forum 91

Newsletter of the Chair of Urban Water Systems Engineering

ANNUAL REPORT OF THE CHAIR OF URBAN WATER SYSTEMS ENGINEERING

2020

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Foreword

Dear Friends,

The year 2020 will certainly be remembered by all of us for a long time to come as a year of profound changes, some of which - one can only hope - may also develop positively. The Covid-19 pandemic has presented us all with unprecedented challenges and will continue to do so for quite some time. Many people have lost loved ones or suffered serious illnesses, many long-held assumptions have been fundamentally called into question, and many people as well as companies and entire countries are struggling to cope with the economic consequences of the pandemic.

Even though it has been a challenging year for us, we are happy and very grateful that we have mastered the challenges of the pandemic surprisingly well so far.

With this issue, I am pleased to present you with our 2020 Annual Report. Despite Corona, this year was also characterized by exciting research activities and gratifying third-party funding, even though we have reduced our physical participation in national and international conferences to virtually zero. Our staff members are still very active in publishing their findings in scientific publications and sharing them with the national and international scientific community in virtual lectures this year. We are very happy for Dr.-Ing. Veronika Zhiteneva, Dr.-Ing. Sema Karakurt-Fischer, and Dr.-Ing. Dietmar Strübing for the successful completion of their PhD degrees this year. We can also be proud of Dr.-Ing. David Miklos, who was awarded the Willy Hager Prize 2020 for his doctoral thesis, as well as Dr.-Ing. Johann Müller, who won second place in the German Water Management Young Talent Award 2020 for his doctoral thesis. We would like to congratulate all of them once again!

In the past year we grew by some new PhD students who introduce themselves to you in this annual report together with their other colleagues at the chair.

Similar to many other events, we had to cancel this year's Wastewater Technology Seminar (ATS) due to the pandemic. Next year, however, we will resume our seminar series with the Water Technology Seminar (WTS) on March 3, 2021 as a virtual event with the topic "New requirements for drinking water treatment by perfluorinated compounds (PFAS)", which was organized by Dr. Oliver Knoop. This topic is not only highly relevant in the Free State of Bavaria but also in Germany and we have been able to attract leading speakers for this event. The 48th ATS is planned for July 14, 2021 in Ismaning and will be dedicated to the topic "Stormwater Management in Times of Climate Change" under the leadership of Prof. Brigitte Helmreich. The programs of these events can be found in this issue of FORUM and on our web portal. There you can also register online (www.sww.bgu.tum.de/). We would be very pleased about your interest in these events.

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, Environmental Planning and Engineering, and Sustainable Resource Management. However, lectures were largely held virtually in both the summer and winter semesters. In addition to a large number of lectures, exercises and practical courses, the members of the department supervised an impressive number of 85 master's theses, student research projects and bachelor's theses.

After the very successful organization of the 12th International Conference on Water Reclamation and Reuse of the International Water Association (IWA) in June 2019 in Berlin, I have resigned as chair of the Water Reuse Specialist Group after six years of serving on that position. However, I continue to be involved in the WRSG as well as the Strategic Council of the IWA. With the decision of the German Cabinet in October 2020, I was very pleased to be appointed to the German Government's Scientific Advisory Council on Global Change for the term 2020-2024.

On behalf of my staff, I would like to express my sincere gratitude for your support and interest in our students and our work. In particular, we would like to thank you for the support of our sponsoring association, which makes a very important contribution to the education of our doctoral students and undergraduates by funding travel to attend conferences as well as grants for research work.

We wish you a successful year and hope that you enjoy reading our 2019 annual report!

Best regards,

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Research Center

The mission of the research center at the Chair of Urban Water Systems Engineering 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.

The research center is directed by Prof. Brigitte Helmreich.

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Physicochemical Laboratory, Trace Compounds Analysis, and Microbiological Laboratories

A central facility of the chair and the research center is the affiliated laboratory, divided into three areas: the physicochemical laboratory led by Dr. Susanne Petz, the trace compounds analysis unit led by Dr. Oliver Knoop, 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 3), 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 3: Determination of single and sum parameters through cuvette tests using the HACH-photometer.

The analytical laboratory specialized in the characterization and identification of organic molecules from aqueous samples with trace compounds analysis (target screening) using chromatographic separation techniques coupled to highly sensitive mass spectrometric detection techniques (LC-MS/MS). 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 microplastics using a thermal desorption-pyrolysis-GC/MS, respectively.

Figure 2: 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). 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 Drainage Systems

The research group drainage systems headed by Prof. Dr. Brigitte Helmreich is focusing on sustainable stormwater management in urban areas. Numerous cities are already experiencing extreme redensification and a significant reduction in inner-city green spaces. This makes natural stormwater management a major challenge. At the same time, the frequency, duration, and intensity of weather extremes such as heavy rainfall events and heat waves are increasing in the context of climate change and lead to regular hydraulic overloading of the sewage system or the increase of summer heat stress and water shortage in particularly affected regions. Robust, sustainable concepts for stormwater management must be developed.

In addition to the quantitative analysis of the stormwater runoff from paved areas, qualitative aspects must not be neglected. One focus of the research group is therefore the monitoring of pollutants from stormwater runoff of paved areas (roads, facades, roofs) as well as the development and evaluation of decentralized treatment facilities.

Figure 5: Retention soil filter for the treatment of traffic area runoff.

In 2020 we focused on evaluating the condition of the Bavarian sewer system as a basis for forecasting the need for rehabilitation. Two projects that dealt with the operational performance of decentralized treatment systems for runoff from traffic areas were successfully completed. One research project deals with the runoff of biocides from building facades and the associated relevance for the environment. A new research project focussing on the optimization of vegetated infiltration swales has started. The focus here is not only on the safety of drainage and the retention of pollutants but also on biodiversity and insect protection. Such multifunctional infiltration troughs should in future find greater acceptance in settlement areas and be better prepared for the extremes of climate change.

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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 settlement 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.

The aim is not only the development of an improved technical urban water system but also vegetation- and animal-ecological integrated infiltration system. The research on adapted and suitable vegetation is carried out by employees of the Weihenstephan-Triesdorf University of Applied Sciences. The Chair of Urban Water Systems Engineering focuses on the development of suitable and optimized topsoil through substrate admixture, which concentrates on drainage safety and the retention of heavy metals and biocides from traffic-area-, facade- and roof-surface-runoff. This will be done in three steps: 1. laboratory tests with columns for pollutant retention. 2. semi-technical tests in the open air with vegetation to investigate the material load and operational stability. 3. pilot tests in the residential area with the proven soil-substrate mixtures and different planting. Additional observation of stormwater tree pits with the topsoil-substrate mixtures were done.

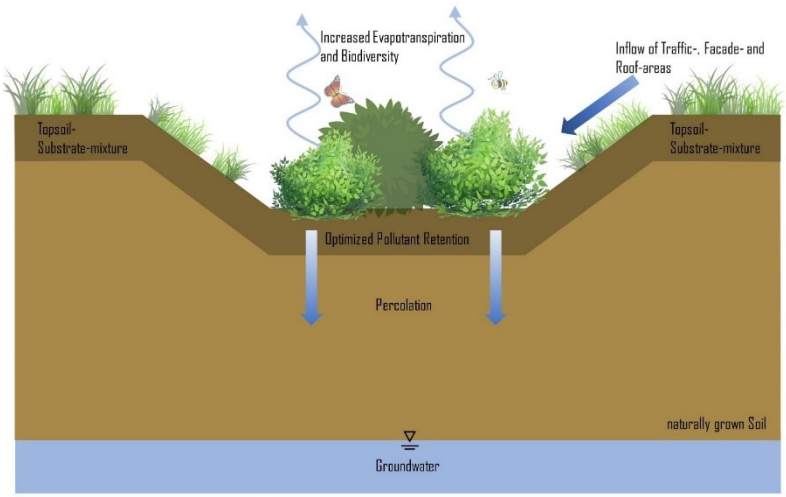

Figure 6: Schematic structure and effect of multifunctional infiltration swales.

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.

FUNDING:

BAVARIAN ENVIRONMENT AGENCY

COLLABORATION:

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

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BAVARIAN ENVIRONMENT AGENCY, CITY OF MUNICH

Practical Experience in Handling Decentralized Stormwater Quality Treatment Devices for Traffic Area Runoff

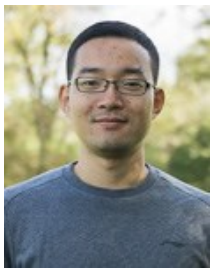
In the course of a sustainable groundwater management, traffic area runoff is more often percolated on-site. Due to traffic-related emissions, atmospheric pollutions and temporary punctual emissions (accident/construction site/event) the traffic area runoff can be polluted heavily to some extent with heavy metals or organic substances.

In urban regions natural retention of runoff by vegetated topsoil must be provided by technical solutions, due to the limited space. This can prevent contamination of the soil and groundwater systems.

Figure 7: Testing facility for traffic area runoff treatment.

Besides numerous laboratory studies, few scientifically documented experiences in the field exist.

The objective of the research project was to perform independent application oriented research on decentralized stormwater quality treatment devices, which are approved by the Deutsches Institut für Bautechnik (DIBt). For this, three treatment plants (two shaft systems and one filter substratum channel) with different functionalities were constructed in Munich on a street with heavy traffic under equal conditions. To capture seasonal influences, the study ran for two years. The emergence of hazardous substances and their detention and remobilization under the influence of deicing salts and long-lasting impounding were studied. Operational aspects were recorded and analyzed. Additionally, insufficiently investigated substances, including gasoline additives (MTBE/ETBE), cyanides contained in deicing salts, and fine particles were monitored.



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FUNDING:

CHINA SCHOLARSHIP COUNCIL

Study on Complexation of Biocides, Pesticides and Heavy Metals from Building Runoff in Presence of Dissolved Organic Matter (DOM)

Biocides and pesticides originate from building surface (facades, roofs) during wet weather are frequently detected in sewer system and suburban water catchments. Toxicity research shown some of these organic pollutants and their transformation products (TPs) could pose adverse effect to aquatic organisms. Additionally, heavy metals from building surface are transported to environment by stormwater runoff as well. In this process, the contact of biocides, pesticides, heavy metals and DOM is given. Regarding the physicochemical properties of these four compounds, the interaction between all dissolved substances in stormwater runoff or during their percolation or treatment is possible. Unfortunately, knowledge on this aspect is limited. In order to effectively removing these substances and their TPs, a full understanding of interactions between compounds is necessary and urgent.

The aim of this work is therefore to create a basic understanding of the reactions / reaction mechanisms under different environmental conditions as a basis for developing effective treatment systems and the understanding why treatment systems fail under some circumstances.

To achieve the objectives, technologies like EEM analysis, semi-equilibrium dialysis and HPLC-MSMS analysis will be applied in the research. Results from EEM analysis shown both Cu^{2+} and Zn^{2+} could complex with DOM, Cu^{2+} shows much higher complexation ability than Zn^{2+}. However, complexation between Mecoprop, Diuron and DOM was not observed, results need to be further confirmed by semi-equilibrium dialysis.

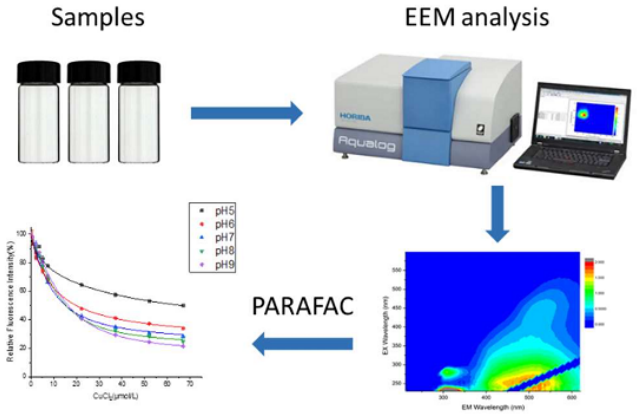

Figure 8: Graphic abstract of complexation study between heavy metals and DOM.

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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.

The main objective of the project 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.

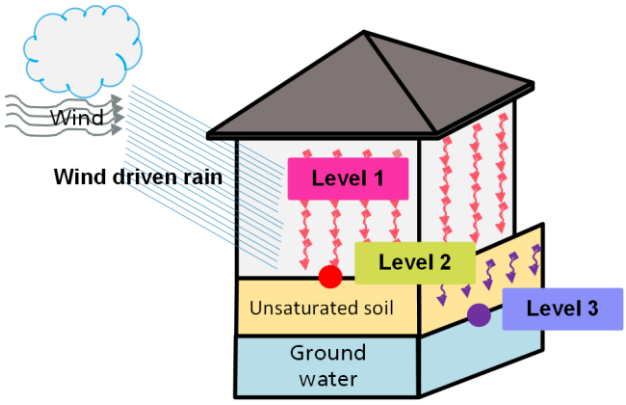

Figure 9: "3-Level Model" schema: The model is divided in three different levels; "Level 1" is the facade runoff model, "Level 2" is the model for leaching processes and substance transport on the facade and finally the "Level 3" is the leachate forecast and evaluation of the environmental impact.

To achieve this overall objective, three specific sub-objectives are planned.

1) Identification of the mechanisms underlying the leaching of ingredients from irrigated construction products.
2) Development of a model for the description of substances release (emission) from plasters and mortars.
3) This is followed by the modeling of the material transport through "the soil" up to a defined assessment point and the comparison with limit values. Development of the leachate forecast.

FUNDING:

ASSOCIATIONS FOR INSULATION SYSTEM, PLASTERS AND MORTARS GERMANY

COLLABORATION:

FRAUNHOFER INSTITUTE FOR BUILDING PHYSICS

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FUNDING:

BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION

Current State of the Sewer Infrastructure in Bavaria - Status 2018

The functionality of the public sewer system is of decisive importance for the effective and safe removal of wastewater and rainwater in municipalities. At the same time, existing systems represent a considerable share of municipal assets. In order to ensure the operational capability of public sewer systems, it is essential to have comprehensive knowledge of the condition and potential renovation requirements.

The Chair of Urban Water Systems Engineering of the Technical University of Munich is carrying out a study on the condition of public sewer systems in Bavaria financed by the Bavarian State Ministry of the Environment and Consumer Protection (StMUV) on behalf of the Bavarian Environment Agency (LfU). The main focus of the study, which has been ongoing since May 2019, is the assessment of the condition of the public Bavarian sewer systems in 2018 on the basis of various criteria. Besides, the study aims at estimating the need for restoration and the resulting costs and examines the development of the situation identified in a preliminary report from 2012. The assessment of the condition of the sewer system in 2018 is based on the evaluation of regionally representative annual sewer network reports provided by the Bavarian Water Management Agencies. The available information was supplemented by further data, queried directly from selected sewer network operators by means of an additional questionnaire. On the basis of a representative sample, projections of the condition of the entire Bavarian sewer system with regard to various criteria were carried out. The classification, discussion and interpretation of the data from 2018 will take into account previous studies from 2006 and 2012 as well as other related studies.

Figure 10: Sewer system.

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Development of a Strategy to Use Stabilized Ammonium Fertilizer to Improve the P Supply to Young Plants from Poorly Soluble P-Fertilizers and the P-Soil Stock to Minimize the Input of N and P from Agricultural Land into Water Bodies

A three-year research project was completed this June, which dealt with the absorption of the nutrients phosphorus (P) and nitrogen (N), which are essential for plant nutrition. In fertilizers, nitrogen is often in the form of ammonium. Ammonium is converted to nitrate in the soil through nitrification. The nitrate is dissolved in soil water and can be transported into the groundwater and thus contribute to a deterioration in the quality of the groundwater. However, if possible to prevent this transformation, e.g. with a nitrification inhibitor, the ammonium can remain in its original form and become an advantage for the nutrient uptake by the plant. At the center of the project was the hypothesis that an ammonium-based diet of maize leads to a particularly strong lowering of the pH value in the rhizosphere, which in turn enables the mobilization of less available P from appropriate forms of fertilizer or the soil itself. In addition, the aim of the project was to demonstrate this effect using recycling P-fertilizers, which are regularly less water-soluble.

