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Newsletter of the Chair of Urban Water Systems Engineering

ANNUAL REPORT OF THE CHAIR OF URBAN WATER SYSTEMS ENGINEERING

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Foreword

Dear Friends,

With this issue, I am pleased to present our annual report 2019. The past year was characterized by a very busy research agenda including preparing and securing several new grant proposals, the organization of two national and one international events, and some changes in our staff and related adjustments.

The staff of the chair continued to be highly dedicated in publishing their research findings in peer-reviewed international journals and delivering talks at national and international conferences. We are especially happy for Dr. rer. nat. Karin Hellauer, Dr.-Ing. Nils Horstmeyer and Dr.-Ing. Johann Müller for the successful completion of their doctorate degrees last year. We are also proud of Dr.-Ing Max Weißbach, who was awarded the 2019 Willy-Hager Prize for his dissertation. In particular, we are happy for Prof. Dr. Christian Wurzbacher, who secured an award for an Emmy-Noether Research Group funded for six years by the German Science Foundation (DFG). This is a highly competitive program in support of young scientists offering financial support to head an independent research group in preparation for a subsequent professorship. Finally, Philipp Sperle, one of our graduate students, received the H.P. Scholz Award 2019 for his Master's thesis. We congratulate you all once again!

In the past year, seven new doctoral students joint the chair, and they introduced themselves along with their fellow colleagues in this annual report. In 2019, we continued to enjoy the direct exchange of visiting scholars from Australia, China, Italy, Nepal, Brazil, the Czech Republic, and the United States, some of whom visited us for several months. Building upon the fruitful discussions, we are looking forward to further developing these connections through ongoing and future joint research activities and visits.

After a few years of pause, we organized the 30th Water Technology Seminar (WTS) last February focusing on 'Strategies in Dealing with Groundwater Contamination by Perfluorinated Chemicals' at the Oskar-von-Miller Forum in Munich. This is a topic area of increasing interest not only in Bavaria but globally. More than 100 participants enjoined excellent talks and fruitful discussions. The 30th WTS was prepared by Dr. Oliver Knoop. In July 2019, we successfully held the 47th Wastewater Technology Seminar (ATS) with the topic of 'Advanced Wastewater Treatment - Requirements, Financing and Implementation' in Ismaning organized by Dr. Uwe Hübner. We are now gearing up for the 48th ATS scheduled for July 15th, 2020 in Ismaning. This ATS is organized by Prof. Brigitte Helmreich and will address 'Stormwater Management *in lieu* of Climate Change'. You can find more information about this event in this annual report and on our website. Registration for this event is also already open (www.sww.bgu.tum.de/). We would be very pleased to see you at this event.

Also in the past year, the team made significant contributions to our 'core business' - the education of students in the Bachelor's programs of Environmental Engineering and Civil Engineering, as well as in the Master's degree programs of Environmental Engineering, Civil Engineering, Environmental Planning and Engineering, as well as

Sustainable Resources Management. In addition to a large number of lectures, exercises and lab sessions, we advised a total of 108 Bachelor's and Master's theses and study projects.

In the international arena, our students and staff helped organizing the 12th International Conference on Water Reclamation and Reuse of the International Water Association (IWA) in June 2019 in Berlin. More than 400 delegates from across the world participated in this event, which was held in Germany for the first time. Nationally, our staff members have been involved in several working groups of the DWA, the German Water Chemistry Society as well as internationally in the NORMAN Network and IWA. In October, the elections were held for representatives of the different science sectors of the German Science Foundation (DFG). With support from many colleagues, I am happy to report that I have been elected to represent the 'Water and Wastewater Engineering' and 'Water Chemistry' sectors in the panel 318 'Water Research' during the working period 2020-2023. As representative of the Specialist Groups, I was also elected to serve on the Strategic Council of the International Water Association.

The year 2019 also brought some changes in our leadership. Dr. Susanne Petz took over the head of our Chemistry Laboratory in February 2019. Unfortunately, Dr. Bertram Skibinski, who led the research group 'Membrane Filtration' decided to leave us in November 2019.

On behalf of all my employees, I am very grateful for your continued support and interest in our students and our work. We are also particularly thankful for the support from our sponsors. These contributions are making a difference in the training of our doctoral and graduate students by offering travel support and small research grants.

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-size 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. Beside 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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Treatment of high salinity industrial wastewaters

Biological treatment requires nutrients and trace chemicals
Wastewater from industrial plants often has high salt concentrations, which, if composed unilaterally, affect biological treatment. For the discharge of waste water, depending on the amount of waste water, minimum requirements must be observed, especially with regard to COD and nitrogen.

