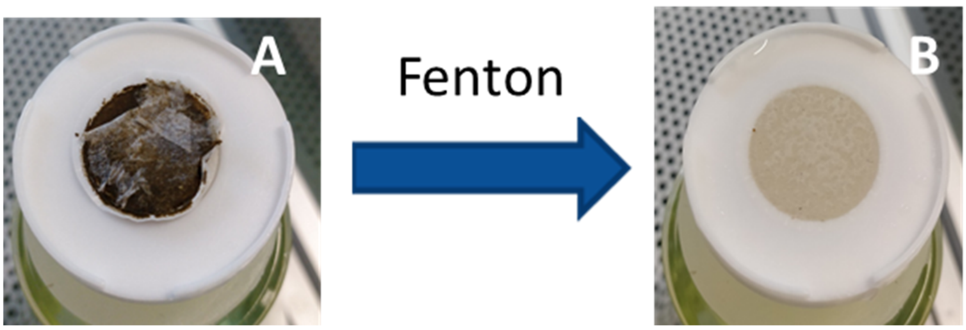

Figure 45: Effect of sample preparation: A. Filtered sludge sample, B. After Fenton treatment.

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External Doctoral Candidates

Comparing Samples Treated with Activated Carbon by Their Fingerprints of Highly Polar Molecular Features

Surface water samples were treated in batches with different types and different amounts of activated carbon. Beforehand, the samples were spiked with a multicomponent standard mixture. Prior to the analysis, the samples were filtered and spiked again with internal standards. They were then measured using polarity-extended chromatography, consisting of hydrophilic interaction liquid chromatography (HILIC) and reversed-phase liquid chromatography (RPLC) coupled to a high-resolution mass spectrometer.

Following the "non-target screening" approach, full scan data of a broad mass range was acquired.

Molecular features are now extracted from the data, specified by their mass, retention time and signal intensity. The features from the sample treated with activated carbon are compared with those from the untreated sample and the changes in signal intensities are expressed by the fold changes. It is assumed that a logarithmic fold change of 0 indicates consistency.

COLLABORATION:
AFIN-TS GMBH,
WESTFÄLISCHE
WASSER- UND
UMWELTANALYTIK
GMBH

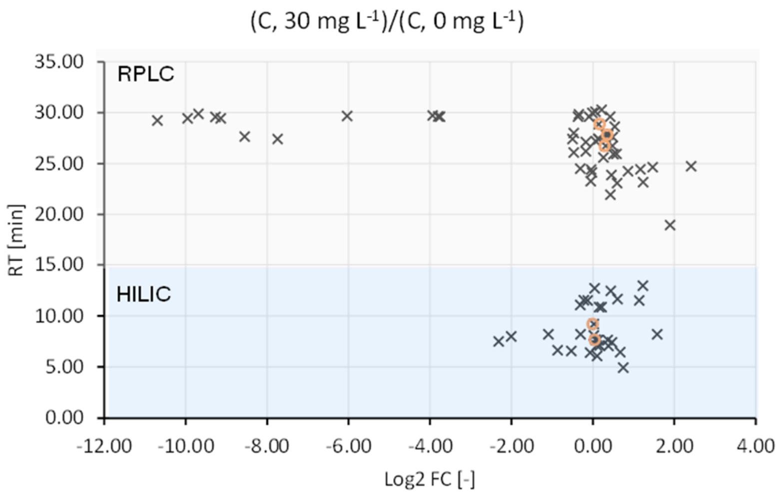

Figure 46: Logarithmic fold changes (FC) are plotted against the chromatographic retention time (RT). Polar features eluted before 15 min from the HILIC column (blue). Internal standards are marked by the orange circles.

Susanne Minkus was an external PhD student and employed by the AFIN-TS GmbH in Augsburg. She was supervised by Prof. Dr. J. Drewes and Dr. PD T. Letzel.

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FUNDING:

BAVARIAN ENVIRONMENT AGENCY

Screening for Unknown PFASs in a Polluted Surface Water

Due to chemical policy restrictions for longchain perfluorinated substances an increasing number of per- and polyfluorinated substitutes are used in industrial and consumer products. Often nether the chemical structure nor analytical standards and methods are available allowing to analyze these substances.

The Non-Target- and Suspect-Screening-Analysis are used for the identification of unknown or suspected substances in water samples. From January 2020 to May 2022 a monthly Non-Target Screening for unknown and suspected PFAS in river water samples taken up- and downstream from an industrial PFAS-discharge was carried out. The exact mass of the molecules in the samples can be determined with high resolution and accurate LC-MS/MS. The developed workflow enables the data reduction and prioritization on PFASs by e.g. mass defect and Kendrick mass defect plots. In addition to suspect lists, a fragment list was implemented to screen for characteristic neutral losses and fragment masses and facilitate the tentative identification of prioritized signals.

In downstream samples, 52 PFAS were tentatively identified by Suspect- and Non-Target-Screening. Partly fluorinated short-chain carboxylic and sulfonic acids were predominantly detected. Over the entire investigation period, both the intensities of the individual PFAS and the PFAS composition varied significantly. Insights from this Non-Target approach on novel PFAS can be used to optimize future wastewater monitoring programs.

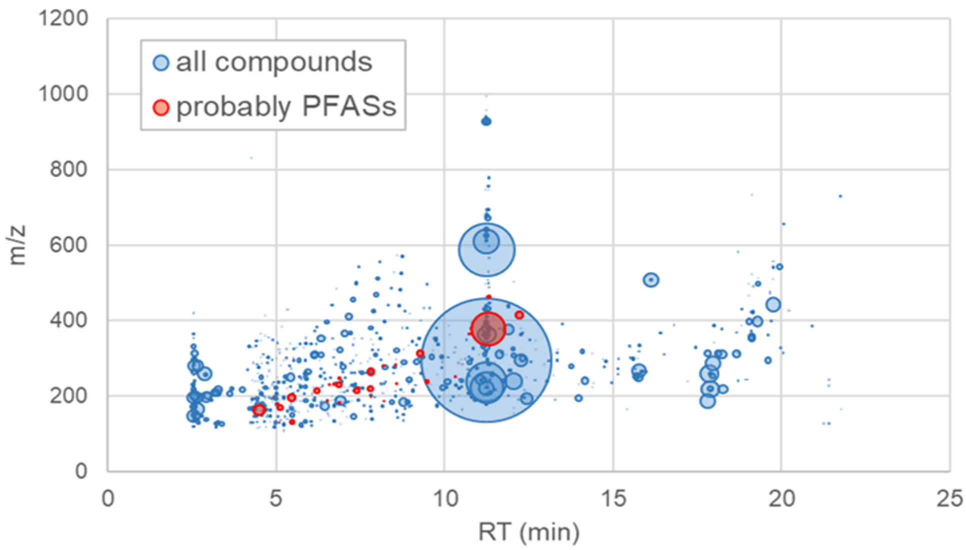

Figure 47: Compounds detected in the downstream river water sample by HR LC-MS/MS and reduction to probably fluorinated substances. The size of the dots corresponds to the peak area of the signal.

Hanna Ulrich is an external PhD student and works at the Bavarian Environment Agency. Hanna's doctoral thesis is supervised at the TUM by Prof. Dr. J. Drewes and Dr. PD T. Letzel.