For this purpose, numerous model tests were carried out on a laboratory scale with different soils, also with regard to the fertilization technology used (e.g. band fertilization).

FUNDING:
INDUSTRY FUNDING

Figure 11: Model tests with maize plants in laboratory scale.

COLLABORATION:
WEIHENSTEPHAN UNIVERSITY OF APPLIED SCIENCES

The results of the model tests were then validated in a field test with a very low P supply. Here, too, the aim was to demonstrate an improvement in the P uptake of the plants in the youth stage of the maize plant.

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Research Group
Energy Efficient Wastewater Treatment

Wastewater treatment plants are currently the largest consumers of municipal electricity, despite wastewater containing more than enough energy that would be required for its purification. While the treatment of wastewater under the given limits for discharge still has the highest priority, there are some approaches that can simultaneously reduce the energy required for the treatment while recovering more energy from the wastewater itself.

An increase in efficiency in the conversion of hardly degradable substrates is exemplarily possible by a pretreatment with ultrasound. The investigations have shown that besides the increased methane yield, additional effects should be considered. For a holistic assessment, and possibly improved dewaterability, a reduced amount of biosolids for disposal and the effects on sludge rheology and foaming tendency have to be taken into account.

The addition of co-substrates into the existing sludge digestion can also significantly increase the biogas yield. Using existing infrastructure is a sensible approach to implement co-digestion and achieve the often reported synergistic effects by mixing of substrates with different properties. However, this is occasionally accompanied by challenges, such as substrate pretreatment and storage, potentially an increased amount of residues for disposal, and a possible backload of the wastewater treatment plant with nitrogen-rich centrate from sludge dewatering.

The latter can be treated via deammonification in the side stream as an alternative to the robust but energy-intensive process of nitrification/denitrification. This requires less energy for aeration and even completely dispenses with the use of a carbon source through an autotrophic process. However, the comparatively low energy gain for the microorganisms involved also requires tight process monitoring and control.

There is even the possibility of at least partially recovering the energy bound in the ammonium from the wastewater. This process also uses a nitritation (conversion of ammonium into nitrite) as a first stage, but then switches to a denitritation, in which nitrous oxide is intentionally generated with the addition of a carbon source. However, this novel process is still under investigation, with several challenges yet to be tackled.

Finally, wastewater treatment plants can also contribute to the energy transition by applying microbiological methanation. Excess electricity from renewable sources can first be converted into hydrogen by means of an electrolyzer and then together with CO_2 into methane to be stored. Biofilm-based technologies under thermophilic conditions have proven to be suitable particularly under dynamic operation.

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

The share of renewable energies in the German electricity mix is steadily increasing. In order to succeed the energy transition, there is a trend to further expand the implementation of renewable energy technologies. The development of conversion and storage technologies is a key element to ensure an efficient and sustainable energy supply.

One approach is the power-to-gas technology. During energy overproduction, excess electricity is used to produce hydrogen (H_2) by electrolysis. Subsequently, hydrogen can be converted into storable biomethane (CH_4) by the synthetization with carbon dioxide (CO_2). A particularly promising concept is the microbiological production of methane in thermophilic anaerobic trickle bed reactors in which so-called archaea are immobilized on carrier materials. This microorganism uses the supplied gases for their metabolism.

In a previous project, methanation in anaerobic thermophilic trickle bed reactors at lab-scale already demonstrated a high performance with methane production rates of up to 15.4 $L_{CH4}/(L_{trickle\ bed}*d)$ at methane 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.

FUNDING:

BAVARIAN MINISTRY OF ECONOMIC AFFAIRS REGIONAL DEVELOPMENT AND ENERGY

COLLABORATION:

BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE

To further test the potential of biological methanation in the thermophilic anaerobic trickle bed reactor, a pilot-scale reactor was installed at the Garching wastewater treatment plant. With a reaction volume of 1 m^3, the applicability of the reactor concept should be demonstrated on a semi-industrial scale. This makes the reactor one of the largest anaerobic trickle bed reactors in the world. Considering the location, an important research question is the use of biogas from the wastewater treatment plant's digester as an alternative CO_2 source. This would allow the upgrading of biogas up to grid injection gas quality at the point of origin.

Figure 12: Pilot-scale reactor at the Garching wastewater treatment plant.

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FUNDING:

FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY

COLLABORATION:

BANDELIN ELECTRONIC GMBH & CO.

UltraMethan-Subproject: Increasing the Energy-Efficiency of Wastewater Treatment Through Innovative Ultrasound Disintegration

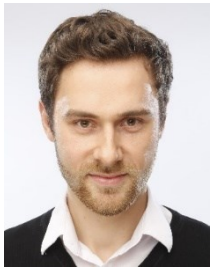
Wastewater treatment plants are the largest municipal energy consumers. Although wastewater theoretically contains enough energy to cover the entire treatment process in form of biogas potential, often only a fraction of the wastewater's chemical energy is recovered. Energy recovery is generally carried out during the anaerobic treatment of the sewage sludge that is produced during the purification process. However, typical degrees of degradation are only about 50% to 60% without a sludge pretreatment.

The target of the research project UltraMethane is, hence, an improvement of anaerobic digestion due to the application of ultrasound. Through ultrasound-induced cavitation, sludge flocs are disintegrated, and microorganism cells are disrupted, which results in an improved microbiological degradation and consequently, in an increased biogas yield.

Figure 13: Continuously operated biogas test system.

To date, ultrasound was typically applied as a pre-treatment for waste activated sludge (WAS). However, as WAS exhibits relatively high total solids contents (> 5%), the efficiency of the process may be critically impaired through sound wave attenuation. Hence, as a novel approach, co-treatment of digested sludge (DS) has been investigated. The advantage of such an approach is that DS exhibits a considerably lower total solids content (~ 3%) so that the effects of sound wave attenuation are much less pronounced. Furthermore, DS co-treatment allows concentrating the disintegrating effects on the most recalcitrant constituents of the sludge.

Thanks to these advantages, results obtained from the continuous experiments conducted in the lab of the Technical University of Munich demonstrated that DS co-treatment was able to significantly enhance both methane production and organic matter removal. Yet, due to the high energy demand of the US reactor, an economic operation of the co-treatment approach remained challenging. Hence, to render the alternative treatment scheme economically viable, future research should especially investigate the potential of low energy input sonication for DS co-treatment.



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UltraMethan- Subproject: Development of an Ultrasonic Test Reactor for the Intensive Disintegration of Large Amounts of Sewage Sludge in a Flow-Through Process

The objective of the UltraMethan project (grant no. 03ET1396A) was to develop a new ultrasonic system to increase the biogas yield in anaerobic sludge stabilization. The digestion process is accelerated by the mechanical disintegration of the sludge particles achieved by sonication. This is achieved by the dissolution of sludge flocs and the increased surface available to the anaerobic microorganisms after the disintegration. A further advantage apart from the increase of the gas yield is the associated reduction of the sewage sludge quantities to be disposed of by an accelerated degradation on the one hand and better dewatering on the other hand. The disintegration of the sludge should be performed by means of ultrasound-induced cavitation in a highly efficient surface oscillation system to be developed, which can be retrofitted into existing sewage treatment plants without any difficulties.

Jochen Bandelin is responsible as a process engineer for the development of highly efficient ultrasonic systems for sewage sludge treatment at BANDELIN electronic GmbH & Co KG in Berlin. His doctoral thesis is supervised by Jörg E. Drewes and Konrad Koch. The focus of his doctoral thesis is the systematic investigation of the disintegration performance of ultrasound-induced cavitation in highly viscous media. For a positive energy balance of the process, it is necessary to determine those forms of sonication which achieve the highest efficiency in sonication of sludges of different viscosity by an optimal relation of amplitude, field size, ultrasonic frequency, and power density. For this purpose, the effectiveness of tube and sonotrode reactors for the sonication of excess sludge and digested sludge under the same conditions was compared for the first time. The experimental results show that a large number of smaller reactors of 2-3 inches (Figure 14) with a high power density result in a more efficient increase of the gas yield of excess sludge and digested than larger reactors with a lower power density.

FUNDING:
FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY

COLLABORATION:
BANDELIN ELECTRONIC GMBH & CO.

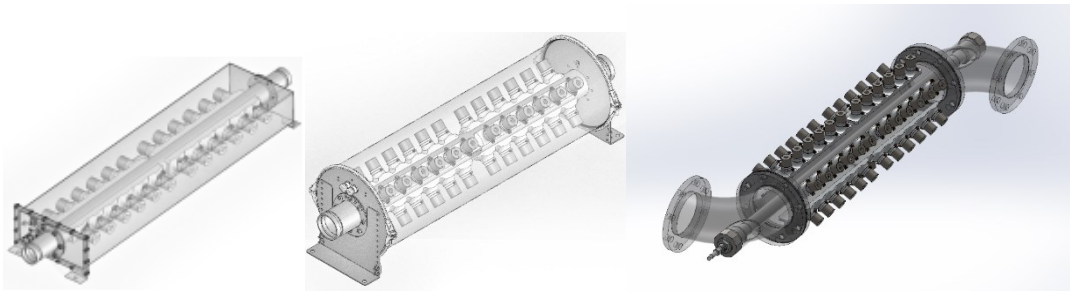

Figure 14: Tubular reactor designs investigated within the project: 2-inch tubular reactor (left), 3-inch tubular reactor (middle), 6-inch double tubular reactor (right).

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Increased Methane Productivity in Anaerobic Digesters by CO_2 Enrichment

Wastewater treatment plants use about 20 % of the municipal energy consumption and emit roughly 3 million tons of CO_2 every year. Thus, it is crucial to improve the balance between energy demand and energy production by additionally reducing the CO_2 footprint of wastewater treatment plants. Currently, the chemical energy bound in wastewater is, at least partly, recovered in form of energy-rich methane gas gained by the anaerobic digestion of sewage sludge. During the anaerobic treatment, CO_2 is produced as a byproduct.

Recent studies reported an increasing methane productivity by CO_2 enrichment. However, the transformation pathways that lead to an increased methane formation by CO_2 conversion have only been hypothesized so far. This project aims at identifying the main mechanisms of bioconversion of CO_2 by applying stable isotope labeling of the injected CO_2 and comprehensive microbial analysis of the digested sludge. Therefore, continuous anaerobic digestion tests are performed with two laboratory-scale biogas test systems.

FUNDING:

GERMAN RESEARCH FOUNDATION

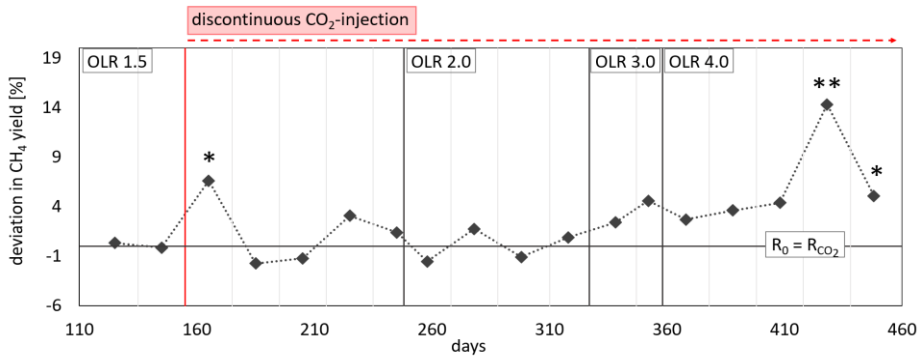

Figure 15: Average deviation of CH_4 yield per hydraulic retention time at different organic loading rates (OLR) of the experimental reactor compared to the control.

COLLABORATION:

HEIDELBERG UNIVERSITY, BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE

Discontinuous CO_2-injection into the experimental reactor led to an initial increase of the methane yield compared to the control. However, a permanent increase in methane productivity was only achieved at high organic loading rates (OLR) and thus enhanced the availability of volatile fatty acids (VFA). This indicates that for an increased CO_2 to CH_4 bioconversion sufficiently high OLRs or substrates that lead to high VFA concentrations in the fermentation broth are needed.

The results will help to find the best full-scale operation conditions to increase the methane formation by CO_2 enrichment in the digesters. Using the “waste product” CO_2 in anaerobic digestion to exploit the potential for energy production from waste streams can therefore make a substantial contribution to advance the energy transition.

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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 a 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 the mitigation of these emerging contaminants.

One research focus in 2020 was to evaluate the combination of ozonation and biofiltration in the context of water reuse. In a 2-year project with funding from US Water Research Foundation and coordinated by Trussell Technologies, empirical data from various operators applying ozone and biofiltration have been evaluated. The tasks of TUM include the development of indicator and surrogate concepts for the evaluation and monitoring of this process combination.

In another project, we investigate together with the Münchner Stadtentwässerung, if disinfection efficiency by ozonation can be enhanced by optimization of tertiary filtration. For this purpose, pilot-scale rapid sand filtration is tested on-site and ozonation of filtrates is carried out with different ozone doses at bench-scale.

Figure 16: Bench-scale ozonation.

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

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 compared to standard *in-situ* injection methods. From the combination of ozone with hydrogen peroxide as an advanced oxidation process, we expect an effective removal of monocyclic, aromatic compounds (BTEX) from polluted groundwater. Within this joint German-Israeli research cooperation, we aim to develop membrane-based ozonation for in-situ groundwater remediation.

For successful implementation fundamental research on passive, bubble-free gas introduction at low flow velocities will first be conducted in lab-scale reactors. The test of different membrane materials and hydrogen peroxide doses shall provide more insights into the options and limitations of the proposed technology. A modified mass transfer model will be developed to describe different scenarios of gas introduction. This can potentially be useful for other promising applications in advanced wastewater treatment and drinking water ozonation.

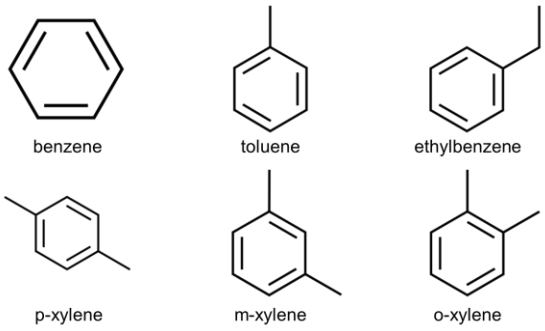

Figure 17: BTEX compounds.

FUNDING:

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

Further, we aim to identify suspected aliphatic products of BTEX oxidation (see Figure 17) by using HILIC-MS. Our partners at Tel-Aviv University will conduct experiments on a larger scale to optimize the membrane system and its operation (Figure 18). The proposed setup will finally be tested at full-scale to assess the effectiveness of the concept for remediation of a contaminated site.

COLLABORATION:

TEL AVIV UNIVERSITY

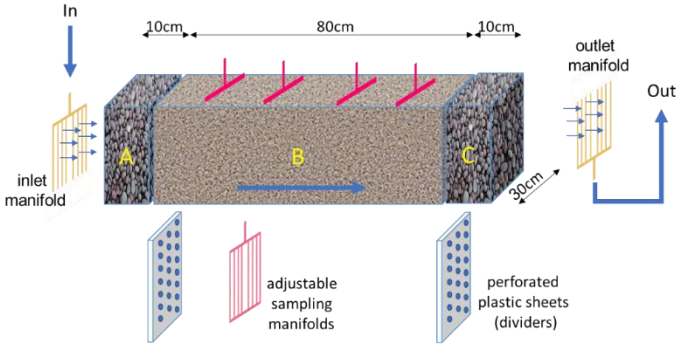

Figure 18: Experimental setup with porous media and passive gas introduction.