Carbon removal
Biodegradability studies show that degradation rates of > 80% can be achieved in carbon degradation (COD), even at salt concentrations of 30 g/L and inhibitions (after off-house) of less than 1%. In the current project, the treatment of wastewater from an industrial laundry plant, more than 90% of COD could be degraded, even at 4 % inhibition, a salt concentration of ~ 10 g/L and a COD load of 2.6 g/(m³ d). However, according to the ion analysis, various additives had to be dosed into the homogeneous wastewater during chemical-physical pretreatment. Anaerobic treatment with more than 5 gCSB/L could also be economically feasible, as was demonstrated with the "Automatic Methane Potential Test System".

Nitrogen removal
In a further project dealing with the removal of nitrogen from highly saline industrial wastewater after anaerobic pretreatment, one- and two-stage process options were tested.
The first stage (nitritation) showed stable operation at 32 °C, achieving > 50% NH_4-N oxidation at ~ 10 g/L salt (conductivity 26 mS/cm) and 3 g/L nitrogen in the influent. However, after 25 weeks of measurement, no stable operating conditions could be achieved in the second stage (anammox), which showed 150 gN(m³ d) nitrogen degradation and 80% nitrogen degradation. In contrast, in a single-stage SBR at a load of about 230 gN(m³ d), 90% of the nitrogen could be reduced in an operationally stable manner.

The COD of this industrial wastewater was only ~ 30% degradable, and at the low COD/NH_4-N ratio of < 0.2, the microbes were stabilized by a low dosage of a carbon source. The results of the N_2O measurements showed only slightly measurable N_2O concentrations in the single-stage treatment in the SBR, whereas in the first stage with permanent aeration, concentrations thirty times greater were seen. Accordingly, it can be assumed that the difference of up to 20% of the nitrogen balance is emitted as N_2O gas during nitritation.

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 (since 02/2019), the trace compounds analysis unit led by Dr. Oliver Knoop and the microbiological laboratory led by Dr. Christian Wurzbacher.

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

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

The characterization and identification of organic molecules from aqueous samples with trace compounds analysis (target screening) can be carried out using chromatographic separation techniques coupled to highly sensitive mass spectrometric detection techniques (LC-MS/MS). Volatile organic compounds as well as particles originating from micro plastics can be detected with the help of headspace-GC/FID and a thermal desorption-pyrolysis-GC/MS, respectively.

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

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

New devices: in 2019, we expanded our laboratories with some high quality new acquisitions and exchanged old devices.

Physicochemical laboratory

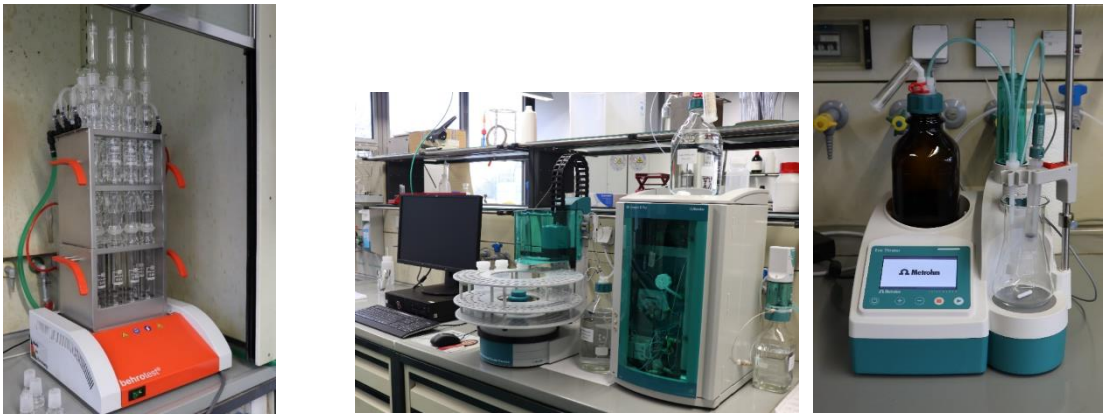

Figure 5: CSB/SMA 12 L by Behr; Center: Ion chromatography system 930 IC Compact Flex with 858 Professional Sample Prozessor by Metrohm; Right: Eco Titrator Acid/Base by Metrohm

Trace compounds analysis

Figure 6: Left: 1260 Infinity-LC-System by Agilent; Right: ZETAVIEW® Basic NTA by Particle Metrix

Microbiological laboratory

Figure 7: Left: DeNovix QFX Fluorometer; Right: Infinite M Plex Plate Reader by Tecan

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Research Group Drainage Systems

The research group drainage systems headed by Prof. Dr. med. 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 8: Traffic area runoff in winter

The research group also deals with strategies for the assessment and rehabilitation of sewer systems. Maintaining the efficiency of the drainage system is crucial to ensuring sanitation, so periodic assessment of the status of the sewer system is essential. For this reason, based on a 2012 study, a survey and evaluation of the status of the sewage system is being carried out on behalf of the Bavarian State Office for the Environment. Likewise, in 2019 master theses were carried out to predict the need for restoration of the sewage system.