Visiting Scientists

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Lab to Land: Research Project on Scalability of Innovations in Sanitation Technologies as key to enabling the WEF Nexus approach

Despite several decades of innovation in sanitation technologies in terms of decentralization, novel treatment, resource recovery etc., the uptake from laboratory scale to large-scale implementation has been minimal. While major academic inquiries in the Water, Sanitation and Hygiene (WASH) sector have focused on sustained adoption from a user perspective, there is a lack of understanding on what the drivers and barriers to technology scalability at a sectoral level. This research therefore aims to understand the factors that determine scalability and mainstream uptake of innovative sanitation technologies. With increasing insecurity in the water, energy and food sectors, sanitation technologies will play an increasingly important role in the coming decades. Therefore, understanding the diffusion of innovations from academia and research to industry and users is very valuable.

The overarching research question that Dr. Narayan focused on during his research stay at SWW TUM was: “What are the factors for innovative sanitation technologies to scale?”. In order to include a diverse set of contexts, different case studies were chosen in India and Sub-Saharan Africa in order to answer the research question.

https://www.eawag.ch/en/aboutus/portrait/organisation/staff/profile/abishek-sankara-narayan/show/

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N-doped graphene oxide/graphitic-C_3N_4/Ag_3PO_4 plasmonic material for photocatalytic degradation of some emerging contaminants in wastewater treatment plant influent

Dr. Martins Omorogie has been back at the Chair since December as a postdoc for a year and a half as Alexander von Humboldt fellow. He is working on the development of a plasmonic nitrogen-doped graphene oxide/graphite-C_3N_4/Ag_3PO_4 material for the photocatalytic degradation of emerging pollutants in the wastewater treatment plant influent (WWTP).

Feasibility Study: Implementation of a Wastewater Surveillance System for COVID-19 in Tashkent

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Dr. Mirshina Olga Pavlovna is a specialist in hygiene and epidemiology, and a candidate of medical sciences (PhD). She is the Chief Specialist of the Ministry of Health for Municipal Hygiene, Chief Specialist of the Sanitary-Epidemiological Welfare and Public Health Service of the Republic of Uzbekistan.

She monitors issues of sanitary-hygienic control of communal hygiene facilities (water supply, sanitation, sanitary cleaning, planning, and development of residential areas), and human environment (water and water reservoirs, atmospheric air and soil) in the Republic. In the project of the GIZ, she functions as a specialist in the organization of sampling and delivery of samples with subsequent analysis of laboratory results, taking into account the sewage system of the city in connection with the prevalence of coronavirus infections in the districts of the city of Tashkent.

Boris Pleshkov Andreevich has been working as a virologist in the Service of Sanitary-Epidemiological Welfare and Public Health of the Republic of Uzbekistan.

He has been conducting PCR studies for influenza and other respiratory viruses since 2009. In 2019 and 2022, he was trained by WHO on recommended methods for wastewater concentration. In the GIZ project, he is presented as a laboratory specialist responsible for conducting PCR testing of wastewater samples for SARS-COV-2.

Elena Mun is an Epidemiologist with a master's degree in bacteriology and virology from Tashkent Medical Academy, Uzbekistan. She has also completed a master programme in public health at Georgia State University, USA in 2017.

Ms. Mun has been working in public health for more than 15 years. Her professional expertise ranges from monitoring and evaluation of health programmes, the coordination of epidemiological and sociological studies HIV/TB advocacy communication, supervision and training of research teams and staff members; outreach to key populations. She worked for Tashkent City AIDS Centre, GFATM and USAID health projects, PWC, and the British Embassy Tashkent.

Currently Elena Mun is managing the Pandemic Response Component of the GIZ project "Management of advanced medical technology in Uzbekistan". Ms. Mun is coordinating activities related to laboratory quality assurance, diagnostic imaging, respiratory support, and epidemiological surveillance including wastewater surveillance (WWS).

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FUNDING:
GERMAN ACADEMIC EXCHANGE SERVICE, COORDINATION FOR THE IMPROVEMENT OF HIGHER EDUCATION PERSONNEL

COLLABORATION:
FEDERAL UNIVERSITY OF MINAS GERAIS

Photocatalytic Recycled Membranes from TiO_2 and Graphene Wastewater

Emerging Contaminants (ECs) have attracted the scientific community's attention in recent years because they have already been detected in wastewater, surface, underground, and even drinking water. Although their effects are not fully understood, studies point to their potential toxicological risks. Conventional wastewater treatment plants and water treatment plants are inefficient in totally removing ECs, requiring advanced treatments for this purpose. That said, this project aims to develop and investigate a photocatalytic membrane reactor composed of the union of catalysts to membranes that generate synergic benefits. The immobilization of the catalyst on membrane surfaces is a promising alternative for its recovery and retaining in the reaction medium. The association also allows the reduction of membranes fouling through the degradation of the foulants compounds by the catalyst, keeping stable permeate flow and minimizing energy consumption.

One of the novelties of this project is to develop and evaluate the performance of Photocatalytic Membranes (PM) composed of recycled membranes (RO membrane after lifespan converted into UF membrane), TiO_2 nanoparticles synthesized by greener route, and graphene oxide (GO). For this purpose, five steps are addressed. The first consists of synthesizing and characterization the PM and preliminary removal/degradation tests of dyes and synthetic matrix of Pharmaceutical Active Compounds (PhACs). The second step concerns the evaluation of the membrane's capacity to remove ECs from municipal wastewater after secondary treatment. In the third, the performance of the system with the suspended catalyst will be evaluated. Fourth, the operating parameters will be optimized, and, finally, an economic analysis of the process will be carried out.

Preliminary results showed an increase in the membranes' performance modified with nanocomposites (dye removal ~100% and almost constant flux) compared to ones without modification (dye removal ~ 56% and flux drop approximately 32%). In addition, the modified membrane was able to remove more than 90% of some PhACs during UV-C irradiation for one and a half-hour of permeation. By modifying membranes with nanocomposites, an increase on membrane hydrophilicity was demonstrated. Moreover, considerable attenuations of diclofenac (92%) and antipyrine (87%) were achieved using the membranes for the treatment of domestic wastewater after biological treatment. The membranes demonstrated stability for ten months.

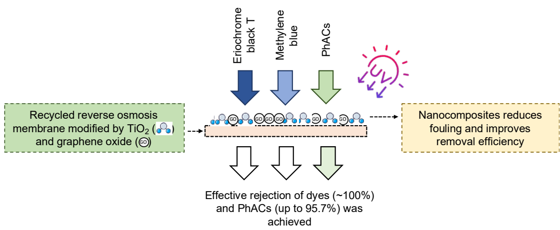


Figure 48: Principle of photocatalytic membranes.

Caique Oliveira is an external Ph.D. student from Federal University of Minas Gerais (Brazil) under the supervision of Prof. Dr. Míriam Amaral.