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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. Despite its utility, it has one major disadvantage, the formation of stable and potentially toxic ozonation products (**OPs**). This drawback has garnered attention in the scientific community, due to the unknown and potentially detrimental effects of OPs in the environment and on human health. To date, 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 that demonstrates the predictability of the reaction pathways 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 behavior of OPs (i.e., stability, persistence, and biological activity) depending on their chemical functionality.

FUNDING:

GERMAN RESEARCH FOUNDATION

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, which will be performed through mass spectrometry.

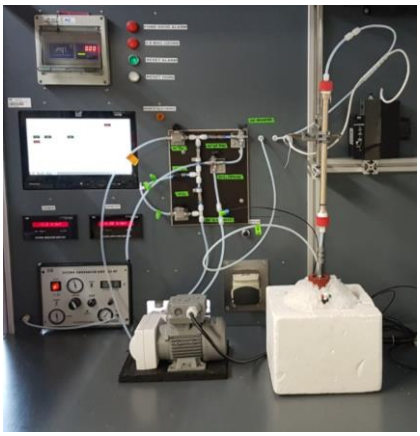

Figure 19: Modified ozonation system for the production of heavy ozone ($^{18}O_3$) stock solution.

COLLABORATION:

HELMHOLTZ CENTER FOR ENVIRONMENTAL RESEARCH

To date, we established the labeling method through an ozone generation system, which was modified and optimized (Figure 19) for its use with heavy oxygen ($^{18}O_2$). With this new labeling approach, we will be able to reliably detect and characterize OPs even in complex matrices like effluent organic matter, if they are formed from oxygen transfer reactions. In addition, the labeling will help to track the stability of OPs in biological treatment systems.

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Development of Adaptive Advanced Methods and Systems for the Removal of Recalcitrant Per- and Polyfluoroalkyl Substances from Water

As a part of 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 the Friedrich-Schiller-University in Jena, we intend to further explore proven concepts of degradation through ultrasound cavitation and to establish 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.

As a second research direction we are 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 together with the Catalysis Research Center of TUM. 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

FUNDING:

EUROPEAN COMMISSION

COLLABORATION:

CATALYSIS RESEARCH CENTER, FRIEDRICH-SCHILLER-UNIVERSITY JENA, UNIVERSITY OF SANTIAGO DE COMPOSTELA

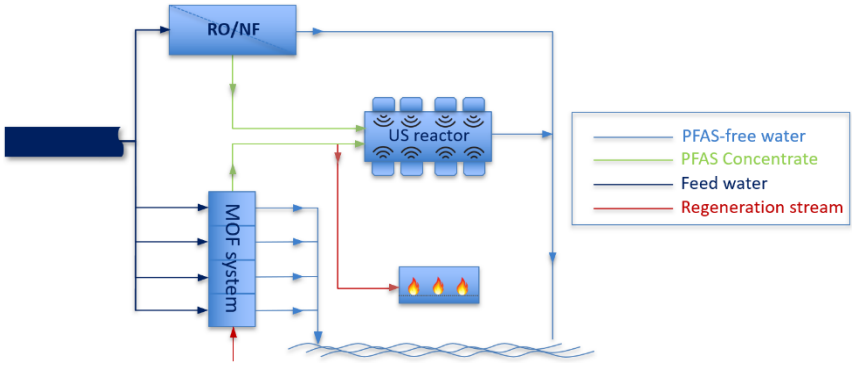

Figure 20: Schematic representation of the treatment concept for PFAS-polluted water.

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Bioenergetic-Metabolic Model for Prediction of Trace Organic Chemicals Bacterial Transformation

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 inventive water treatment technologies that allow catering for the varied treatment demands for a plethora of interconnected streams arising from recycling loops. Within this project, we aim to model the bacterial transformation of trace organic chemicals (TOrCs) by coupling co-metabolism and mixed-substrate growth in a bioenergetic-metabolic framework (Figure 21).

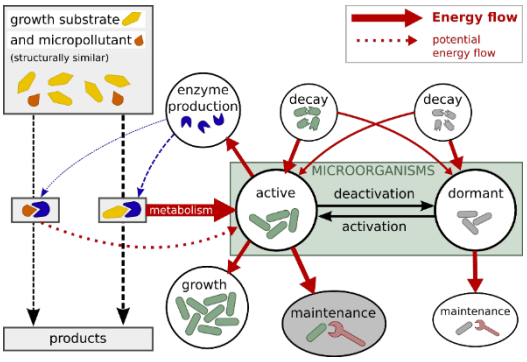

Figure 21: Illustration of the bioenergetic model developed at TUM and University of Tübingen.

As sand filter systems have shown good removal of TOrCs under oligotrophic conditions, a retentostat system (Figure 22) is used to maintain a controlled oligotrophic environment and achieve microbial adaptation. Results from retentostat experiments will provide insights on the fundamental processes behind the biotransformation of TOrCs.

FUNDING:

EUROPEAN COMMISSION

Four substances with a simple structure that can be found in TOrCs were selected for microbial adaptation in single carbon source experiments. While sodium acetate is very common in nature and it has a well-understood metabolism. Aniline, triethylamine, and 1,3-dichlorobenzene are xenobiotics.

A bioenergetic-metabolic model will be trained and validated with data from retentostat experiments. Experimental analyses include primary substrate and possible by-products concentrations, cell counting, 16S rRNA sequencing, and metagenomics. It is expected for the model to predict conditions for TOrCs biotransformation, but also to allow identification of intermediates and enzymes involved in the process.

COLLABORATION:

THE CATALAN INSTITUTE FOR WATER RESEARCH

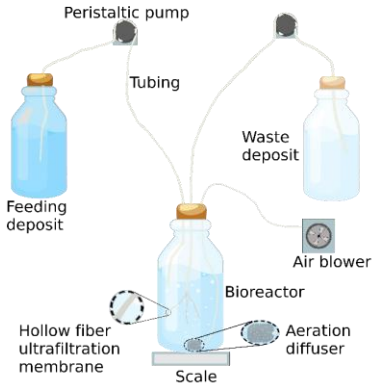

Figure 22: Retentostat experimental set-up illustration.

Research Group Water Recycling

Feasibility of Water Reclamation for Agricultural and Urban Reuse in Lower Franconia, Germany

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Lower Franconia is one of the driest areas in Bavaria. The region around the city of Schweinfurt is representative for other locations with comparable challenges. In order to guarantee an integrated and sustainable management of the locally overexploited groundwater resources, alternative options for the extraction, distribution and potential uses of reclaimed water are needed.

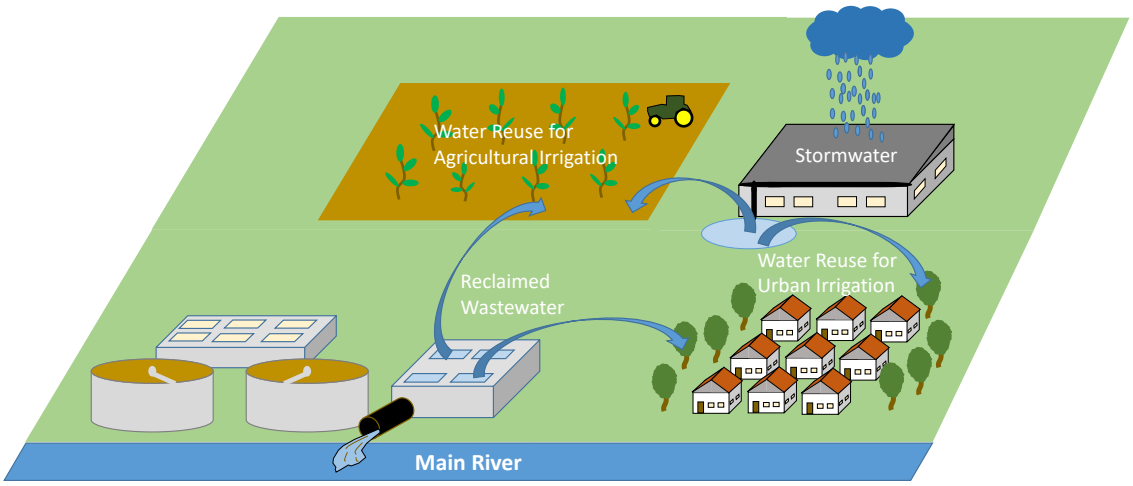

Figure 23: Water reuse concept for agricultural and urban irrigation.

In addition to the establishment of a stakeholder process, potentially usable alternative water resources as well as the agricultural and urban water demand were quantified and evaluated with regard to their potential. It has been shown that the reuse of a small proportion of the advanced treated wastewater from the wastewater treatment plant in Schweinfurt could reliably replace the entire agricultural and urban irrigation requirement. The local quarry ponds also represent substantial water reservoirs. A corresponding treatment technology could be derived likely meeting existing national, international and user-specific quality requirements. The potential reclaimed water quality generated by advanced treatment technologies (ultrafiltration combined with ozonation or powdered activated carbon) was estimated on the basis of modeling and the resulting risk originating from an irrigation application was assessed. Based on the findings from the stakeholder meetings, concepts and recommendations for the application of reclaimed water for agricultural and urban irrigation purposes were developed. Cost estimates were performed for the process adjustments and for the water reuse concepts for agricultural irrigation.

FUNDING:

GOVERNMENT OF LOWER FRANCONIA, BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION

COLLABORATION:

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

During the BMBF funded project TrinkWave, a cooperation of 12 German partners which was completed in 2020, we aimed to develop new multi-barrier treatment processes for water reuse based on sequential managed aquifer recharge technology (SMART). In addition multidisciplinary assessment and monitoring approaches have been tested to evaluate the innovative treatment process combinations for indirect potable water reuse.

Within the joint project, TUM aimed to optimize the previously established SMART concept and develop the innovative SMART*plus* technology at pilot-scale. The pilot-scale SMART*plus* bioreactor at TUM facilitates the analysis of inactivation efficiency for pathogens (especially viruses), the removal of antibiotic-resistant bacteria and genes, and the reduction of anthropogenic trace substances. Current research activities are aiming to better characterize and further optimize in-situ oxygen injection via membrane diffusion, to improve hydraulic (plug-flow) conditions in the bioreactor, and to integrate additional barriers for the establishment of a multi-barrier treatment system. Another focus is the development of an adequate process monitoring and control system for the pilot-scale bioreactor based on online monitoring parameters (dissolved oxygen, UV absorbance).

In addition, it is planned to test the application of the SMART concept at demonstration-scale in Berlin in collaboration with the Berliner Wasserbetriebe (BWB). For this purpose, the knowledge gained from the SMART*plus* operation at TUM will be incorporated into the design and implementation of the new treatment system.

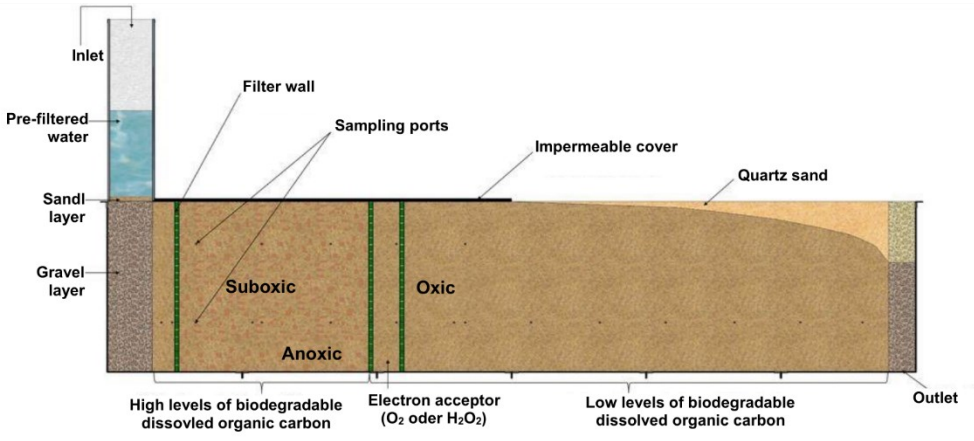

Figure 24: Schematic of the SMARTplus pilot-scale test facility at TUM.

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Reuse-Brew: Demonstration of Direct Potable Reuse for Beverage Production

Water as a resource is not everywhere available in sufficient quantity and quality. In addition, the existing water sources are increasingly under stress in many places due to increasing urbanization, climate change, agricultural and industrial activities. These challenges are forcing many water suppliers and consumers to tap new but also unconventional water resources. One potential source is municipal wastewater, which usually requires intensive treatment before reuse. On the other hand, municipal wastewater is usually available close to the actual water demand and, is mostly independent of seasonal fluctuations.

The aim and motivation of this project were 1) to demonstrate the feasibility of wastewater reuse with established technologies but also with new approaches, 2) to educate the public about water scarcity and wastewater reuse, 3) to present the current research and development work as well as available technology solutions. In order to attract more attention but also to demonstrate the actual quality of the purified wastewater, it was utilized to brew our beer (*Reuse Brew*). Following conventional treatment processes, 1) a biological denitrification, 2) a sequential biofiltration, 3) a membrane filtration and 4) an advanced oxidation process with UV light and hydrogen peroxide (UV-AOP) were applied. Finally, 4 000 L of treated water that conformed to the German drinking water ordinance could be handed over to the Chair of Brewing and Beverage Technology (TUM), where it was refined to a Bavarian pale lager (800 L).

COLLABORATION:
XYLEM SERVICES GMBH,
CHAIR OF BREWING AND BEVERAGE TECHNOLOGY

Figure 25: Water samples of the different treatment steps as well as the finished beer.

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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, food security and the 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 to test the viability of this approach. Further, such development needs to be embedded from the outset in a participatory multi-stakeholder process.

Figure 26: WEF NEXUS approach.

Figure 27: Series of international Urban Wef Nexus workshops.

The Urban WEF Nexus Research Group analyzes the interactions between the sectors water, energy and food, as well as other related sectors such as transportation and solid waste, and devises alternative future urban development scenarios to support the development of pilot projects at urban scales. The research group works in several case study locations including Leh, India; Munich, Germany; Kumasi, Ghana; and NGonga, Niger.

Leh Town is the capital of Ladakh, a semi-arid high-altitude region in the Indian Himalayas. 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 Password: wefnexusleh.

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Research Group Membrane Filtration

Membrane processes play a central role in the closure of internal water cycles, the reuse of municipal wastewater and seawater desalination. The research of the Membrane Filtration group at the Chair focuses on the mitigation of biofouling by integrating UV-LEDs into membrane modules, the combination of powdered activated carbon and ozone with ceramic ultrafiltration membranes, and the retention of microbial and chemical contaminants by high-pressure membranes.

In another BMBF project, we have been working since the end of 2018 on the question of how far unwanted biofouling on the membrane, which impairs 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 micro-organisms to positively influence the properties of the biofilm formed 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 as well as organic trace substances. The mechanisms of the retention of antibiotic resistance carriers have to be elucidated in order to guarantee a high effluent quality. Furthermore, the formation of cake 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.

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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 a 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 based on typical membrane module performance parameters, such as permeability decline and feed channel pressure drop (FCPD) increase (Figure 28). The built biofilms are extracted and analyzed for various parameters including ATP content, extracellular polymeric substance composition, and microbial diversity.

When applying an intermittent current as a 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.