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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 pollution and temporary pointemissions (accident/construction site/event) the traffic area runoff can be polluted heavily to some extent with heavy metals or organic substances.

Figure 9: Testing facility for traffic area runoff treatment

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.

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

The objective of the research project is 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 will be performed for 2 years. The emergence of hazardous substances and their detention and remobilization under the influence of deicing salts and long-lasting impounding are studied. Operational aspects are recorded and analyzed. Additionally, insufficiently investigated substances, including gasoline additives (MTBE/ETBE), cyanides contained in deicing salts, and fine particles are monitored.

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BAVARIAN ENVIRONMENT AGENCY;
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Complexation behavior of biocides and metals in urban stormwater runoff

Trace organic component in building runoff like biocides are getting more and more attention, considering their wide application in urban area. Among which mecoprop, diuron, OIT and terbutryn are frequently detected in urban catchment at µg/L degree. Besides that, according to a study carried out in Freiburg, Germany, the concentration of biocides in groundwater were found to increase after a rain event. Which means potential direct contact of humans to biocides with a long exposure time. In addition to biocides, copper and zinc ion are typical contaminants in roof runoff especially for roofs made out of metal. The effect of coexistence of these two kind of contaminants in stormwater is still unclear, and therefore, needs to be investigated in further studies.

The objective of this study is to use state-of-the-art technologies to analyze the formation of complexes of biocides and heavy metals with organic compounds. Meanwhile, the mechanism of complexation are elucidated and a cost-effective treatment strategy is established.

To achieve the objectives, analytical methods like EEM, FTIR and HPLC-MSMS analysis will be applied in the research. For EEM analysis, Aqualog will be used to collect the data of fluorescence intensity of each contaminant in different conditions, the changes can be used to evaluate the interaction between different contaminants. After EEM analysis, samples are prepared for FTIR analysis. Through FTIR, functional groups that play a role in complexation can be recognized and complexation mechanism can be explained. In the end, HPLC-MSMS analysis will be used to quantify biocides in tests to establish an appropriate treatment strategy.

Figure 10: Biocides inhibit unwanted organisms on building facades

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COUNCIL

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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 11: Specimens of outdoor leaching tests in Fraunhofer-IBP (Valley, Germany)

In order to achieve this overall objective, four 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. Preparation of a mass transport model. This model is intended to simulate the propagation of substances relevant to the environment in soil and in groundwater using a geological flow.
4. Preparation of a proposal for the evaluation of material releases on basis of a transfer function, possibly incorporating existing modeling approaches.

FUNDING:
FRAUNHOFER INSTITUTE FOR BUILDING PHYSICS

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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 conditions 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 Bavarian public sewer systems in 2018 on the basis of various criteria. The estimation of the need for restoration and the resulting costs as well as an examination of 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 will be 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 are 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 12: Example of a sewer system

FUNDING:
BAVARIAN STATE MINISTRY OF THE ENVIRONMENT

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Feasibility of water reclamation for agricultural and urban reuse in Northern Franconia, Germany

The increasing trend of urbanization and climate change impacts have significant consequences for drinking water supply and sanitation worldwide. In particular, the impact of climate change on water resource availability in regions that have not been characterized yet by a lack of freshwater supplies could be overcome by approaches including water reclamation and reuse.

Northern Franconia, Germany is a region with less than 450 mm annual precipitation and is traditionally characterized by limited water resources and increasingly competing water demands in the recent past by the agricultural sector, industrial/commercial needs, public drinking water supply, and maintaining ecological base flows. Impacts from climate change will further aggravate this situation.

Therefore, the aim of this study is to assess the feasibility of long-term water reclamation for agricultural and urban reuse in this region in order to expand the conventional water resource portfolio.