International Cooperation Partners

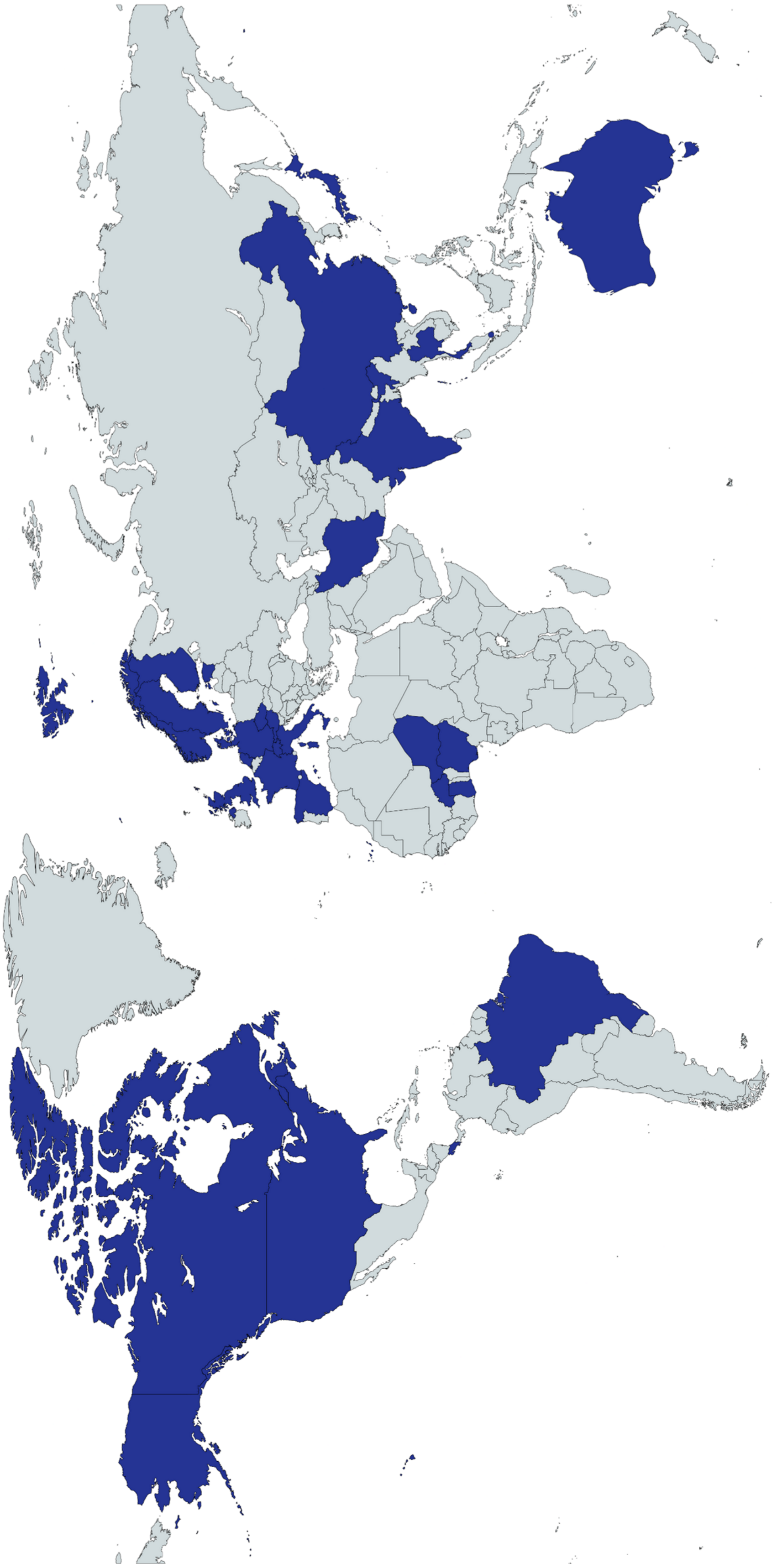


Figure 49. International partners.

Country	Institution
Australia	University of Queensland Murdoch University Griffith University - Water Future Program of Future Earth
Austria	Vienna University of Technology University of Natural Resources and Life Sciences, Vienna Danube University Krems University of Vienna
Brazil	Universidade Federal de Minas Gerais Pontifícia Universidade Católica de Minas Gerais Universidade Federal da Bahia Universidade Federal de Viçosa
Burkina Faso	Université Aube Nouvelle
Canada	Université du Québec à Montréal
China	Tsinghua University Renmin University of China Dalian Institute of Chemical Physics Beijing University of Technology Chinese Academy of Sciences Peking University Sichuan University Beijing Normal University
Costa Rica	University of Costa Rica
Czech Republic	University of Chemistry and Technology, Prague
Denmark	Technical University of Denmark European Environment Agency, Denmark Aarhus University
Estonia	University of Tartu
Finland	University of Turku
France	National Research Institute for Agriculture, Food and Environment
Ghana	Kwame Nkrumah University of Science and Technology
India	ASEEM Foundation Council on Energy, Environment and Water Himalayan Institute of Alternatives Ladakh Indian Institute of Technology Bombay Indian Institute of Science – Bangalore Ladakh Ecological Development Group
Iran	Iranian Research Organization for Science and Technology Isfahan University of Technology
Israel	Tel Aviv University
Italy	University of Ferrara University of Naples Parthenope University of Brescia
Japan	Japan Agency for Marine-Earth Science and Technology Yokohama National University

Continues on the next page

Country	Institution
Namibia	Namibia University of Science and Technology
Netherlands	University of Amsterdam
Niger	Abdou Moumouni University
Nigeria	Redeemers University University of Ibadan
Norway	University of Tromsø – The Arctic University of Norway University of Bergen
Singapore	Swiss Federal Institute of Technology in Zürich - Future Cities Lab Global Technical University of Munich, Asia Technical University of Munich, Create
Spain	Spanish National Research Council - CSIC Institute of Environmental Assessment and Water Research Catalan Institution for Research and Advanced Studies Institute for Fats Catalan Institute for Water Research Royal Botanic Garden of Madrid University of Girona Universidad Pablo de Olavide University of Barcelona
Sweden	Lund University Uppsala University University of Gothenburg Chalmers University of Technology Swedish University of Agricultural Sciences Stockholm University
Switzerland	Swiss Federal Institute of Aquatic Science and Technology Swiss Federal Institute of Technology
Thailand	Mae Fah Luang University
United Kingdom	University of Birmingham University of York Aberystwyth University Cranfield University
United States	Cornell University Northwestern University University of California at Berkeley Yale University Stanford University Oklahoma State University University of Michigan, Ann Arbor Massachusetts Institute of Technology

National & International Committees

DWA Working Groups

Brigitte Helmreich is actively involved in various DWA working groups. She is deputy chairwoman of the **DWA technical committee ES-3** *"Plant-related planning"*, spokeswoman of the working group **DWA-ES-3.1** "*Infiltration of precipitation water*", member of the working groups **DWA-ES-3.11** "*Multifunctional surfaces*", **DWA-ES-3.7** "*Decentralized plants for precipitation water treatment*" and **DWA-ES-1.2** "*Substance inputs into drainage systems*". She is also an active member of the **DWA Technical Committee IG-2** "*Industry-specific industrial wastewater and waste"*.

Jörg E. Drewes is involved in the **DWA Technical Committee KA-8 "***Advanced Wastewater Treatment"*, in the **DWA Working Groups Biz 11.4** "*International Water Reuse*" as well as **KA-8.1** "*Anthropogenic Substances in the Water Cycle"* and **KA-8.4** *"Water Reuse"*. He continues to serve on the Management Committee of the **IWA Water Reuse Specialist Group**, as well as the **Strategic Council** of the International Water Association (IWA). Prof. Drewes has been nominated again for a new term to serve as a member of the BMG/Federal Environmental Agency **Drinking Water Commission**. He was elected as vice chair of the commission. He also served as **spokesperson of the Expert Commission** *"Water Supply in Bavaria"* of the Bavarian State Government. Prof. Drewes also is the Chair of the Expert Panel on *"Chemicals of Emerging Concern in Ambient Waters"* of the **California State Water Resources Control Board, USA** and a member of the expert commission *"Proposed Criteria for Direct Potable Reuse in California"* of the **National Water Research Institute (NWRI), USA**.

Uwe Hübner is an active member of the **DWA technical committee KA-8.5** *"Ozonation at wastewater treatment plants"*.

German Water Chemistry Society

Uwe Hübner is actively involved in the technical committees "*Transformation Processes in Biological Wastewater Treatment and Wastewater Reuse*" and "*Oxidative Processes*" of the **German Water Chemical Society**. Among other things, the groups prepare status papers summarizing the current state of knowledge on biodegradation processes.