FUNDING:

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

UV-EL GMBH, DELTA UMWELT-TECHNIK GMBH

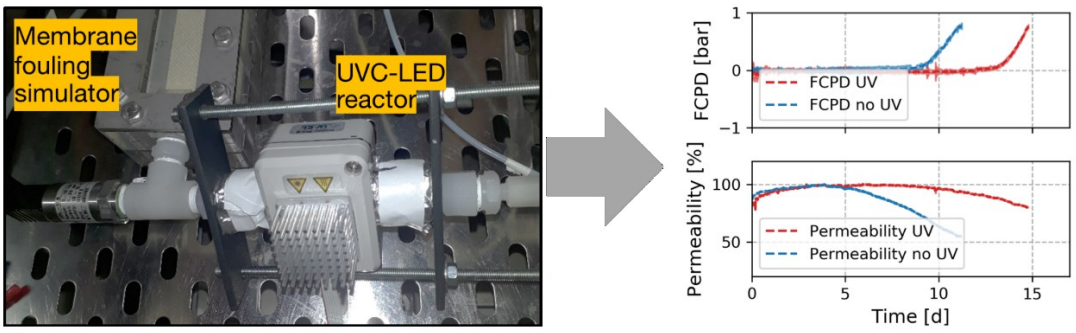

Figure 28: UVC-LED reactor attached to a membrane fouling simulator and the effects of UV pre-treatment on the feed channel pressure drop (FCPD) increase and permeability decline.

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Inline Dosing of Powdered Activated Carbon and Coagulant Prior to Ultrafiltration

The removal of pathogens, as well as trace organic chemicals (TOrCs), is important where water reuse with high water quality requirements is practiced. Hybrid membrane processes such as inline dosing of powdered activated carbon (PAC) prior to ultrafiltration membranes (UF) have already shown promising potential for the abatement of these constituents.

However, questions regarding the optimization of the operational stability by the employment of coagulation and its interferences with inline dosed PAC, have not yet been comprehensively investigated.

Within the scope of this pilot-scale study, inline dosing of PAC was combined with or without the addition of coagulant prior to UF. By the application of PAC inline dosing, significant TOrC removal could be achieved. Coagulation clearly reduced the build-up of transmembrane pressure. The operational mode of precoating the UF with coagulant combined with continuous inline dosing of PAC exhibited particularly good TOrC removal results along with optimized membrane fouling mitigation. In contrast, the simultaneous and continuous dosing of PAC and coagulant is not recommended, in particular owing to detrimental effects of the coagulant on TOrC removal efficiency by PAC.

FUNDING:

GOVERNMENT OF LOWER FRANCONIA, BAVARIAN STATE MINISTRY OF THE ENVIRONMENTAL AND CONSUMER PROTECTION

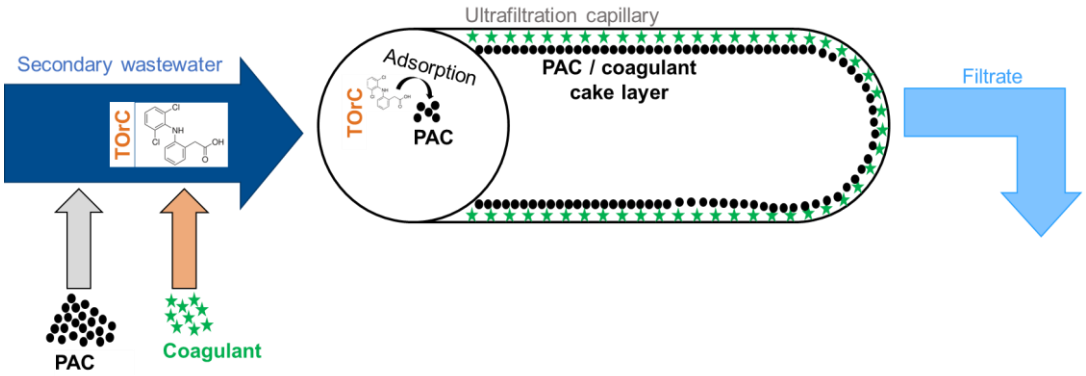

Figure 29: Hybrid membrane process PAC inline dosing prior UF.

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FUNDING:

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

Optimization of the Removal Efficiency of Antibiotic Resistant Bacteria and Antibiotic Resistant Genes by Micro- and Ultrafiltration at Municipal WWTPs

Antimicrobial resistance (AMR) has become not only a threat to human health in clinical facilities, but also an environmental challenge with regard to the spread of antibiotic resistant bacteria (ARB) and antibiotic resistance genes (ARGs) into the aquatic environment. Worldwide, antibiotics are introduced to treat bacterial infections in human and in veterinary therapy. Aquaculture uses antibiotics as growth promoters. Since humans and animals cannot completely metabolize antibiotics, large amounts of antibiotics and antibiotic resistant bacteria emitted by feces find their way into the so-called urban water cycle (wastewater/ biosolids/ manure, surface water, drinking water).

The fate of ARB and ARGs was studied within the 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 evaluate their biological or hygienic-medical relevance as well as significance in raw water for drinking water.

Studies of conventional wastewater treatment resulted in ARB and ARGs removal of 2 - 3 orders of magnitude. However, conventional wastewater treatment was not able to reduce ARB and ARGs to acceptable levels if downstream exposure to human activities could be expected.

Aim of the studies in municipal wastewater was the focus on the ARB and ARGs removal efficiencies of advanced treatment processes (ozonation, UV-irradiation and membrane filtration) resulting in reduced ARB and ARGs abundance levels in wastewater effluents.

ARB and ARGs analyses of advanced treatment processes demonstrated that membrane filtration was the most efficient technology to reduce ARB and ARGs. The focus of further examinations was on ARGs removal efficiencies of the membrane filtration process at different filtration modes (backwash and chemical enhanced backwash mode) and possible AMR-associated regrowth in filtrate.

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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. We are looking for ways to better understand microbial functions. One focus of research is the interaction and diversity of organisms within microbial biofilms with a focus on fungi and their function.

Microbes possess a number of enzymes for the degradation of all kinds of substances, ranging from high molecular weight polymers to aromatic compounds. Fungi are a group of microorganisms that produce very efficient exoenzymes that can transform difficult-to-degrade organic substances. Of particular interest are the largely unexplored aquatic fungi that could potentially be used in wastewater reactors. 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. Molecular methods are often used quantitatively (qPCR) or qualitatively (high throughput sequencing, microscopy, flow cytometry).

Figure 30: Microbial Systems Research Group.

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Drivers of Diverging TOrCs Transformation Efficiencies in Biofiltration Systems

Trace organic compounds (TOrCs) such as pharmaceuticals, personal care products, pesticides, have become emerging concerns in the aquatic environment. These anthropogenic and xenobiotic compounds are frequently detected in surface water, groundwater and even drinking water at the concentration ranging from few ng·L^{-1} to several µg·L^{-1}. Biofiltration which allows microorganisms to attach to the filter's surface and develop biofilm could become a promising technology to remove TOrCs during wastewater treatment processes, as many kinds of organic compounds are proved to be biodegradable either by direct catabolism or cometabolism. To date, the micropollutant biotransformation mechanisms, as well as the underlying drivers behind the degradation processes, remain elusive. Therefore, to uncover the "black box" researches regarding the associations between the abundance of taxa, enzymes, pathways, and TOrCs biotransformation are necessary.

In this study, six different sand materials from rapid sand filters of municipal WWTPs and two materials from slow sand filters used for water treatment were sampled, 51 TOrCs which have been typically found in municipal wastewater were spiked in the cultivation media. This study aims to improve the understanding of biotransformation mechanisms of TOrCs and to suggest novel indicators for a more comprehensive evaluation of individual or global TOrCs removal efficiencies. For this purpose, we put the eight sand filters under strictly controlled laboratory conditions, thereby excluding parameters (redox conditions, carbon and nitrogen availability, HRT) that could influence transformation rates. This leads to the exclusion of all parameters, but the microbiology, allowing us to directly link transformation rates with taxa and genes that are present during the experimental incubations. We hypothesize that differences in transformation rates will be mirrored in a differential a) microbial community and b) gene abundances. This may lead to the identification of indicator taxa, genes, or pathways for individual TOrCs.

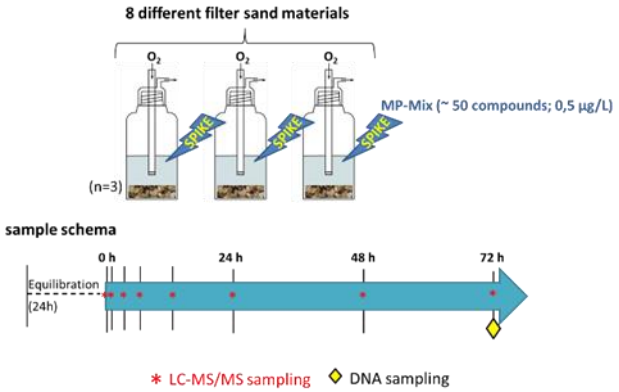

Figure 31: Batch experiment design.

FUNDING:
CHINA SCHOLARSHIP COUNCIL

COLLABORATION:
STOCKHOLM UNIVERSITY, GERMAN FEDERAL INSTITUTE OF HYDROLOGY

ALI NAWAZ

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Resolving Aquatic Fungal Dark Matter (FDM) Using Laser Dissection and Long-Read Sequencing

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. To bridge this gap between known and unknown fungi, mycologists have applied culture-independent next-generation sequencing technologies. Nevertheless, these efforts turned out to be not enough to populate the Fungal Tree of Life (FToL) with newly described fungal species.

Therefore, since April 2020 being part of the Microbial System Research Group led by Dr. Wurzbacher, my project goal is to resolve the aquatic fungal dark matter using a combined approach of laser dissection of fungal single cells and subsequent long-read third-generation sequencing of the full fungal ribosomal operon. I am working towards the establishment of a methodological platform (Eco-ACDCS: **Eco**logical **A**nnotated **C**ell **D**issection for **C**ultivation and nucleic acid **S**equencing) which will be the key to resolve the fungal dark matter in aquatic habitats. The objective is to set up a workflow that could provide results within one week period from sample dissection to the identification of the targeted fungi. Right now, we are focused on aquatic fungi but once the platform is established, we will extend the scope to other microbial eukaryotes as well.

In addition to this, I am also collaborating with a research group from IGB-Berlin to work with fungal metagenomes from two lakes in north-east Germany.

FUNDING:

GERMAN SCIENCE FOUNDATION

COLLABORATION:

LEIBNIZ-INSTITUTE OF FRESHWATER ECOLOGY AND INLAND FISHERIES, GOTHEBURG UNIVERSITY, YOKOHAMA UNIVERSITY

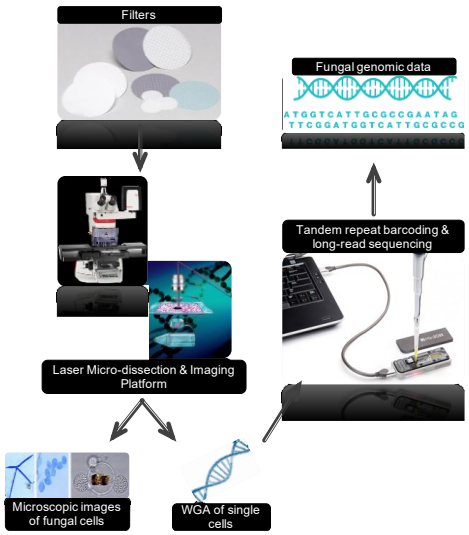

Figure 32: Methodological platform to image, dissect, whole genome amplification (WGA), and long-read sequencing of fungal single-cells collected from the filters.

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FUNDING:

GERMAN RESEARCH FOUNDATION

COLLABORATION:

BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE

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 like wastewater treatment plants (WWTPs), it is crucial to consider the fungal kingdom during investigations to understand and optimize the work with the whole microbial community. In recent studies, it became apparent that the kingdom of fungi, here commonly represented by yeasts and Cryptomycota, is abundant in WWTPs.

The superordinate objective of this study is to gain insight into the function and diversity of fungi in the aquatic environment using biofilms in down-flow hanging sponge (DHS) reactors fed with wastewater as model systems. In those trickling filter-like systems Cryptomycota appeared as dominant eukaryotic organisms. Using qPCR and ribosomal marker genes the ratio of fungi to bacteria as well as the total biofilm composition will be monitored. The interaction network between present microorganisms in the system and the functional role of fungi in the immobilized biofilms are going to be studied. Lastly, the identification of basic active enzymatic pathways of fungi in the community is intended.

To enable those examinations the development and optimization of standardized and reliable workflows for (meta-)barcoding, stable isotope labeling and metatranscriptomics of Cryptomycota are pursued.

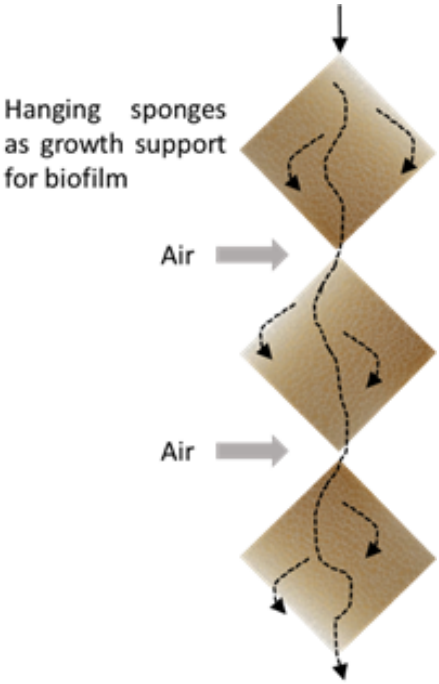

Figure 33: Concept of a DHS reactor. Ping (2010), Imperial College Press, London.

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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

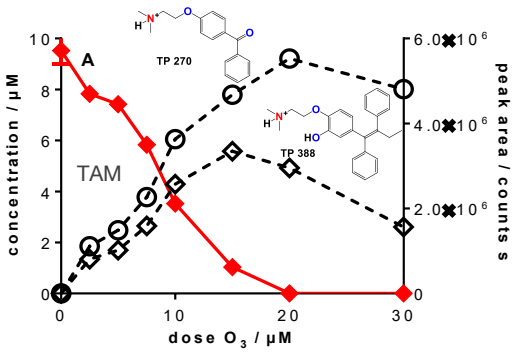

Figure 34: Left: AB Sciex QTRAP 5500 mass spectrometer for the identification of transformation products. Right: Example for the formation of transformation products during ozonation.

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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. Organic matter has a similar density to microplastics and needs to be removed via digestion methods, such as oxidation, alkaline, acidic, as well as enzymatic digestion. 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. Both hydrogen peroxide and Fenton protocols were effective at removing organic matter without affecting the seven tested microplastics (PS, PE, PP, PET, PVC, PA, and PLA) in the size range of 80 - 300 µm.

The Fenton reaction was further utilized during a sampling campaign where effluents of wastewater treatment plants (WWTPs) were sampled to determine the microplastic retention efficiency of two tertiary sand filters. 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 L for 100 µm & 50 µm filters, 200 L for 10 µm filter, as well as 2.5 L for the < 10 µm fraction.

FUNDING:
BAVARIAN RESEARCH FOUNDATION

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

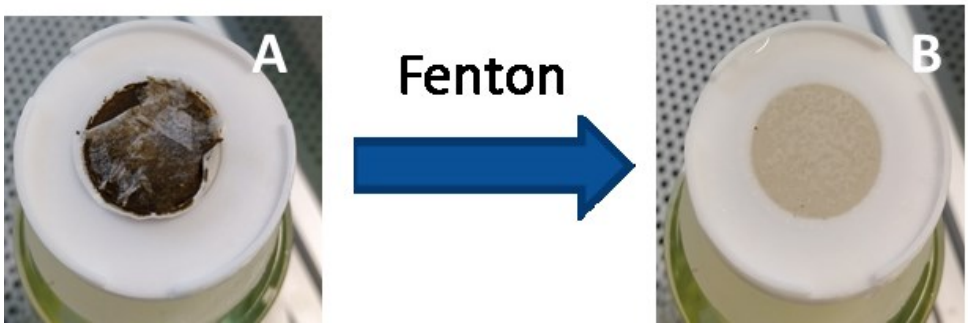

Figure 35: Efficiency of sample preparation for the removal of organic matter: A: Filtered sludge sample, B: After Fenton treatment.