Christian Wurzbacher is actively involved in the technical committee "*Pathogens and Antibiotic-Resistant Bacteria in the Water Cycle*", a subcommittee of the **German Water Chemical Society**. The group elaborates the current state of knowledge and perspectives in dealing with pathogens in the water cycle.

Journals – Editors

Jörg E. Drewes serves since 2020 as the Associate Editor of the journal *ACS ES&T Water*.

Christian Wurzbacher serves since 2016 as a Technical Editor of the journals *MycoKeys* and *Biodiversity Data Journal*.

Brigitte Helmreich is a guest editor for the journal *Water* editing a special issue on "*Challenges and sustainability of Water Sensitive Cities* ".

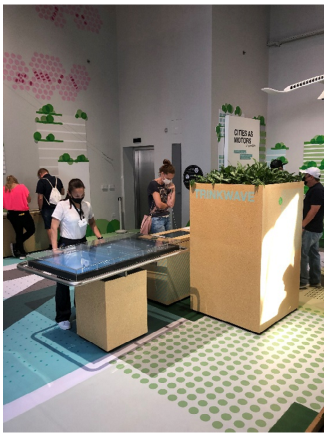
Konrad Koch and **Uwe Hübner** are guest editors of Water magazine for special issues on "Biomethane Potential Tests - A Key Tool for Anaerobic Digestion Research and Practice" and "Oxidative Processes in Water and Wastewater Treatment Systems".

In addition, **Konrad Koch** is currently a guest editor of a special issue on "*Organic carbon recycling for net zero emissions and sustainable organic carbon flow between urban and rural areas*" in the journal *Environmental Technology & Innovation*.

Workshops & Other Activities

The **Roland Mall Foundation** presented three gifted students from the field of water and environment each with a scholarship of €500/month for the entire standard period of study of the Master's program in 2022. The students **Fabian Stöhr, Julia Zimmermann and Zakaria Bashiri** were selected based on their previous accomplishments.

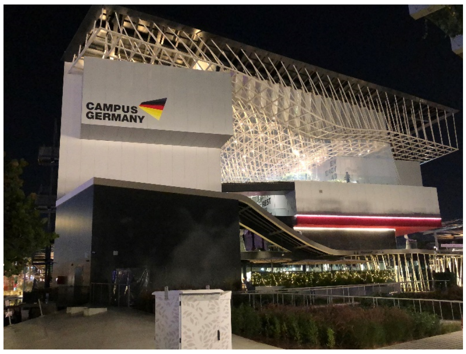
Participation at the EXPO 2020 in Dubai, UAE



In March of 2022 the EXPO 2020 in Dubai closed its doors. The chair participated in the exhibition in the German Pavillion. The focus of Campus Germany was practices leading to sustainability. We featured our nature-based water treatment system SMART funded by the German Ministry of Education and Research.

EXPO 2020 DUBAI UAE | CAMPUS GERMANY

OFFICIAL PARTICIPANT – GERMANY



Sciencecyclists

In 2022, we collectively biked over 23,465 kilometers to and from the chair. This equates to 3.4 tons of CO_2 saved in comparison to an average car, and 8.9 tons of CO_2 in comparison to an economy flight.

Chair excursion in November 2022

Our chair excursion this year was on November 14th, 2022 with sunny weather via the Kesselalm to the Breitenstein. The tour started from the Birkenstein hiking parking lot in Fischbachau, from where we hiked up to the Kesselalm in about an hour. At the Kesselalm we could enjoy the sun with refreshing drinks and snacks. Afterwards we could climb the Breitenstein summit. Many thanks to the organizers of the company outing Sonia Kau, Javad Ahmadi and Konrad Koch.

Figure 50: Chair excursion Birkenstein.

Upcoming Events

50th Wastewater Technology Seminar – Anniversary Conference on 50 years Wastewater Research – Implications for the Future

Since 1970 the Chair of Urban Water Systems Engineering supported by the Association of the Chair the Wastewater Technology Seminar Series (ATS), where we feature the most recent developments in the area of drainage systems, stormwater management, biological wastewater treatment, automation, resource recovery and water reclamation and reuse to engineering practice augmented by newest insights from research into these areas. The 50th anniversary will be celebrated with a special event to reflect the development over five decades with accomplished international and national leaders in the field and the interested public to discuss new trends and developments of the wastewater sector in the future.

Please join us for this exciting event over two days at the Science Congress Center of the Technical University of Munich at the Research Campus Garching on July 5-6, 2023. We will address pressing issues related to drainage systems and sponge cities, biological wastewater treatment targeting carbon and nutrients, resource recovery and carbon footprint, advanced wastewater treatment and water reclamation and reuse, as well as aspects of climate adaptation, digitalization and public health. You can get more information at: https://www.cee.ed.tum.de/sww/foerderverein/ats/

This seminar is targeted to serve municipalities, consulting engineers, water and permitting agencies, manufacturers, research institutes as well as universities.

12. Aqua Urbanica 2023

Our chair has recently been on the Scientific Board of **Aqua Urbanica**, which consists of six sister institutions for urban water management: Eawag-ETH Zurich, the Ostschweizer Fachhochschule, Graz University of Technology, Kaiserslautern University of Technology, the University of Innsbruck and Munich University of Technology in cooperation with the national Organizations DWA, ÖWAV and VSA exists. This German-speaking D-A-CH series of conferences, which takes place once a year, focuses on rainwater and mixed water management in urban areas. The topic of the Aqua Urbanica 2023, which will take place on **October 9th and 10th, 2023 in Garching**, is "**The water and pollutant-conscious city - climate-adapted rainwater management meets the problem of pollutants**". It deals with the planning and implementation of a water-conscious city. The focus is on the interaction of opportunities to counteract the consequences of climate change and the risks of the pollutant issue that is partly associated with it. In addition to positive effects on the urban climate, measures in the area of gray, blue and green infrastructure can also act as sources and sinks for material loads from precipitation runoff. For a water-conscious city, water protection is just as important as maintaining the local water balance and adapting to increasing climate extremes. Basic research is just as welcome as case studies from practice and models. Diverse contributions from planners, authorities, manufacturers and universities/technical colleges are welcome in order to enable a far-reaching exchange of experiences.

More information at https://www.tugraz.at/events/aquaurbanica/home

Publications

Peer-reviewed Journal Articles

1) Al-Azzawi, M.S.M.; Gondhalekar, D.; Drewes, J.E. (2022): Neighborhood-Scale Urban Water Reclamation with Integrated Resource Recovery for Establishing Nexus City in Munich, Germany: Pipe Dream or Reality? Resources 11 (7), 64.
2) Bardi, M.J.; Mahmood, A.; Lippert, T.; Bandelin, J.; Koch, K. (2022): Stimulating Effect of Hydrostatic Pressure on Ultrasonic Sewage Sludge Treatment for COD Solubilization and Methane Production. Bioresource Technology 348, 126785.
3) Becker, L.; Gondhalekar, D. (2022): Estimating the Water and Carbon Footprints of Growing Avocados in the Munich Metropolitan Region Using Waste Heat as a Water-Energy-Food Nexus Potential. Frontiers in Sustainable Food Systems 6, 857650.
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33) Gondhalekar, D. (2022): Resiliente Städte: der Nexus Ansatz. Session organized by BMW Foundation RISE Cities Programme. In: Festival der Zukunft, 24. July 2022, Deutsches Museum, Munich, Germany.

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35) Gondhalekar, D. (2022): Water Reclamation with Resource Recovery as a Key Enabling Factor for Net Zero Carbon Circular and Rejuvenatory Urban Development, German University in Cairo Webinar: Water-Energy-Food Nexus (sustainable environment), 1. June 2022, online.

36) Gondhalekar, D. Nexus City: Water Reclamation with Resource Recovery for Net Zero Carbon Urban Development. Asian Water Forum, Asian Development Bank, 09. August 2022, online.

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41) Helmreich, B. (2022): Elemente der Wassersensiblen Stadt als Tools zur Erhaltung des lokalen Wasserhaushalts. In: Bauwerksbegrünung und Regenwassermanagement – Planungshinweise. Akademie der Architektenkammer NRW gGmbH, Düsseldorf, 29. January 2022, online.

42) Helmreich, B. (2022): In Zukunftsaufgaben der Regenwasserbehandlung. DWA-Landesverband Baden-Württemberg, 1. December 2022, Stuttgart, Germany and online.

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50) Helmreich, B. (2022): Vor-Ort-Behandlung von Niederschlagsabflüssen im Siedlungsraum. Abschlusskolloquium Forschungsvorhaben Entwicklung eines Modells zur Bewertung der Umwelteigenschaften üblicher Putze und Mörtel im Außenbereich, Fraunhofer Institut für Bauphysik, Valley, 5. October 2022.

51) Helmreich, B. (2022): Wasserbewusste Stadtplanung – Bedeutung und Tools. In: Seminar klimaresiliente, wassersensible Städte der Zukunft. StUMV, 28-29. September 2022, Munich, Germany.

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53) Hübner, U.; Lippert, T.; Ilić, N.; Drewes, J.E. (2022): Konventionelle und innovative Verfahren der Trinkwasseraufbereitung. Fachtagung des Umweltcluster Bayern zu Sanierung von PFAS-Schadensfällen, 22. September 2022, Schrobenhausen, Germany.

54) Hübner, U.; Müller, J.; Knoop, O.; Drewes, J.E. (2022): Demonstrating Average Removal of Trace Organic Compounds During Advanced Wastewater Treatment Based on Indicator Compounds – A Question of Combinatorics and Selection. 12th IWA Micropol & Ecohazard Conference, 6-10. June 2022, Santiago de Compostela, Spain.

55) Hübner, U.; Spahr, S.; Lutze, H.; Wieland, A.; Rüting, S.; Gernjak, J.; Wenk, J. (2022): Emerging Advanced Oxidation Processes for Water and Wastewater Treatment –Guidance for Systematic Future Research, IWA World Water Congress & Exhibition, 11-15. September 2022, Copenhagen, Denmark.

56) Ilić, N.; Mukherjee, S.; Hübner, U.; Knoop, O.; Fischer, R.; Drewes, J.E. (2022): Tailoring MOFS to Achieve Unrivalled Adsorption of PFAS from Water - A Fundamental Study of Correlation Between Structure and Performance. 12th IWA Micropol & Ecohazard Conference, 6-10. June 2022, Santiago de Compostela, Spain.

57) Koch, K.; Hafner, S.; Astals, S.; Weinrich, S. (2022): Evaluation of Common Supermarket Products as Positive Controls in Biochemical Methane Potential (BMP) Tests. 17th IWA World Conference on Anaerobic Digestion, 17-22. June 2022, Ann Arbor, USA (poster).

58) Lang, W.; Helmreich, B.; Bienert, S. (2022): Grün Blau Grau verbinden: Pfade zur Klimaanpassung im Wohnungsbau – ein Schlaglicht aus der Forschung. In: Lebenswerte Stadt der Zukunft – klimagerechtes Planen und Bauen, 5. October 2022, Munich, Germany.

59) Lippert, T.; Bandelin, J.; Vogl, D.; Alipour Tesieh, Z.; Wild, T.; Drewes, J.E.; Koch, K. (2022): Full-Scale Assessment of Ultrasonic Sewage Sludge Pretreatment Using a Novel Double-Tube Reactor. 17th IWA World Conference on Anaerobic Digestion, 17-22. June 2022, Ann Arbor, USA.

60) Ponzelli, M.; Radjenovic, J.; Drewes, J.; Koch, K. (2022): The Impact of Graphene Oxide on Methane Production Kinetics. NOWELTIES' Final Conference - New Materials and Inventive Wastewater Treatment Technologies, Harnessing Resources Effectively Through Innovation, 11-12. May 2022, Dubrovnik, Croatia.

61) Rosenberger, L.; Helmreich, B. (2022): Klimaanpassung im Wohnungsbau: Planung der blau-grünen. 11. Aqua Urbanica, 14-15. November 2022, Zweideln-Glattfelden, Switzerland.

62) Sierra Olea, M.; Jennings, E.K.; Lechtenfeld, O.J.; Reemtsma, T.; Hübner, U. (2022): Isotopically Labeled Ozone in Wastewater Treatment: Assessment of Biodegradability of OPs from Oxygen Transfer Reaction of Ozone with S- and N-Containing Moieties. SETAC North America 43rd Annual Meeting, 13-17. November 2022, Pittsburgh - Pennsylvania, USA (poster).

63) Sierra Olea, M.; Kölle, S.; Jennings, E.; Reemtsma, T.; Lechtenfeld, O.J.; Drewes, J.E.; Hübner, U. (2022): Ozonation with Heavy Oxygen (^{18}O) - A Novel Labeling Technique for the Elucidation of Ozonation Products. 12th IWA Micropol & Ecohazard Conference, 6-10. June 2022, Santiago de Compostela, Spain.

64) Stinshoff, P.; Helmreich, B. (2022): Multifunktionale Versickerungsmulden im Siedlungsraum. 11. Aqua Urbanica, 11. Aqua Urbanica, 14-15. November 2022, Zweideln-Glattfelden, Switzerland (poster).

65) Vega Garcia, P.; Schwerd, R.; Helmreich, B. (2022): Modellierung des Verbleibs von Bioziden und ihren Transformationsprodukten bei der Versickerung von Fassadenabflüssen. 11. Aqua Urbanica, 14-15. November 2022, Zweideln-Glattfelden, Switzerland (poster).

66) Weinrich, S.; Delory, F.; Astals, S.; Koch, K.; Hafner, S. (2022): Simple Kinetic Models for Clear Comparison of Anaerobic Digestion at Different Scales and Operating Conditions. 17th IWA World Conference on Anaerobic Digestion, 17-22. June 2022, Ann Arbor, USA.

Theses

Doctoral Dissertations

1) Al-Azzawi, Mohammed: Microplastic in the Aquatic Environment: Developing a Reliable and Rapid Holistic Analytical Process for Monitoring Microplastics in Wastewater Treatment Plant Effluents.
2) Minkus, Susanne: Development and Validation of an Orthogonal Polarity-Extended HRMS Screening to Detect Highly Polar Trace Organic Compounds in the Aquatic Environment.
3) Schwaller, Christoph: Agricultural Irrigation Demand Modelling and Assessment of Membrane Ultrafiltration Alone or Hybridized with Inline Dosed Powdered Activated Carbon for Non-Potable Water Reuse Application.
4) Vega Garcia, Pablo: Development of a Model to Assess the Environmental Properties of Common Outdoor Plasters and Mortars.