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Analysis of (Sub)Microplastic Particles and Sorbed Trace Organic Chemicals with TD-Pyr-GC/MS

The focus of this work within the interdisciplinary research project "SubµTrack" is on the analysis of "submicron particles" (50 nm -100 µm) and adsorbed pollutants, such as pesticides or insecticides.

Micro-, sub micro-and nanoparticles are increasingly regarded as vectors for trace organic chemicals (TOrCs). To determine adsorbed trace organic chemicals on polymers, a complex sample preparation has usually had to be carried out. Using a newly developed method of thermodesorption-pyrolysis-gas chromatography-mass spectrometry (TD-Pyr-GC/MS) it is possible to identify adsorbed TOrCs on the particles as well as the polymers in one analytical set-up. This ensures a high sample throughput for the qualitative analysis of trace substances and polymers, as the measuring time per sample is only 2 h. First, the adsorbed substances are desorbed from the particle by thermal desorption (TD); then the polymer is fragmented by pyrolysis (PYR). Both techniques are directly coupled to the same GC-MS system that analyzes the desorbed molecules or pyrolysis products, as shown in Figure 36.

Within the scope of this method development, the trace substances phenanthrene, triclosan, and α-cypermethrin were tested on the polymers polystyrene (PS), polymethyl methacrylate (PMMA), and polyethylene (PE). Defined and additive-free particle sizes were used, including polystyrene (sub)micro (41 µm and 40 µm) and nanoparticles (78 nm) as well as PE and PMMA particles in a size of 48 µm. It could be shown that the sorption of phenanthrene (PMMA 48 µm << PS 40 µm < PS 41 µm < PE 48 µm < PS 78 nm) and α-cypermethrin (PS 41 µm < PS 40 µm < PE 48 µm < PMMA 48 µm < PS 78 nm) is strongly polymer-dependent. Triclosan adsorbed only on PE and the PS nanoparticles (78 nm).

FUNDING:

FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COLLABORATION:

BS-PARTIKEL GMBH

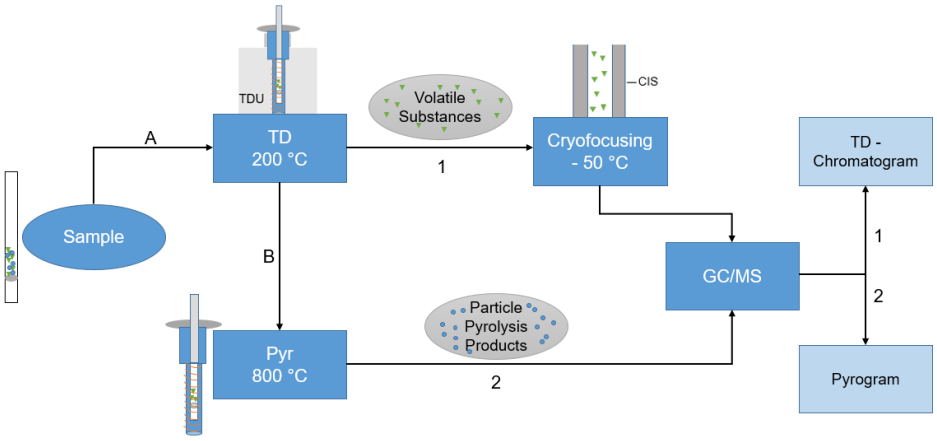

Figure 36: Flowchart TD-Pyr-GC/MS: (A) Thermodesorption of the sample (200 °C), whereby the volatile substances are desorbed (1) and cryofocused in the cold injection system (CIS, followed by a GC/MS analysis. The same sample (B) is then pyrolyzed at 800 °C (2) and introduced into the GC/MS.

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Prediction of ESI Ionization Rates with Machine Learning

The electrospray ionization ion source (ESI) is the most frequently used kind of ion source for the coupling of liquid chromatography (LC) with mass spectrometry (MS). It is a soft ion source, that allows measuring the mass-to-charge ratio of the unfragmented analyte molecule. Additionally, the high amount of solvent in the sample after the LC separation is not interfering with ESI due to its' working principle. However, a major drawback of ESI is the variation of the ionization efficiency in the range of several orders of magnitude. The ionization efficiency not only depends on the substance to be ionized but also on the measurement conditions. Therefore, a quantification with ESI always requires a reference substance even if just the estimated concentration is of interest. A possibility to predict the quantification via the ionization rate of substances measured with LC-ESI-MS would be especially useful for non-target analysis of water samples. This would allow us to rapidly identify potentially relevant compounds.

As the ESI ionization rate depends on a large number of parameters, a prediction is so far only possible to a very limited extend. To develop a method that allows the prediction of ESI ionization rates in real life, the ionization rate of a large number of different substances shall be measured in a great variety of measurement conditions. The generated data shall subsequently be used to develop and train a machine learning model that does the ionization rate prediction based only on the properties of the analyte and measurement conditions.

COLLABORATION:
THE LEIBNIZ SUPERCOMPUTING CENTRE OF THE BAVARIAN ACADEMY OF SCIENCES AND HUMANITIES

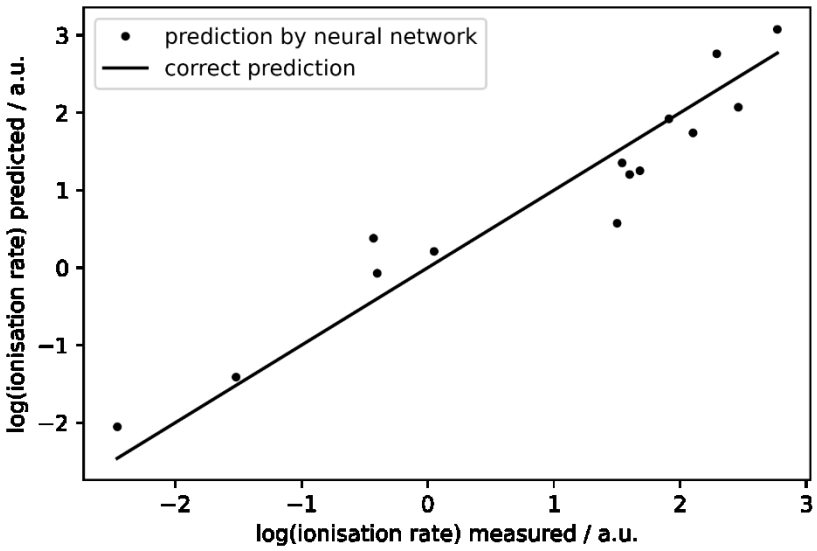

Figure 37: Predicted ionization rates of different substances using a neural network plotted against the respective measured ionization rates.

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FUNDING:

BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION

COLLABORATION:

STADTENTWÄSSERUNG WEIßENBURG, WEBER-INGENIEURE GMBH, INGENIEURBÜRO DR. RESCH + PARTNER PARTG

Advanced Wastewater Treatment in Weißenburg, Experiences from Full-Scale Operation

The installation of additional treatment barriers in municipal wastewater treatment plants is considered a viable option to mitigate the discharge of anthropogenic trace organic compounds (TOrCs) into receiving streams. In a Bavarian pilot project, the wastewater treatment plant of the city of Weißenburg was equipped with an advanced treatment unit in 2017. Here, advanced treatment consists of ozonation with subsequent filtration over sand or granular activated carbon.

Key aspects of this project which started in January 2020 are the examination of TOrC removal achieved by the advanced treatment unit in Weißenburg during regular operation, a process evaluation, and the development of recommendations for the future operation of the unit. The plant operation is evaluated via sampling campaigns and the analysis of an extended list of indicator substances and other relevant process parameters. Besides monitoring the removal capacity of the unit, also the potential for operational and economical optimization is investigated. Here, especially the optimization of the ozonation process control via the ΔUV_{254} concept is the focus of this study. To evaluate economical aspects related to the advanced treatment, costs for maintenance, and operation during regular operation are analyzed. Besides, the study assesses common process options for advanced treatment for their synergistic potential (e. g. additional removal of nutrients and COD, and improvement of the microbial water quality).

Based on the results from this study, recommendations for the design and operation of advanced treatment units at Bavarian wastewater treatment plants for the enhanced removal of TOrCs are to be derived.

Figure 38: Advanced treatment unit at the wastewater treatment plant Weißenburg.

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(DR. RER. NAT. HABIL)

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FUNDING:
BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION, EGYPTIAN MINISTRY OF HIGHER EDUCATION

COLLABORATION:
HELMHOLTZ CENTER MUNICH

Novel Analytical Strategies for Anthropogenic Compounds in Plants: Vegetable Biomonitors for Contaminants in the Environment

Plants play an important role in the maintenance of life. They provide us with food and are considered as a pool of new metabolites which can be used for treatment of various diseases and they transform carbon dioxide. Moreover it has been shown that plants are capable of cleaning the environment, i.e. mainly water, from pharmaceuticals like diclofenac. The project presented here will focus on the plant metabolite pathways, the involved enzymes and the resulting transformation products. In addition, wether the pollutant change the plant biosynthesis cycle and wether the pollutants can push the biosynthesis cycle in specific direction by generating a lot of substrates to specfic pathway. Consequently, plants can get the pollutants into its biosynthesis cycle.

Thus, our major goal was to figure out whether the biological degradation pathways can be reflected by the analytical data obtained from polarity extended RPLC-HILIC-MS analysis. The aim of the project presented here is to provide a conceptual theoretical framework based on analysis of different plant extracts before and after exposure to different pollutants using novel RPLC-HILIC-ToF-MS technique. The project conducted using Metabolomics approach. Metabolomics will assist in the establishment of a deeper understanding of the complex interactive nature of plant metabolic networks and their responses to environmental changes. The metabolomics approach has the following steps; First, extraction method validated which will be applicable to extended-polarity chromatography analysis via target and non-target screening. Second, dataset interperte to invistigate the changes in plants metabolites and pathways changes behind them through statistical stratgies. Finally, the open access database PLANT-IDENT was filled with more than 3,000 biogenic compounds, and can already be used on the open access FOR-IDENT platform since July 2019 for free, to identify ‘known unknowns’ and/or suspects.

Further details can be found on https://water.for-ident.org/#!home. Rofida’s doctoral thesis is supervised at TUM by Jörg Drewes and Thomas Letzel (guest of the chair).

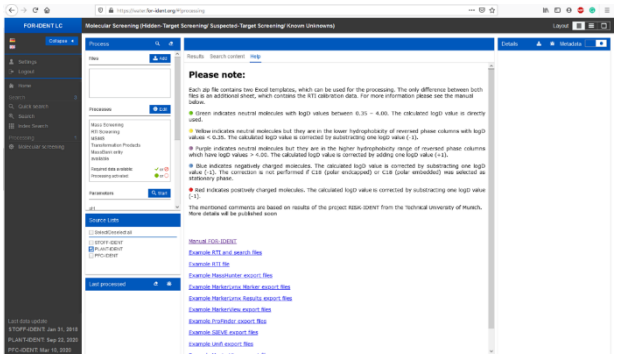

Figure 39: Screenshot of Plant-Ident open access platform.

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External Doctoral Candidates

Polar Trace Organic Compounds in The Danube River

In the course of the fourth "Joint Danube Survey" we analyzed 51 samples of the Danube river and its tributaries, especially for polar trace organic compounds of anthropogenic origin. The samples were measured using a serial coupling of hydrophilic interaction chromatography (HILIC) and reversed-phase liquid chromatography, coupled to a QTOF mass spectrometer with an electrospray ionization source (ESI).

The samples were measured and evaluated according to the "non-target screening" strategy. During each measurement, a broad mass range was screened in full scan mode.

Lists of candidate molecules were extracted from the raw data, grouped, and filtered. In this study, candidates which eluted from the HILIC column were considered, since they are most likely polar and therefore have a log D value < 0.

Using the candidate lists, the compound database STOFF-IDENT as part of the FOR-IDENT platform was queried for potential substances. Of all the proposed substances, those with a log D < 0 were further considered. These proposed substances were then further prioritized and categorized according to the probability of occurrence in the samples as well as the availability and quality of fragment spectra. This approach allowed molecular candidates to be identified with an increased level of confidence before the appropriate reference standards were purchased and measured.

Susanne Minkus is an external Ph.D. student and works at AFIN-TS GmbH. Her doctoral thesis is supervised by Jörg Drewes and PD Dr. Thomas Letzel (guest of the chair).

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

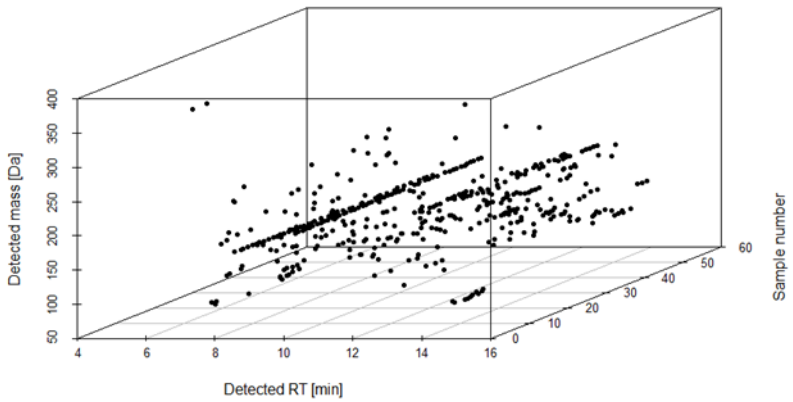

Figure 40: The molecular candidates, described by their mass and retention time (RT), are plotted on the XY plane. The samples are plotted on the Z-axis. The figure shows that some candidates appear over long stretches of the Danube.

HANNA ULRICH

(DIPL.-GEOÖK.)

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Identification and Behavior of Polyfluorinated Precursors in the Environment

Due to chemical policy restrictions for long-chain perfluorinated substances, an increasing number of per- and polyfluorinated substitutes are used in industrial and consumer products. Often neither the chemical structure nor analytical standards and methods are available allowing to analyze these substances. The objective of this work is to use different approaches to get information about the polyfluorinated precursors in the aquatic environment.

The total concentration of per- and polyfluorinated substances (PFASs) in the aquatic environment can be detected with the TOP-assay (Total Oxidizable Precursor Assay). Thereby the unknown polyfluorinated precursors are converted to the measurable perfluoroalkylic acids by oxidation. By comparing the fluorine concentration measured by the TOP assay with the fluorine concentration of the known PFASs compounds (detected with the analytical standard method) the part of the unknown PFASs can be estimated. The TOP-assay is validated for the different matrices ultrapure water, soil eluates, and wastewater.

The Non-Target- and Suspect-Screening-Analysis are used for the identification of unknown or suspected substances in water samples. The exact mass of the molecules in a sample can be determined with high resolution and accurate LC-MS/MS. Subsequently suspected screening lists, substance and spectrum databases can be used to get proposals for the unknown substances. The substance database 'PFC-IDENT' was built up within the project and so far, includes more than 4.600 substances. It can be used on the FOR-IDENT platform. First environmental samples were analyzed by high resolution and accurate LC-MS/MS and are evaluated with this platform and databases.

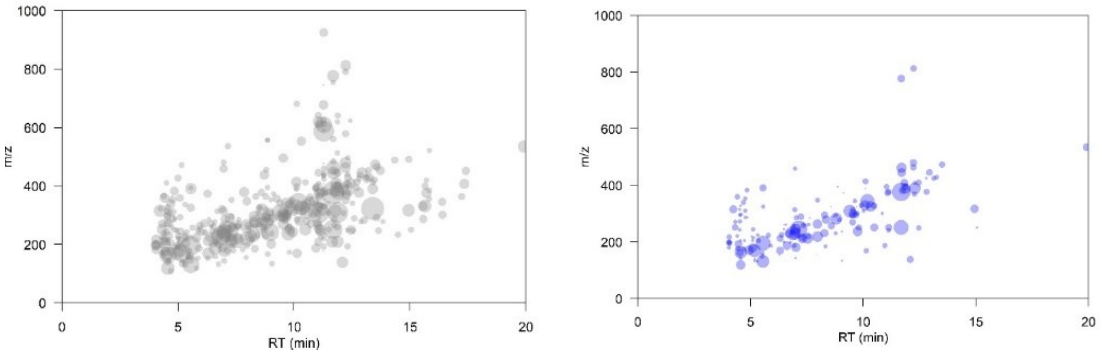

Figure 41: Substances detected in a surface water sample by high resolution mass spectrometry (left) and reduction to probably fluorinated substances (right).