Master's Theses

1) Abeshev, Kuat: Expanding Water-Energy-Food Nexus Thinking Through Life Cycle Assessment Methodology: Environmental Performance of a Community Supported Agriculture Farm.
2) Ahana Pramanik: Evaluation of the Potential of Water-Energy Nexus Implications: Case Study Bhairoba Sewage Treatment Plant, Pune, India.
3) Akhimova, Elizaveta: Recycling of Laundry Wastewater with the Application of Ceramic Nanofiltration.
4) Al Jarrah, Mohammad: Development of House Made Ultra-Filtration Membrane Modules and its Use for Maintenance Energy Estimation in a Microbial Community from Activated Sludge Adapted to Aniline.
5) Andalib, Afrina: Studying the Effect of Ultrasonic Frequency and Power on the Degradation of Per- and Polyfluoroalkyl Substances and Exploring the Synergetic Effect of Coupling Flotation with Ultrasonic Treatment.
6) Basak, Nirjhar: Comparative Study on Different Remediation Strategies Applied in PAH-Contaminated Soils.
7) Bi, Jianyuan: The Interaction of Biocides and Heavy Metals with Centrifugally Fractionated DOM.
8) Borges de Mendonça, Rodrigo: Modelling Selected Food Supply Chain Networks for Brazil and Disruption Testing.
9) Bötte, Fabian: Biotransformation of a Mixture Of 25 TOrCs by Aniline, Histidine and Di-Sodium Succinate Degraders.
10) Castillo Nolte, Alejandro: Integration of Small Hydroelectric Systems in the Andes of Peru with a Nexus Approach.
11) Cochrane, Christopher: A Nexus Approach to an Urban Carbon Footprint Account.
12) Colina, Andrijana: Interaction of Per- and Polyfluoroalkyl Substances and PTFE Microparticles in Aquatic Phase: Fundamental Research on Isotherm Adsorption Behavior.
13) Därr, Dorothee: Investigation of Measures for the Energetic Optimization of a Municipal Wastewater Treatment Plant Within the Scope of a Potential Study.
14) Eder, Simon: Comparative Studies on the Treatment of Leachate from the Großlappen Landfill Using Biological, Sorptive or Chemical-Mechanical Processes on a Pilot Scale.
15) Feder, Sandra: Laboratory Evaluation of Different Soil Amendments to Remove Contaminants in Urban Stormwater Runoff for Bioretention Cells - Two Column Experiments to Test the Heavy Metal and Biocide Removal of Soil Amendments.
16) Fleetwood, Daniel: Bio-Electrochemical Production of the Energy Carrier Dimethyl Ether (DME) from Wastewater: An Environmental Evaluation Via LCA.

17) Fokkins, Kevin: Quantification of Maintenance Energy Requirement in a Microbial Community from Activated Sludge Adapted to Histidine as Unique Carbon Source.
18) Geelani Rameez: Evaluation of consistency of the Umbrella regulation (Mantelverordnung) in relation to the practiced environmental protection.
19) Gega, Eva: Progressive Succession of Microbes in Down-Flow Hanging Sponge Reactors.
20) Güreli, Emine Nil: Biomethanation in a Trickle Bed Reactor: Comparison of CO_2 Sources with an Evaluation of Sulfur Source Effect.
21) Haas Goschenhofer, Sophie: Development of Methods for the Dimensioning and Evaluation of Smart Cisterns as a Novel Measure in Water-Sensitive Urban Design.
22) Heimann, Amelie: Profitability Analysis of a Power-to-Gas Plant in Germany.
23) Hillebrand, Veronika: The Physiological Impact of the Interaction Between a Native Unionid Mussel and the Invasive Zebra Mussel *Dreissena polymorpha* in Response to Water Temperature Variations.
24) Irshad, Umar: Biodegradation of 4-Nitro-Sulfamethoxazole and Ibuprofen Spiked with Ozonation Products of Light and Heavy Oxygen.
25) Khan, Mohammad Shehryaar: Optimization of UVC-LED Pre-Treatment Integrated in Spiral-Wound Elements for Biofouling Control in Membrane Desalination Processes.
26) Knabl, Magdalena: Effects of Varying Flux and Transmembrane Pressure on the Retention and Integrity of MS2 Bacteriophage During Ceramic Ultrafiltration.
27) Kosar, Merve: Design of a Sustainable Water Supply System for Dar Village, Niger.
28) Krist, Tim: Development and Modeling of a Water Treatment System for a Self-sufficient Hydrogen Energy System.
29) Kwadwo Yeboah Asamoah: Estimating the Potential for Energy Autonomy in Wastewater Treatment Plants (WWTP) Using the Water-Energy-Food Nexus Approach as a Model for Sub-Saharan African Cities.
30) Lange, Kim: Comparative study of the annual water balance in the context of climate adaption in a residential area in Ingolstadt.
31) Legner, Nicolas: Urban Climate Adaptation with Decentral Stormwater Management Measures: Simulation of Heavy Rainfall Events in Schwabach, Bavaria.
32) Matthes, Nicola: Removal Rates and Sorption Behavior of SARS-CoV-2 and Comparable Viruses in Biofilm and Wastewater.
33) Mohri, Milena: Assessment of the Phytoextration Potential of Herbaceous Plant Species Occurring in Germany Using a Meta-Analytical Approach.
34) Nguyen, Hoang Hiep: Biogas Production Under the Influence of Graphene Oxide in Overloaded Reactors.
35) Nguyen, Xuan: Removal of Recalcitrant COD and TrOCs from Heavily Polluted Wastewater – An Assessment of Feasibility Using BDD Electrodes.
36) Özal, Göksu: Process Integration of Hydrothermal Liquefaction of Sewage Sludge with Wet Oxidation and Power-To-X Technologies: Improved Fuel Production Concept.
37) Pakta, Arsa: Proposal of Soil Aquifer Treatment (SAT) System as a Managed Aquifer Recharge (MAR) Technology for Management, Treatment, and Reuse of Rainwater and Municipal Wastewater In Dar, Niger.
38) Pasquazzo, Giulia: Investigation of the Removal of Benzoic Acid and 1,4-Dioxane in a Simulated Groundwater Flow Environment Via Ozonation Using a PDMS Gas-Liquid Membrane Contactor.
39) Philips, Harsha: Feasibility Study on Zero Wastewater Discharge Technologies for Water Intense Production Sites of Henkel Adhesive Technologies.
40) Prasad, Meenakshi: Selection of a Suitable Membrane for the Elimination of Metabolically Produced Water in Trickle Bed Reactors – A Techno-Economical Assessment.
41) Preiß, Lisa-Marie: Urban Trees as an Element of the Water Sensitive City - Using them as Area Drainage Systems and Requirements Due to Climatic Stresses.

42) Reiser, Patrick: Comparative Study of the Annual Water Balance of the “Klimaquartier” in Schweinfurt Under the Influence of Climate Change.
43) Rocha Santos, Giovanni: Validation of Different Methods for Quantification of Per- and Polyfluoroalkyl Substances in Dental Care Products.
44) Schill, Rebecca: SARS-CoV-2-Abwasserüberwachung: SARS-CoV-2 wastewater monitoring: Understanding spatiotemporal instabilities and noise in the relationship of wastewater samples and clinical cases.
45) Shaaban, Safenaz: The Influence of Epoxiconazole and Penicillin on Aquatic Microorganisms in Down-flow Hanging Sponge Reactors.
46) Speer, Anna: Comparison of a 1D Model and 1D-2D Model for the Dimensioning of a Small Flood Retention Basin as Flood Protection for the Village of Oberempfenbach.
47) Tiwari, Kapil: Effect of Oxygen Partial Pressure on MBBR Treatment of Produced Water.
48) Ukpedor, Perfect: A Cross-sectoral Analysis of Circular City Indicators Integrating Circular Economy and Nexus Framework.
49) Waldapfel, Bianca: Potential Analysis for Decentralized Treatment of Organically Highly Polluted Washing Wastewater Based on a Case Study from the Chemical Industry.