COLLABORATION:
BAVARIAN ENVIRONMENT AGENCY

Hanna Ulrich is external Ph.D. student and works at the Bavarian Environment Agency. Hanna's doctoral thesis is supervised at the TUM by Jörg Drewes and Thomas Letzel (guest at the chair).

RENATO LIGUORI

(M.SC.)

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Visiting Scientists

Renato Liguori is a biotechnologist specialized in biochemistry with a strong interest in bioinformatics investigating the potential usage of microbial communities for the treatment of contaminated sites. His Ph.D. thesis takes place at the University Parthenope, Napoli, Italy, supervised by prof. Vincenzo Pasquale.

At TUM he is a guest scientist of the Microbial Systems group and his research focuses on investigating the degradation potential of eight different sand filter materials under defined incubation conditions in collaboration with the BfG. The study aims to shed light on the different transformation rates of a diverse range of treatment plants. The hypothesis is that individual microbial community members and/or individual genes are responsible for the transformation process. This will be resolved by analysing the microbial community composition and its metagenomes.

In addition, Renato Liguori is investigating the microbial communities of decentralised treatment systems for urban street runoff. This study will examine the so far unknown microbial communities of the treatment systems system. In particular, we will investigate how the microbiology may influence the retention of pollutants such as heavy metals or antibiotic resistance genes.

International Cooperation Partners

Last year, we further expanded our international partner network (Figure 42).

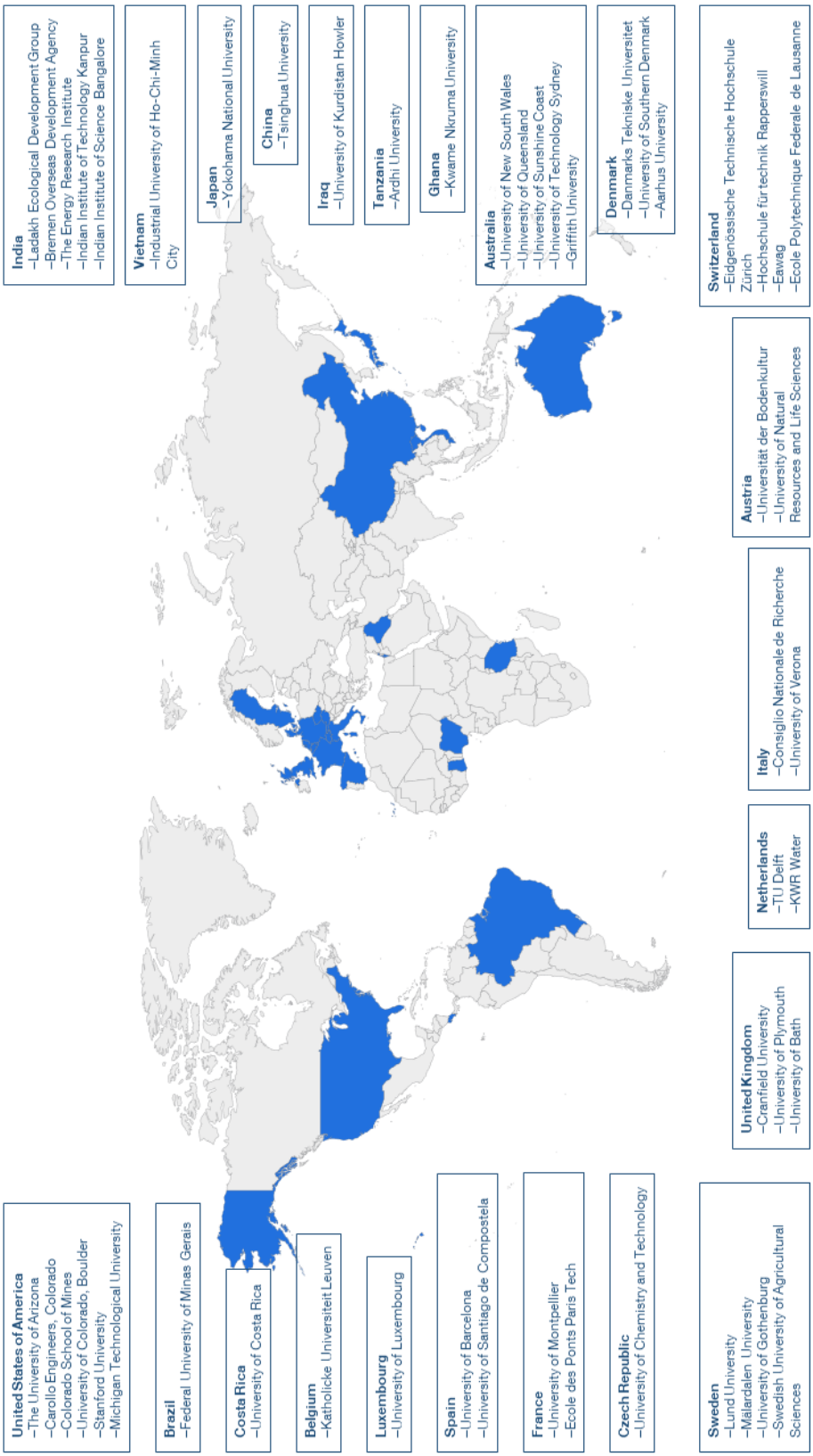

Figure 42. International partners.

National & International Committees

German Advisory Council on Global Change (WBGU)

Jörg E. Drewes has been appointed by the German government to the WBGU for the term 2020-2024. The interdisciplinary advisory council with 9 members provides orientation for political decision-makers on the complex interplay of global environment and development problems. Prof. Drewes is supported in his work for the WBGU by Christoph Schwaller as a personal advisor.

DFG-Fachkollegium

Jörg E. Drewes is currently a member of section 318 „*Water Research*" of the German Science Foundation (DFG), where he represents the area of water chemistry and urban water system engineering.

DWA Working Groups

Brigitte Helmreich is the spokesperson of the **DWA Working Groups ES-3.1** "*Percolation of Rainwater*" and **ES-3.11** "*Multifunctional areas*" and a member of the DWA Committee of Experts **ES-3** "*Plant-Related Planning*", where she the deputy chairman.

She is currently active in various working groups of the DWA for the revision of the **DWA-A 138** "*Planning, construction and operation of plants for infiltration of rainwater*" (ES-3.1) and the new leaflets **DWA-M 179** "*Decentralized plants for rainwater treatment*" (ES-3.7) and **DWA-M 194** *"Multifunctional areas"*. In addition, she is an active member of the **DWA Technical Committee IG-2** "*Sector-specific Industrial Waste Water and Waste*" and of the Working Group **IG 2.4**. "*Wastewater from the starch industry*".

Jörg Drewes is involved in the **DWA Technical Committee KA-8** "*Advanced Wastewater Treatment*", in the **DWA Working Groups Biz 11.4** "*Water Reuse*" and **KA-8.1** "*Anthropogenic Substances in the Water Cycle*".

Uwe Hübner is an active member of the **DWA Committee of Experts KA-8.5** "*Ozonation at Wastewater Treatment Plants*".

German Water Chemistry Society

Uwe Hübner is actively involved in the expert committees "*Transformation processes in biological wastewater treatment and wastewater reuse*" and "*Oxidative processes*" of the **German Water Chemistry Society**. The groups develop status papers that summarize the current state of knowledge on biological degradation 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 Chemistry Society**. The group develops the current state of knowledge and perspectives in dealing with pathogens in the water cycle.

Expertengremium Wasserzukunft Bayern 2050

Jörg E. Drewes has been appointed to the expert panel "*Water Future 2050*" by the State Government of the State Government of the Free State of Bavaria.

International Committees

Jörg Drewes is active in the Strategic Council of the **International Water Association** as the representative of the Specialist Groups.

Journals – Editors

Jörg Drewes continues to serve as Associate Editor of *ACS Environmental Science & Technology Water*, severed as associate editor of the Journal of Water Reuse and Desalination. Additionally, and is member of the Editorial Board of *Environmental Technology Reviews.*

Konrad Koch was a guest editor of the journal Water for a special issue on "Biomethane Potential Tests - A Key Tool for Anaerobic Digestion Rese-arch and Practice".

Brigitte Helmreich was a guest editor of the journal *Water* for a special issue on "*Rainwater Management in Urban Areas*".

Christian Wurzbacher is special editor of the journals *MycoKeys* and *Biodiversity Data Journal*.

Ali Nawaz is Associate Editor of *Frontiers in Fungal Biology*.

Workshops & Other Activities

The **Roland Mall Foundation** presented four 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 2020. The students (**Julia Degenhart**, **Simeon Schaller**, **Kevin Fokkens,** and **Magdalena Knabl**) were selected based on their previous accomplishments.

Young Water Reuse Professionals (YWRP)

Staff members of the chair under the leadership of Dr.-Ing. Sema Karakurt-Fischer were in the year 2020 also involved in the Young Water Reuse Professionals (YWRP) group of the IWA Water Reuse Special Group (WRSG), which was founded in 2015. The aim is the international networking of "young scientists" among each other as well as the exchange with "senior scientists" and industry representatives in the field of water recycling. The activities include the support of platforms and structures for mutual exchange (IWA Connect), WRSG Newsletter and participation in the planning of the IWA Water Reuse Specialist Conferences.

Interested parties please contact Dr.-Ing. Sema Karakurt-Fischer: sema.karakurt@tum.de

Sciencecyclists

In 2020, we collectively biked over 37,497 kilometers to and from the chair. This equates to 5.4 tons of CO_2 saved in comparison to an average car, and 14.2 tons of CO_2 in comparison to an economy flight. We aim to increase overall and individual contribution in 2021!

Upcoming Events

31st Water Technical Seminar, March 3rd, 2021: New challenges for the drinking water treatment by perfluorinated compounds (PFAS)? – ONLINE

Based on the new toxicological assessment of per- and polyfluorinated alkyl substances by the European Food Safety Authority (EFSA) and the implementation of a range of PFAS into the European Drinking Water Directive, the relevance of the PFAS group increased strongly. Due to their high mobility and persistence, these compounds can distribute in the environment and cannot be easily removed using conventional drinking water treatment techniques. Hence, this group of compounds can therefore threaten the supply of safe drinking water.

In our seminar, we want to give an overview on the new insights on PFAS concerning the new toxicological assessment and new limit values for drinking water. These new limit values bring along new analytical and technical challenges. Finally, we want to present new technical solutions and give an outline of the consequences for polluted regions.

The event is held in German.

The registration form can be found here: http://www.bgu.tum.de/sww/wts31/

Programm

08:30 Uhr Öffnung der Online-Plattform

09:00 Uhr **Begrüßung, Nettiquette und Einführung**
Prof. Dr.-Ing. Jörg E. Drewes,
TU München

Themenblock: PFAS in der Umwelt
Moderation: Prof. Dr. Jörg E. Drewes

09:15 Uhr **Perspektive des UBA zur Relevanz von PFAS im Trinkwasser**
Dr. Camilla Beulker
Abt. II.3, Umweltbundesamt

09:35 Uhr **PFAS-Bestandsaufnahme im bayerischen Trinkwasser**
Dr. Holger Knapp
Bayerisches Landesamt für Gesundheit und Lebensmittelsicherheit

09:55 Uhr **Diskussion**

Themenblock: Toxikologie und Risikobewertung
Moderation: Prof. Dr. Jörg E. Drewes

10:10 Uhr **Human-Toxizität von PFAS, neue Erkenntnisse**
Dr. Michael Schümann
Behörde für Gesundheit und Verbraucherschutz, Hamburg
Human Biomonitoring Kommission

10:30 Uhr **Ableitung von Leitwerten und GOWs für Trinkwasser**
Dr. Alexander Eckhardt
FG II 3.6, Umweltbundesamt

10:50 Uhr **Diskussion**

11:20 Uhr Mittagspause

Themenblock: Analytik von PFAS, Herausforderungen und Lösungsansätze
Moderation: Dr. Oliver Knoop

11:50 Uhr **Analyse nach revidierter EU Trinkwasserrichtlinie: Summe PFAS und PFAS Gesamt**
Frank Thomas Lange
TZW Karlsruhe

12:20 Uhr **Einzelstoffanalytik und Nachweisgrenzen**
Alexander Kämpfe
FG II 3.2, Umweltbundesamt

12:50 Uhr **Diskussion**

Themenblock: Geeignete Aufbereitungsverfahren zur Entfernung von PFAS aus dem Trinkwasser
Moderation: Dr. Oliver Knoop

13:05 Uhr **Konventionelle Verfahren für die Trinkwasseraufbereitung**
Prof. Dr.-Ing. Jörg E. Drewes
Lehrstuhl für Siedlungswasserwirtschaft, TU München

13:25 Uhr **Innovative Verfahren für die Trinkwasseraufbereitung**
Thomas Lippert & Nebojsa Illic
Lehrstuhl für Siedlungswasserwirtschaft, TU München

13:55 Uhr **Erfahrungen aus der Region Baden-Baden & Rastatt**
Peter Riedinger
Stadtwerke Baden-Baden

14:15 Uhr **Diskussion**

14:30 Uhr **Schlusswort**
Prof. Dr. Jörg E. Drewes,
TU München, Garching

48th Wastewater Technical Seminar (WWTS) on July 14th, 2021

Currently, cities are experiencing above-average growth. In numerous urban centers, there are already pronounced densifications and a significant reduction of inner-city green spaces. From a water management point of view, this poses a major challenge to near-natural rainwater management. At the same time, the frequency, duration, and intensity of extreme weather events such as heavy rainfall and heat waves are increasing in the face of climate change, leading to regular overloading of the sewer system and increasing summer heat stress. This requires an urban planning rethink and the development of urban infrastructure that serves both the regulation of hot and heavy rainfall. The seminar aims to shed light on urban water management in times of climate change from different perspectives, discussing the needs of the inhabitants and the feasibility and affordability of water-sensitive urban development. The focus will also be on the changes to the DWA regulations for the discharge of rainwater runoff from paved areas into ground and surface waters.