Study Projects

1) Ahoor, Danika: Optimization of a Closed-Loop Ozone Generation System for Heavy Ozone Production.
2) Al-Areqi, Aya: Investigation of Different Metals Salts Effect as Coagulants on Filterability and Other Surrogate Parameters in Wastewater Treatment.
3) Atanova, Angelina: C40 Competition: Mobility and Urban Design Reinvention of Balvanera Sur, Buenos Aires, Argentina.
4) Bötte, Fabian: Analysis of Trace Organic Chemicals Bio-Transformation by an Aniline Degraded Microbial Community.
5) Contreras Vomend, Fernando Mario: Assessment of the Catalytic Activity of Manganese Dioxide and Iron (III)Oxide Hydroxide Via the Formation of Hydroxyl Radicals for their Use in Heterogeneous Catalytic Ozonation.
6) Franz, Benedikt: Adsorption of Copper and Zinc on Optimized Topsoil with Substrate Amendments for Enhanced Urban Stormwater Treatment.
7) Gadalla, Islam: Formulating a GHG Emissions Inventory for TUM.
8) Griffith, Harry: OSDRIA – Deep Dive.
9) Hofmeier, Veronika: Review of Drinking Water Treatment Technologies in Sub-Saharan Africa.
10) Khan, Mohammad Shehryaar: Development and Validation of a Cultivation and Flow-Through Biodosimetry Procedure for *Aquabacterium citratiphilum*.
11) Kirzeder, Franz: Overview of the Design and Operating Parameters of Trickle Bed Reactors for Biological Methanation.
12) Melhem, Mohannad: Assessing the Sustainable and Unsustainable Water Utilization in Various Sectors in Lahore, Pakistan.
13) Milde, Lukas: Development and Construction of a Sequential Managed Aquifer Recharge Technology (SMART) Column Setup for Analyzing the Dissolved Oxygen Consumption for Improved Removal of Trace Organic Compounds.
14) Mondorf, David: Economic Evaluation of the Relationship Between Drinking Water Supply and Agricultural Best Management Practices in the Sio-Malaba-Malakisi River Basin.
15) Mraz, Christina: Looking for a Needle in a Haystack: Optimized Method Development for Nile Red Fluorescence Staining and Tracking of Microplastic Particles in Environmental Samples.
16) Nguyen, Hoang Hiep: Evaluation of Algae Growth in LEDs Integrating Bioreactor.

17) Nguyen, Xuan Quyet: UV Light Modeling of a Steady-State Water Reactor Using COMSOL Multiphysics.
18) Ozluer, Meltem: Biotransformation of Atenolol and Sulfamethoxazole by Aniline and Histidine Degraders.
19) Rendon Velazquez, Claudia Margarita: Site Assessment and Project Proposal Development with a WEF Nexus Approach in Sub-Sahara Areas: Case Study in Rwanda.
20) Schill, Rebecca: Impact of Carbon Dioxide Enrichment on Hydrogen in Anaerobic Co-Digestion.
21) Straub, Julian: Removal of Arsenic from Landfill Leachate.
22) Strebel, Annika: Guideline for the Treatment of Highly Polluted and Heterogeneous Industrial Waste Water.
23) Sultana, Habiba: UVC-pretreatment Using LEDs for Biofouling Control in Reverse Osmosis Membrane Systems.
24) Ukpedor, Perfect: Impact of CO_2 Enrichment at Varying Organic Loading Rates in Anaerobic Co-Digestion by Analyzing VFA/TIC Ratio and VFA.
25) Waldapfel, Bianca: Researching Processing Strategies and Statistical Methods for Nontarget Screening Data to Compare Samples.

Bachelor's Theses

1) Braun, Johanna: A Literature Review of the Effects of Ultraviolet Irradiation on Microorganisms with a Focus on Inactivation and Repair Mechanisms for LED Specific Applications.
2) Bühler, Leonie: Tree Pits - Different Designs and Options.
3) De Amicis Barbieri Botelho, Guilherme: Fungal Diversity in Wastewater Treatment Plants
4) Gadalla, Islam: Formulating a GHG Emissions Inventory for TUM.
5) Gerstner, Julian: Potential Analysis for the Use of Industrial Originating Sodium Brine as a High-Quality Road Salt for Winter Service.
6) Giglberger, Felix: Coupling Urine Diverting Flush Toilets with Anaerobic Co-Digestion in the Global South - Modelling Climate Benefits in Kpong, Ghana.
7) Hansen, Emily: Piney Point Phosphate Plant: An Environmental Investigation and Wastewater Treatment Plan.
8) Heymes, Natacha: Water Supply of the Municipality Peißenberg.
9) Kolb, Laurenz: Screening for Unknown PFASs in the Aquatic Environment and Concentration-Dependent Comparison of Detected Compounds.
10) Meier, Dominik: Model Construction and Validation of a Sewer Network with PCSWMM Using the Example of the City of Ingolstadt.
11) Nißl, Andreas: Measurement of the Stein an der Traun Sewage Treatment Plant to Apply for a Water Law Permit.
12) Robinson Padron, Carmen: Mycobiome (Fungal Populations) in Urban Aquatic Systems.
13) Stöhr, Fabian: Multifunctional Use of Urban Areas - Examples and Requirements.
14) Zimmermann, Julia: Evaluation of Semi-Technical Experiments of Infiltration Swales with Soil Amendments to Remove Organic Contaminants (Biocides) in Urban Stormwater Runoff.

Dissertations and Awards

Congratulations to **Dr.-Ing. Pablo Vega** for successfully defending his dissertation, titled *"Development of a model to assess the environmental properties of common outdoor plasters and mortars"* on August 12th, 2022. His committee members included Prof. Brigitte Helmreich, Prof. Anya Vollpracht (RWTH, Aachen) und Prof. Klaus Sedlbauer (TUM). The chairman of the commission was PD Dr.-Ing. Konrad Koch.

Figure 51: Dissertation committee of Dr.-Ing. Pablo Alberto Vega García (Prof. Klaus Sedlbauer joined remotely).

Figure 52: Dissertation committee of Dr.-rer. nat. Susanna Minkus (Prof. Thorsten Schmidt joined remotely).

Congratulations to **Dr. rer. nat Susanna Minkus** for successfully defending her dissertation, titled "*Development and validation of an orthogonal polarity-extended HRMS screening to detect highly polar trace organic compounds in the aquatic environment*" on November 23rd, 2022. Her committee members included Prof. Thorsten Schmidt (University Essen), Prof. Jörg E. Drewes and Dr. Thomas Letzel (Private lecturer, formerly TUM). The chairwoman of the commission was Prof. Brigitte Helmreich.

Congratulations to **Dr.-Ing. Christoph Schwaller** for successfully defending his dissertation, titled *"Agricultural irrigation demand modelling and assessment of membrane ultrafiltration alone or hybridized with inline dosed powdered activated carbon for non-potable water reuse applications"* on December 19th, 2022. His committee members included Prof. Brigitte Helmreich, Prof. Tzahi Y. Cath (Colorado School of Mines, USA) and Prof. Jörg E. Drewes. The chairman of the commission was PD Dr.-Ing. Konrad Koch.

Figure 53: Dissertation committee Dr.-Ing. Christoph Schwaller (Prof. Cath joined remotely).

Figure 54: Dissertation committee of Dr.-Ing. Mohammed Al-Azzawi.

Congratulations to **Dr.-Ing. Mohammed Al-Azzawi** for successfully defending his dissertation, titled *"Microplastics in the Aquatic Environment: Developing a Reliable and Rapid Holistic Analytical Process for Monitoring Microplastics in Wastewater Treatment Plant Effluents"* on December 20th, 2022. His committee members included Prof. Brigitte Helmreich, Herrn Prof. Martin Jekel (TU Berlin) and Prof. Jörg E. Drewes. The chairman of the commission was Prof. Markus Disse (TUM).

We are pleased to congratulate **Dr.-Ing. Sema Karakurt-Fischer**, who was awarded the Willy Hager Prize 2021 for her doctoral thesis entitled "*Development and validation of a novel treatment concept for planned potable reuse based on sequential managed aquifer recharge technology for more sustainable water management*". The prize is awarded by the Willy Hager Foundation for outstanding work by young university scientists in the field of water and wastewater treatment in Germany. The prize was presented during the annual meeting of the Water Chemical Society within the GdCh 2022.

We are delighted with **Professor Jörg E. Drewes**, who has been awarded the prestigious Dunbar Medal by the European Water Association (EWA).

Figure 55: Dunbar Medal Award on May 30, 2022 at IFAT, Munich, Germany.

Teaching

The Chair of Urban Water Systems Engineering offers a wide range of different courses for the Bachelor study program *Umweltingenieurwesen* and *Bauingenieurwesen* as well as for the Master programs *Environmental Engineering*, *Civil Engineering*, *Ecological Engineering,* and *Sustainable Resource Management*. The emphasis of these courses is placed on water chemistry, advanced water treatment, energy recovery from wastewater, water recycling as well as conceptual design for sustainable water supply and wastewater disposal systems for urban areas. In 2022, the following lectures were offered:

Summer Term

Bachelor

- Kreislaufwirtschaft und Werkstoffe für nachhaltiges Bauen: Koch, Konrad
- Mikrobiologie: Wurzbacher, Christian
- Projektkurs Siedlungswasserwirtschaft: Drewes, Jörg
- Thermodynamik und Energietechnik Übung: Hübner, Uwe
- Thermodynamik und Energietechnik: Hübner, Uwe
- Umweltanalytik: Helmreich, Brigitte; Petz, Susanne
- Umweltrecht: Spieler Martin (TUM-Lecturer)

Master/PhD

- Advanced Water Treatment Engineering and Reuse: Drewes, Jörg
- Anaerobic Treatment and Energy Recovery: Koch, Konrad
- Bewirtschaftung von Kanalnetzen und Regenwassermanagement: Helmreich, Brigitte
- Doktoranden und Masteranden Kolloquium – Proaktiv: Drewes, Jörg; Helmreich, Brigitte; Koch, K., Hübner, Uwe; Knoop, Oliver; Wurzbacher, Christian; Keilman-Gondhalekar, Daphne
- Gute Wissenschaftliche Praxis: Koch, Konrad
- Hydrochemistry Laboratory: Helmreich, Brigitte; Sottorff, Ignacio; Petz, Susanne; Hübner, Uwe; Koch, Konrad
- Industrial Wastewater Treatment and Reuse: Helmreich, Brigitte
- Modeling of Aquatic Systems: Koch, Konrad
- PhD Seminar SiWaWi: Drewes, Jörg; Koch, Konrad
- Planning the Urban Water-Energy-Food Nexus, lecture & project: Keilman-Gondhalekar, Daphne
- Technical Communication Skills in Water and Wastewater Treatment Engineering: Koch, Konrad

- Unit Operations Laboratory on Advanced Water Treatment: Hübner, Uwe
- Wastewater Treatment: Koch, Konrad

Winter Term

Bachelor

- Verfahrenstechnik: Böhm, Bernhard (TUM-Lecturer); Koch, Konrad
- Siedlungswasserwirtschaft Grundmodul: Helmreich, Brigitte; Koch, Konrad
- Verfahrenstechnik Übung: Böhm, Bernhard (TUM-Lecturer); Koch, Konrad

Master/PhD

- Aquatic Microbiology: Wurzbacher, Christian
- Design and Operation of Wastewater Treatment Plants: Athanasiadis, Konstantinos (TUM-Lecturer); Böhm, Bernhard (TUM-Lecturer)
- Doktoranden und Masteranden Kolloquium – Proaktiv: Drewes, Jörg; Helmreich, Brigitte; Koch, Koch, Hübner, Uwe; Knoop, Oliver; Wurzbacher, Christian; Keilman-Gondhalekar, Daphne
- Engineered Natural Treatment Systems: Hübner, Uwe
- Gute Wissenschaftliche Praxis: Koch, Konrad
- Hydrochemistry Laboratory: Helmreich, Brigitte; Sottorff, Ignacio; Hübner, Uwe; Koch, Konrad
- Hydrochemistry: Helmreich, Brigitte
- Modeling of Aquatic Systems: Koch, Konrad
- PhD Seminar SiWaWi: Drewes, Jörg; Hübner, Uwe
- Planungs- und Genehmigungsverfahren nach deutschem und europäischem Wasserrecht: Spieler, Martin (TUM-Lecturer)
- Scientific Methods and Presentation Skills: Möckel, Rolf; Drewes, Jörg
- Technical Communication Skills in Water and Wastewater Treatment: Drewes, Jörg; Koch, Konrad
- Unit Operations Laboratory on Advanced Water Treatment: Hübner, Uwe; Bein, Emil; Ilic, Nebojsa; Sierra Olea, Millaray
- Water and Wastewater Treatment Engineering: Drewes, Jörg

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Friends of the Chair

The Development Fund of the Chair of Urban Water Systems Engineering e.V. at TUM is a non-profit organization to support research and teaching at the chair.

Membership is open to anyone who supports the goals of the foundation. Funds provide seed grants for research efforts:

- Supplement to cover printing costs of scientific reports/publications
- Publish the book series "Reports of Urban Water Systems Engineering"
- Support teaching funds
- Support travel fellowships for doctoral candidates and graduate students
- Partially support of research infrastructure
- Facilitate scientific meetings and workshops in the area of water treatment and wastewater treatment and reclamation

We publish our annual report forum to keep our members informed regarding activities at the Chair of Urban Water Systems Engineering.

In order to fulfill these tasks, we depend on donations. Thus, we welcome financial and in-kind contributions. We do not charge a membership fee.

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The office of the Development Fund is led by Raphaela Hoffmann.

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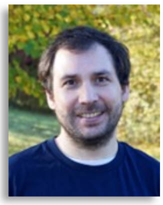

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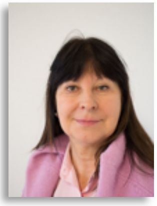

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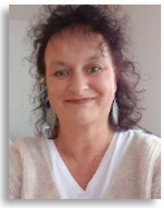

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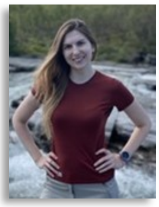

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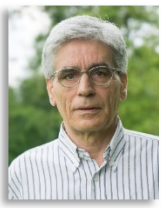

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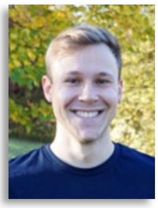

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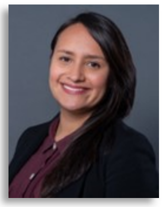

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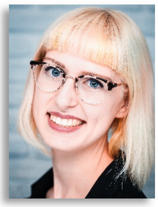

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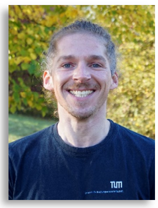

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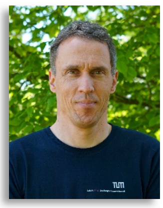

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