The registration form can be found here: https://www.bgu.tum.de/sww/ats/

Programm

09:15 Uhr **Begrüßung und Einführung**
Prof. Dr. Brigitte Helmreich,
TU München

Themenblock: Einführung
Moderation: Prof. Dr. Brigitte Helmreich

09:30 Uhr **Leben in der Stadt der Zukunft – Wie beeinflusst der Klimawandel unsere Städte**
Prof. Dr. Matthias Garschagen
Ludwig-Maximilian-Universität München, München

10:00 Uhr **Starkregenvorsorge im Städtebau und in der Bauleitplanung**
Stefan Brückmann
Ramboll Studio Dreiseitl, Überlingen

10:20 Uhr **Diskussion**

10:40 Uhr **Kaffeepause und Besichtigung des Ausstellerforums**

Themenblock: Herausforderung Klimaanpassungen
Moderation: Prof. Dr. Brigitte Helmreich

11:10 Uhr **Klimaanpassung in der Bauleitplanung – Umgang mit Niederschlagswasser**
Werner Norgauer, BBI Ingenieure, Regensburg

11:30 Uhr **Überflutungsnachweise für Grundstücke im urbanen Raum - Gefährdungspotentiale erkennen und beseitigen**
Daniel Hoedemacker
GFM Bau und Umweltingenieure GmbH, München

11:50 Uhr **Wirtschaftlichkeit wassersensibler Stadtentwicklung – Kosten und Mehrwert alternativer Regenwasserbewirtschaftungsmaßnahmen**
Dr. Nadine Gerner
Emschergesnossenschaft/Lippeverband, Essen

12:10 Uhr **Diskussion**

12:25 Uhr **Mittagspause und Besichtigung des Ausstellerforums**

Themenblock: Neue Regelwerke
Moderation: Prof. Dr. Jörg E. Drewes

14:00 Uhr **Regenwasserversickerung nach dem neuen DWA-A 138 ins Grundwasser – Was ist neu?**
Prof. Brigitte Helmreich,
Lehrstuhl für Siedlungswasserwirtschaft, TU München, Garching

14:20 Uhr **Das neue DWA-A 102 – Zukünftige Anforderungen für das Einleiten von Regenabflüssen in Oberflächengewässer**
Bernd Haller
Regierungspräsidium Karlsruhe, Karlsruhe

14:40 Uhr **Der Wasserhaushalt in der Stadt der Zukunft – neue Regelungen in DWA-A/M 102 für Neubau- und Sanierungsgebiete**
Prof. Mathias Uhl,
FH Münster, University of Applied Science, Münster

15:00 Uhr **Diskussion**

15:15 Uhr **Kaffeepause und Besichtigung des Ausstellerforums**

Themenblock: Planung auf engem Raum
Moderation: Prof. Dr. Jörg E. Drewes

15:45 Uhr **Anforderungen an die Regenwasserbewirtschaftung im urbanen Raum aus Sicht des Betreibers**
Dr. Maximilian Huber
Münchner Stadtentwässerung, München

16:10 Uhr **Dezentralen Behandlungsanlagen als platzsparende Alternative? Praxiserfahrungen**
Steffen Rommel,
Lehrstuhl für Siedlungswasserwirtschaft, TU München, Garching

16:30 Uhr **Diskussion**

16:45 Uhr **Schlusswort**
Prof. Dr. Jörg E. Drewes,
TU München

Publications

Peer-reviewed journal articles

1) Al-Azzawi, M.S.M; Kefer, S.; Weißer, J.; Reichel, J.; Schwaller, C.; Glas, K.; Knoop, O.; Drewes, J.E.: Validation of sample preparation methods for microplastic analysis in wastewater matrices – reproducibility and standardization. Water 12, 2020, 2445.
2) Astals, S.; Koch, K.; Weinrich, S.; Hafner, S.; Tait, S.; Peces, M.: Impact of storage conditions on the methanogenic activity of anaerobic digestion inocula. Water 12, 2020, 1321.
3) Bandelin, J.; Lippert, T.; Drewes, J.; Koch, K.: Assessment of sonotrode and tube reactors for ultrasonic pre-treatment of two different sewage sludge types. Ultrasonics Sonochemistry 64, 2020, 105001.
4) Bandelin, J.; Lippert, T.; Drewes, J.E.; Koch, K.: Impact of high flow rates and increased viscosity of digested sewage sludge on the cavitation intensity in ultrasonic tube reactors. Chemical Engineering and Processing - Process Intensification 152, 2020, 107925.
5) Bartonitz, A.; Anyanwu, I.N.; Geist, J.; Imhof, H.K.; Reichel, J.; Graßmann, J.; Drewes, J.E.; Beggel, S.: Modulation of PAH toxicity on the freshwater organism *G. roeseli* by microparticles. Environmental Pollution 260, 2020, 113999.
6) Friedman L.;Mamane H.;Chandran K.; Jekel M.; Cikurel H.; Hübner U.; Elgart M.; Dagan S.; Santo-Domingo J.; Avisar, J.: Stimulating nitrogen biokinetics with the addition of hydrogen peroxide to secondary effluent biofiltration. Clean Technologies 2, 2020, 53-73.
7) Hafner, S.D.; Fruteau de Laclos, H.; Koch, K.; Holliger, C.: Improving inter-laboratory reproducibility in measurement of biochemical methane potential (BMP). Water 12, 2020, 1752.
8) Heim, C.; Rajab, M.; Greco, G.; Grosse, S.; Drewes, J.E.; Letzel, T.; Helmreich, B.: Fate of Diclofenac and Its Transformation and Inorganic By-Products in different water matrices during electrochemical advanced oxidation process using a boron-doped diamond electrode. Water 12, 2020, 1686.
9) Horstmeyer, N.; Thies, C.; Lippert, T.; Drewes, J.E.: A hydraulically optimized fluidized bed UF membrane reactor (FB-UF-MR) for direct treatment of raw municipal wastewater to enable water reclamation with integrated energy recovery. Separation and Purification Technology 235, 2020, 116165.
10) Huber, M.; Athanasiadis, K.; Helmreich, B.: Phosphorus removal efficiency at municipal wastewater treatment plants in Bavaria – a case study. Environmental Challenges 1, 2020, 100008.
11) Juottonen, H.; Fontaine, L.; Wurzbacher, C.; Drakare, S.; Peura, S.; Eiler, A.: Archaea in boreal Swedish lakes are diverse, dominated by Woesearchaeota and follow deterministic community assembly. Environmental Microbiology, 22, 2020, 3158–3171.
12) Karakurt-Fischer, S.; Bein, E.; Drewes, J.E.; Hübner, U.: Characterizing a novel in-situ oxygen delivery device for establishing controlled redox zonation within a high infiltration rate sequential biofilter. Water Research 182, 2020, 116039.
13) Karakurt-Fischer, S.; Sanz-Prat, A.; Greskowiak, J.; Ergh, M.; Gerdes, H.; Massmann, G.; Ederer, J.; Regnery, J.; Hübner, U.; Drewes, Jörg E.: Developing a novel biofiltration treatment system by coupling high-rate infiltration trench technology with a plug-flow porous-media bioreactor. Science of The Total Environment 722, 2020, 137890.
14) Koch, K.; Hafner, S.; Weinrich, S.; Astals, S.: Evaluation of common supermarket products as positive controls in biochemical methane potential (BMP) tests. Water 12, 2020, 1223.
15) Koch, K.; Hafner, S.D.; Weinrich, S.; Astals, S.; Holliger, C.: Power and Limitations of Biochemical Methane Potential (BMP) Tests. Frontiers in Energy Research 8, 2020.
16) Lippert, T.; Bandelin, J.; Schlederer, F.; Drewes, J.E.; Koch, K.: Effects of ultrasonic reactor design on sewage sludge disintegration. Ultrasonics Sonochemistry 68, 2020, 105223.

17) Magalhães, N.C.; Silva, A.F.R.; Cunha, P.V.M.; Drewes, J.E.; Amaral, M.C.S.: Role of nanofiltration or reverse osmosis integrated to ultrafiltration-anaerobic membrane bioreactor treating vinasse for the conservation of water and nutrients in the ethanol industry. Journal of Water Process Engineering 36, 2020, 101338.

18) Mulugeta, S.; Helmreich, B.; Drewes, J.E.; Nigussie, A.: Consequences of fluctuating depth of filter media on coliform removal performance and effluent reuse opportunities of a bio-sand filter in municipal wastewater treatment. Journal of Environmental Chemical Engineering 8, 2020, 104135.

19) Peces, M.; Pozo, G.; Koch, K.; Dosta, J.; Astals, S.: Exploring the potential of co-fermenting sewage sludge and lipids in a resource recovery scenario. Bioresource Technology 300, 2020, 122561.

20) Pecson, B.; Gerrity, D.; Bibby, K.; Drewes, J.E.; Gerba, C.; Gersberg, R.; Gonzalez, R.; Haas, C.N.; Hamilton, K.A.; Nelson, K.L.; Olivieri, A.; Rock, C.; Rose, J.; Sobsey, M.: Editorial Perspectives: will SARS-CoV-2 reset public health requirements in the water industry? Integrating lessons of the past and emerging research. Environmental Science: Water Research & Technology 6, 2020, 1761-1764.

21) Reichel, J.; Graßmann, J.; Letzel, T.; Drewes, J.E.: Systematic development of a simultaneous determination of plastic particle identity and adsorbed organic compounds by thermodesorption–pyrolysis GC/MS (TD-Pyr-GC/MS). Molecules 25, 2020, 4985.

22) Rommel, S.H.; Gelhardt, L.; Welker, A.; Helmreich, B.: Quantification of settling velocity decrease of road-deposited sediment at low temperatures and de-icing salt application. Water 2020, 12, 3126.

23) Rommel, S.H.; Noceti, L.; Stinshoff, P.; Helmreich, B.: Leaching potential of heavy metals from road-deposited sediment and sorptive media during dry periods in storm water quality improvement devices. Environmental Science: Water Research & Technology 6, 2020, 1890-1901.

24) Sari, M.A.; Oppenheimer, J.; Robinson, K.; Drewes, J.E.; Pisarenko, A.; Jacangelo. J.: Persistent contaminants of emerging concern in ozone-biofiltration systems: analysis from multiple studies. American Water Works Association Water Science 2, 2020, 1-19.

25) Schwaller, C.; Keller, Y.; Helmreich, B.; Drewes, J.E.: Estimating the agricultural irrigation demand for planning of non-potable water reuse projects. Agricultural Water Management 244, 2021, 106529.

26) Silva, A.F.R.; Magalhães, N.C.; Martelli Cunha, P.V.; Amaral, M.C.S.; Koch, K.: Influence of COD/SO_4^{2-} ratio on vinasse treatment performance by two-stage anaerobic membrane bioreactor. Journal of Environmental Management 259, 2020, 110034.

27) Silva, A.F.R.; Ricci, B.C.; Koch, K.; Weißbach, M.; Amaral, M.C.S.: Dissolved hydrogen sulfide removal from anaerobic bioreactor permeate by modified direct contact membrane distillation. Separation and Purification Technology 233, 2020, 116036.

28) Sperle, P.; Wurzbacher, C.; Drewes, J.E.; Skibinski, B.: Reducing the impacts of biofouling in RO membrane systems through in-situ low fluence irradidation employing UVC-LEDs. Membranes 10, 2020, 415.

29) Vega-Garcia, P.; Schwerd, R.; Scherer, C.; Schwitalla, C.; Helmreich, B.: Development of a model for stormwater runoff prediction on vertical test panels coated with plasters and mortars. Water 12, 2020, 2593.

30) Vega-Garcia, P.; Schwerd, R.; Scherer, C.; Schwitalla, C.; Johann, S.; Rommel, S.H.; Helmreich, B.: Influence of façade orientation on the leaching of biocides from building façades covered with mortars and plasters. Science of The Total Environment 734, 2020, 139465.

31) Wagner, M.; Eicheler, C.A.E.; Helmreich, B.; Hilbig, H.; Heinz, D.: Removal of congo red from aqueous solutions at hardened cement paste surfaces. Frontiers in Materials Structural Materials 7, 2020, 567130.

32) Wahman, R.; Graßmann, J.; Sauvêtre, A.; Schröder, P.; Letzel, T.: *Lemna minor* studies under various storage periods using extended-polarity extraction and metabolite non-target screening analysis. Journal of Pharmaceutical and Biomedical Analysis 188, 2020, 113362.

33) Wurzbacher, C.; Kreiling, A.K.; Svantesson, S.; Van den Wyngaert, S.; Larsson, E.; Heeger, F.; Nilsson, R.H.; Pálsson, S.: Fungal communities in groundwater springs along the volcanic zone of Iceland. Inland Waters, 2020, 418-427.

34) Zhiteneva, V.; Hübner, U.; Medema, G.J.; Drewes, J.E.: Trends in conducting quantitative microbial risk assessments for water reuse systems: a review. Microbial Risk Analysis, 2020, 100132.

35) Zhiteneva, V.; Ziemendorf, É.; Sperlich, A.; Drewes, J.E.; Hübner, U.: Differentiating between adsorption and biodegradation mechanisms while removing trace organic chemicals (TOrCs) in biological activated carbon (BAC) filters. Science of the Total Environment 743, 2020, 140567.

Other journal articles and book contributions

1) Dandikas, V.; Lebuhn, M.; Post, M.; Fritz, M.; Koch, K.: Biogasausbeuten - Erklärung verschiedener Methoden und Tests. In: Biogas Forum Bayern, Hrsg. ALB Bayern e.V, www.biogas-forum-bayern.de/bif16, 2020.
2) Duarte, S.; Wurzbacher, C.; Seena, S.: Metabarcoding of litter-associated fungi and bacteria. In: Methods to Study Litter Decomposition (pp. 339-346). Springer, Cham., 2020.
3) Helmreich, B. Umgang mit Regenabflüssen von Metalldächern. Ratgeber Regenwasser, 8. Auflage 2020, S. 16-17.
4) Helmreich, B.; Rommel, S.: Dezentrale Behandlung von Straßenabflüssen im urbanen Raum – wohin geht die Reise? Zeitschrift für Straßenverkehrstechnik, 2020.3, 154-158.
5) Seena, S.; Duarte, S.; Wurzbacher, C.: A bioinformatics primer for the analysis of illumina MiSeq data of litter-associated fungi and bacteria. In Methods to Study Litter Decomposition. Springer, Cham., 2020, 573-582.
6) Spieler, M.; Muffler, L.; Drewes, J.E.: Wasserrechtliche Rahmenbedingungen der Wasserwiederverwendung in Deutschland. Teil 1: Rechtliche Grundlagen. Korrespondenz Abwasser 67(12), 2020.
7) Weinrich, S.; Astals, S.; Hafner, S.; Koch, K.: 8.11 Kinetic modelling of anaerobic batch tests. Collection of Methods for Biogas - Methods to determine parameters for analysis purposes and parameters that describe processes in the biogas sector (ISBN: 978-3-946629-47-4), Deutsches Biomasseforschungszentrum gemeinnützige GmbH (DBFZ), Leipzig, 2020, p. 349-369.

Conferences (Oral Presentations)

1) Astals, S.; Justesen, C.G.; Mortensen, J.R.; Thorsen, R.; Koch, K.; Weinrich, S.; Triolo, J.M., Hafner, S.D.: Low-cost gas density biochemical methane potential (BMP) method. Latin American Meetings on Anaerobic Digestion, 29. October 2020, online, 2020.
2) Drewes, J.E.: Plastik, Mikroplastik...unersetzbar, aber unzersetzbar. Akatech Forum am 11.02.2020 in München (Vortrag), 2020.
3) Helmreich, B.: Das neue DWA-A 138. Regenwassertage der DWA, 16. Juni 2020, Videokonferenz, 2020.
4) Helmreich, B.: Einsatz modular aufgebauter technischer Anlagen mit DIBt-Zulassung zur Behandlung von Niederschlagswasser. Seminar „Wohin mit dem Niederschlagswasser? - Regenwasserbewirtschaftung von der Planung zur Praxis" am 19.02.2020 in Nürnberg (Vortrag), 2020.
5) Helmreich, B.: Technische Regelwerke – das Arbeitsblatt DWA-A 138. Seminar „Wohin mit dem Niederschlagswasser? - Regenwasserbewirtschaftung von der Planung zur Praxis" am 19.02.2020 in Nürnberg (Vortrag), 2020.

Theses

Doctoral dissertations

1) Karakurt-Fischer, Sema: Development and validation of a novel treatment concept for planned potable reuse based on sequential managed aquifer recharge technology for more sustainable water management. 04.12.2020.
2) Strübing, Dietmar: H_2/CO_2 biomethanation in anaerobic thermophilic trickle bed reactors - Development of a flexible and efficient energy conversion technology. 11.02.2020.
3) Zhiteneva, Veronika: Mitigating risk in water reuse systems by enhancing biofiltration with sorptive media. 18.12.2020.

Master's theses

1) Ahmadi, Mohammad: Effect of organic polymers on ultrafiltration PES membranes – a comprehensive lab-scale study at different artificial water matrices.
2) Alipour Tesieh, Zahra: Natural treatment system as an approach for the development of a decentralized wastewater treatment pilot in Leh town, India with a focus on hybrid constructed wetlands.
3) Arivalagan, Akshaya: Use of Mecoprop as a pesticide in the construction industry - Application, occurrence and environmental relevance.
4) Awais, Usama: Effects of varying OLR on VFAs composition and methane productivity in CO_2 enriched anaerobic digestion of sewage sludge.
5) Bayram, Berfin: Life Cycle Assessment of LUQEL Water Station Excellence - Quantitative Analysis of Environmental Impacts and Suggestions for Improvements.
6) Bissinger, Moritz: Evaluation of the nitrification performance of three trickling bed reactors operated at the Garchinger wastewater treatment plant and measures to increase the efficiency as a basis for reducing the ammonium load in the outflow.
7) Bui, Huang: Design and dynamic modeling of wastewater treatment system for paper mill using recycled paper as raw materials: A case study in Binh Duong – Vietnam.
8) Chauhan, Simran: Fluorescence staining and tracking of microplastic particles in a synthetic wastewater treatment plant effluent.
9) Dorape Witharanage, Dinithi Bhagya Amarawardana: Coupling fungal degradative capacities with photosynthesis wastewater treatment process.
10) Heck, David: Impact assessment of CO_2-enriched Inoculum on biomethane potential of sewage sludge using two different batch test methods: gravimetric and manometric.
11) Hsu, Hsin-yu: Genotoxicity removal of ciprofloxacin by a subsequent treatment of ozonation and biofiltration.
12) Khatri, Himani: Investigation of CNT-coated ceramic membranes and their filtration efficiency for the treatment of hard-to-treat industrial wastewater.
13) Kuzmichev, Nikita: Deammonification in industial wastewater treatment.
14) Lenert, Charlotte: Comparison of Trace Organic Chemical Removal in Biofilters Treating Municipal Wastewater Treatment Plant Effluent.
15) Liao, Kuan-Po: Biodegradation of the artificial sweetener acesulfame in wastewater treatment plants.
16) Linziakina, Polina: Optimization of wastewater treatment process: application of kieselgur at cardboard production.
17) Liu, Dan: Occurrence, removal efficiency, and health risk assessment of 5 trace organic chemicals in a potable water reuse scheme.

18) Lutz, Jannik: Groundwater quality assessment within the catchment area of Wolaita Sodo, Ethiopia - First Phase of the Clean Water Project Sodo.
19) Manghabati, Hamed: Rehabilitation and structural concept for the water supply system of the municipality Kulmain.
20) Mayerl, Michael: Enhancement of the water balance of alpine mountain huts through alternative saniation systems.
21) Meola, Alberto: Intermittent micro-aeration in Anaerobic Digestion (AD): determination of optimal oxygen quantity for maximum methane yield through Machine Learning.
22) Nguyen, Anh Thang: The effect of enzyme supplementation on the acidogenesis of papermaking process water.
23) Ottinger, Ida: Resource efficiency in the automotive industry. Optimizing the recycling and disposal of plastic waste from production using the example of three assembly lines.
24) Prechtl, Leonhardt: Development of an effect oriented analytical method by coupling of a neurotoxicity assay with LC-MS.
25) Rainer, Andreas: Assessment and improvement of CO_2 mass transfer and bioconversion efficiency in CO_2 enriched anaerobic digestion of sewage sludge.
26) Renner, Sebastian: Investigations on the retention of microplastics in the activated sludge of laboratory wastewater treatment plants.
27) Rieder, Patrick: Establishment of a measurement method for nanoplastic particles with the ZetaView Nano-Tracking Analyzer and the investigation of the effects of different treatment procedures on nanoparticles.
28) Rodriguez Ramirez, Juan: Hazard characterization of water reuse: Development of a Bayesian network for trace organic chemical removal within a potable reuse treatment train.
29) Ruf, Anastasia: Modeling of waterworks, pumping stations and wastewater treatment plants in the strategic asset management considering the risk development.
30) Schmelzig, Helene: Limits and potential of the Coupled Aerobic-Anoxic Nitrous Decomposition Operation (CANDO).
31) Schmidt, Jonas: Monitoring of microplastics in a laboratory scale wastewater treatment plant via fluorescence tagging.
32) Schmidt, Nicolas: On-line turbidity measurement in a decentralized storm water quality improvement device - Data processing, analysis and design of possible practice-orientated applications.
33) Schmuck, Alexandra: Assessing the effects of controlled redox zonation on the trace organic chemical biotransformation in a pilot scale SMARTplus bioreactor under the supply of oxygen via gas/liquid membrane contactors.
34) Schott, Sebastian: Characterization of particulate matter in road runoff.
35) Shahrour, Mahmoud: Time series generation for hydropower based on flow models. Case Study: Danube.
36) Shehata, Omar: Characterization of a pulsed flow-through UVC-LED reactor and the impact of fluence rate on microbial disinfection.
37) Souf, Amr: Assessing the applicability of sequential biofiltration hybrid systems in treatment schemes for water reuse.
38) Stinshoff, Philipp: Sequential extraction of heavy metals from retained road-deposited sediment and prestressed sorptive filter media of stormwater quality improvement devices.
39) Tessaro, Gloria: Dynamics of microbial adaptation to aniline and to acetate as single growth substrate.
40) Thoma, Mario: Effects of vapothermal pre-treatment of anaerobic degradability of reeds.
41) Weihofen, Björn: Status analysis of the Bavarian sewer system 2018.

Study projects

1) Akhimova, Elizaveta: A review on the hybrid systems of UF, MF combined with O_3 and PAC, with the focus on removal efficiencies of micropollutants including pharmaceuticals and antibiotic resistant bacteria.
2) Betianu, Radu Mihai: Pilot study on the viral load of Munich's wastewater streams.
3) Bui, Hung: Modelling the removal of anthropogenic DBP precursors from swimming pool water by a Hybrid PAC-UF process using AQUASIM Software.
4) Del Rio Melo, Julio: Treatment of highly nitrogen-rich industrial wastewater.
5) Etchechury Gomez, Gerónimo Agustín: In-situ bubbleless oxygen introduction for sequential biofiltration system for water reuse.
6) Fianelli, Francesco: DemoMeth: Gas Utilization Proposal.
7) Franco Pereira, Lucas Cesar: Review of water tariff effectiveness and recommendations for Leh town, Ladakh, India.
8) Geelani, Rameez Ahmad: High quality DNA extraction from water fungi for long read sequencing.
9) Hernandez Robles, Gabriel: Operation of a continuous anaerobic digester with ultrasonication as co-treatment for digested sludge.
10) Hsu, Hsin-yu: Establishing an extraction method for the umu-Assay to screen the genotoxicity of sediments of traffic area runoff.
11) Janicek, Maximilian: Renovation concept as a pilot project for two main sewer systems.
12) Kim, Erin: Fundamental mass transfer analysis of oxygen and ozone delivery to groundwater.
13) Liu, Yu Chen: Performance evaluation of sludge sonication.
14) Lowicki, Maximilian: Ultrasonic sludge pre-treatment in a wastewater treatment plant in full-scale operation.
15) Marhoon, Ahmed: Modeling the transport of biocides in the unsaturated zone using the general conditions of the joint research project "Sickerwasserprognose".
16) Nay, Vongvichra: Sustainability study for drinking water ultrafiltration in rural deployment.
17) Páez-Curtidor, Natalie: Reuse Brew Project – Advanced wastewater treatment for direct potable reuse and beer production.
18) Schmuck, Alexandra: Construction and operational optimization of an in-situ electron acceptor introduction device to deliver oxygen to a pilot scale sequential managed aquifer recharge technology (SMARTplus).
19) Tessaro, Gloria: Assessing the effects of changing operational conditions on the biofilm of the sand taken from SMARTplus bioreactor.
20) Uchaikina, Anna: Investigation of anticoagulant removal by ozonation and adsorption on granulated activated carbon.
21) Weidner, Jonas: Analysis, interpretation and evaluation of a long-term groundwater monitoring in greater Munich.
22) Zhang, Boyang: Mapping local climate zones in the Brussels capital region by using Sentinel-2 imagery with Random Forest classifier in QGIS.

Bachelor's theses

1) Ackermann, Leopold: Investigation of the removal of rodenticides in biological wastewater treatment using a batch experiment.
2) Bergmann, Felix: Efficiency of advanced wastewater treatment operations: ozonation, granular activated carbon, powdered activated carbon.
3) Busse, Lilian: Occurrence of Microplastic in German Surface Waters.
4) Duraku, Erzen: Groundwater remediation using membrane-based in-situ gas introduction – implementation and effectivity.
5) El Khodary: Impact of in-situ UVC feed stream disinfection on the microbial diversity of biofilms formed in reverse osmosis (RO) processes.
6) Gunelj, Karlo: Vibration as Mechanical Antifouling Strategy for Membrane Filtration – An Overview of the State of the Art of Science and Technology.
7) Henkes, Felix: Effects of the corona virus on the environment.
8) Jung, Aaron: Microbiological aspects of traffic area runoff.
9) Lange, Kim: Quantitative and qualitative assessment of stormwater runoff for agricultural irrigation purposes in Northern Franconia.
10) Lehrer, Clara: Qualitative assessment of stormwater collected via roof areas for agricultural irrigation purposes.
11) Marson, Jeff: The possible central role of vitamin B12 (cobalamin) in the cometabolism of microbial communities in the breakdown of micropollutants.
12) Mraz, Christina: Suspendability of microplastics in different solutions and continuous dozing in a laboratory scale wastewater treatment plant.
13) Pöll, Lisa: Compounds of emerging concerns in European water cycle.
14) Püttmann, Enno: Water Safety Plan Opportunities for the High-Altitude City of Leh, Ladakh, India.
15) Rojas Sonderegger, Thomas: Use of geographic information to support decision-making for a sustainable development of Leh town, India.
16) Rösch, Barbara: Optimization of Sorption Experiments with Trace Substances on Micro- and Nanoplastic Particles Focusing Storage Conditions.
17) Schill, Rebecca: Energy efficiency of wastewater treatment plants in Tunisia - A comparison of anaerobic digesters and solar panels based on the example of the WWTP Kairouan II.
18) Stein, Sebastian: Insect protein production - A contribution to the search for alternative protein sources for sustainable human and animal nutrition.
19) Stern, Benedikt: Oxygenation in activated sludge basins - investigation of various influencing factors on oxygenation with pressure ventilation systems.
20) Straub, Julian: Occurrence and fate of TOrCs in wastewater treatment plants.
21) Vandewiele, Michiel: The Nitrogen Uptake and Assimilation in Constructed Wetland Plants - Data Acquisition for PLANT-IDENT.
22) Weise, Kilian: Optimization of a system for the determination of the biochemical methane potential.

Dissertations and Awards

Congratulations to **Dr.-Ing. Dietmar Strübing** for successfully defending his dissertation, titled ‚H_2/CO_2 biomethanation in anaerobic thermophilic trickle bed reactors - Development of a flexible and efficient energy conversion technology' on Febrary 28th, 2020. His committee members included Prof. Largus T. Angenent (University of Tübingen), Prof. Lars D. M. Ottosen (Aarhus University, Denmark) and Herrn Prof. Jörg E. Drewes.

Figure 43: Dissertation committee of Dr.-Ing. Dietmar Strübing

Figure 44: Dissertation committee of Dr.-Ing. Sema Karakurt-Fischer

Congratulations to **Dr.-Ing. Sema Karakurt-Fischer** for successfully defending her dissertation, titled ‚Development and validation of a novel treatment concept for planned potable reuse based on sequentially managed aquifer recharge technology for more sustainable water management' on December 4th, 2020. Her committee members included Associate Prof. Sung Kyu (Andrew) Maeng (Sejong University, Seoul, South Korea), Prof. Christian Griebler (University of Vienna, Austria) and Prof. Jörg E. Drewes.

Congratulations to **Dr.-Ing. Veronika Zhiteneva** for successfully defending her dissertation, titled ‚*Mitigating risk in water reuse systems by* enhancing *biofiltration with sorptive media'* on December 18th, 2020. Her committee members included Prof. Dr. Martin Elsner (TUM, Chair of Analytical Chemistry and Water Chemistry), Prof. Dr. Gertjan Medema (Delft University of Technology, Netherlands) and Prof. Jörg E. Drewes.

Figure 45: Dissertation committee of Dr.-Ing. Veronika Zhiteneva

Teaching

The Chair of Urban Water Systems Engineering offers a wide range of different courses for the Bachelor's 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 2020, the following lectures were offered:

Summer Term

Bachelor

- Grundlagen Ökologie: Knoop, Oliver
- Mikrobiologie: Wurzbacher, Christian
- Thermodynamik und Energietechnik: Hübner, Uwe
- Thermodynamik und Energietechnik Übung: Hübner, Uwe
- Projektkurs Siedlungswasserwirtschaft: Drewes, Jörg
- Umweltanalytik: Knoop, Oliver
- Umweltrecht: Spieler Martin (external lecturer)

Master/PhD

- Advanced Water Treatment Engineering and Reuse: Drewes, Jörg
- Anaerobic Treatment and Energy Recovery: Koch, Konrad
- Industrieabwasserreinigung und Wiederverwertung: Helmreich, Brigitte
- Bewirtschaftung von Kanalnetzen und Regenwassermanagement: Helmreich, Brigitte
- PhD Seminar SiWaWi: Drewes, Jörg; Koch, Konrad
- Wastewater Treatment: Koch, Konrad
- Planning the Urban Water-Energy-Food Nexus: Keilman-Gondhalekar, Daphne
- Doktoranden und Masteranden Kolloquium – Proaktiv: Drewes, Jörg; Helmreich, Brigitte; Koch, Konrad, Hübner, Uwe; Knoop, Oliver; Wurzbacher, Christian; Keilman-Gondhalekar, Daphne
- Application of Urban Climate: Katzschner, Lutz (external lecturer)

Winter Term

Bachelor

- Grundlagen Verfahrenstechnik: Böhm, Bernhard (external lecturer); Koch, Konrad
- Verfahrenstechnik Übung: Böhm, Bernhard (external lecturer); Koch, Konrad
- Siedlungswasserwirtschaft Grundmodul: Helmreich, Brigitte; Koch, Konrad

Master/PhD

- Water and Wastewater Treatment Engineering: Drewes, Jörg
- Engineered Natural Treatment Systems: Hübner, Uwe
- Hydrochemistry: Helmreich, Brigitte
- PhD Seminar SiWaWi: Drewes, Jörg; Koch, Konrad;
- Sanitation in the Global South: Al-Azzawi, Mohammed; Bein, Emil; Feickert Fenske, Carolina; Lippert, Thomas; Muntau, Meriam; Sierra Olea, Millaray; Sperle, Philipp
- Technical Communication Skills in Water and Wastewater Treatment: Drewes, Jörg; Koch, Konrad
- Modelling of Aquatic Systems: Koch, Konrad
- Planung und Betrieb von Kläranlagen: Athanasiadis, Konstantinos (external lecturer); Böhm Bernhard (external lecturer)
- Aquatic microbiology: Wurzbacher, Christian
- Planungs- und Genehmigungsverfahren nach deutschem und europäischem Wasserrecht (external lecturer)
- Statistisch-stochastische Prognosen des baulich-betrieblichen Zustands von Entwässerungssystemen: Raganowicz, Andrzej (external lecturer)
- Doktoranden und Masteranden Kolloquium – Proaktiv:Drewes, Jörg; Helmreich, Brigitte; Koch, K., Hübner, Uwe; Knoop, Oliver; Wurzbacher, Christian; Keilman-Gondhalekar, Daphne

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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.

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- 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.

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

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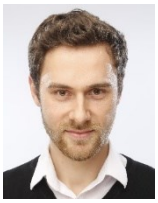

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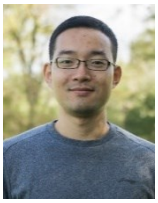

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