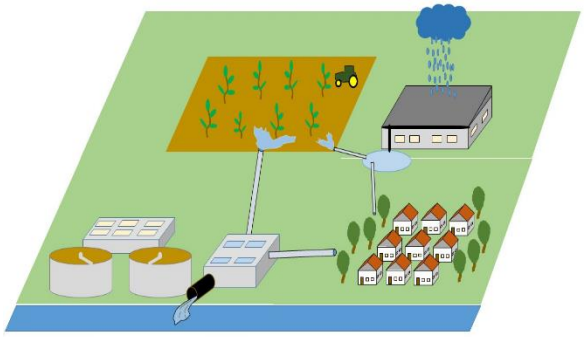

Figure 13: Case study area for water reuse

The study is launched with a comprehensive evaluation of available wastewater and stormwater run-off quantities that could potentially be reclaimed and treated centrally or decentrally to provide fit-for-purpose water qualities for various reuse applications. During the kick-off of this study, a stakeholder group was established with representatives from the user community, farm associations, wastewater utilities, drinking water providers, regulatory agencies, and environmental groups. Based on requirements that were elaborated within the stakeholder group four case study areas representing urban landscape and agricultural irrigation were identified. For these study areas, the local demand but also sources of reclaimed water but also stormwater run-off are specified. Given the seasonality of the demand, flexible and modular treatment options are desired. Treatment options for the various applications favored secondary treated effluent quality followed by powdered activated carbon addition, ultrafiltration, and UV disinfection.

FUNDING:
GOVERNMENT OF UPPER FRANCONIA

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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

In agriculture, the elements phosphorous (P) and nitrogen (N) are essential for plant nutrition. Nitrogen, in the form of ammonia and after nitrification as nitrate, is available to plants, increasing the risk of its loss via leaching, which contributes to groundwater quality deterioration. In contrast, the P-content in the soil is mostly immobilized. One consequence of this is that particle transport (erosion) causes P to be displaced from the soil surface, leading to the eutrophication of water bodies.

In recent years, so-called nitrification inhibitors have been developed, which can stabilize the ammonium phase of a fertilizer for 4 to 6 weeks to mitigate loss.

There is initial evidence that spatial proximity of ammonium, the nitrification inhibitor, and sparingly soluble phosphate in the fertilizer or soil could generate further benefits, namely better recovery of sparingly soluble P compounds. However, the detailed knowledge about the reaction mechanisms, also in connection with so-called biostimulants, are still largely missing.

An important aspect is the use of the pH dependence of the P-supply in the soil solution (optimally pH 5 to 6.5).

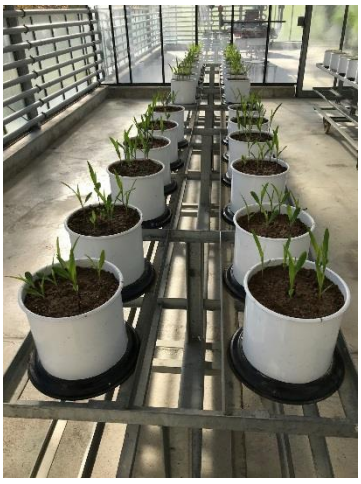

Figure 14: Greenhouse experiments with corn (Zea mays) and oilseed rape (Brassica napus) plants in different soils

Three overall economically and ecologically relevant goals can be achieved through this research:

1. The use of previously poorly plant available P;
2. The reduction of P-reserves in soils and, associated surface water pollution by leaching; and
3. The use of alternative P-sources to achieve partial closure of the P-cycle.

COOPERATION:
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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 own 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. Our investigations have shown that economical operation is only possible when treating with a relatively low specific energy input of <500 kJ/kg_{TS}. The comparison scenario also plays an important role, i.e., to what extent investment and operating costs alone have to be compensated by savings, or whether the ultrassound-induced accelerated degradation can, for example, supersede the construction of another digester.

Interestingly, the anaerobic digestion process can also be stimulated by CO_2 enrichment. While this phenomenon has been observed in many studies already, evidence of the underlying processes is still missing.

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 (e.g., from biogas) into methane to be stored. Biofilm-based technologies under thermophilic conditions have proven to be suitable particularly under dynamic operation. The most promising laboratory-scale approaches will now be validated on a pilot-scale system at the Garching WWTP. In the one m^3 large trickle bed, up to 700 liters of methane from the raw biogas of the digester should be generated hourly.

Last but not least, the further development and standardization of methods for determining the biochemical methane potential (in so-called BMP tests) is another focus of the working group, which manifests itself in active membership in various national and international task forces.

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Optimization of microbial methanation in thermophilic anaerobic trickle bed reactors

The development of new energy conversion and storage technologies becomes increasingly important with changing energy policy towards renewable resources. Within the German gas grid, currently up to 250 billion kWh or 25 % of the yearly gas consumption could be stored for long-term.

Therefore, the project OptiMeth aims at investigating and further developing the microbiological production of methane directly from hydrogen and carbon dioxide ("microbial methanation"), whereby storable biomethane can be used for a demand-oriented supply of energy or, for example, as LNG or CNG for the mobility sector. While hydrogen is produced electrolytically in phases with excess electricity, carbon dioxide can be used directly at the point of origin (e.g. wastewater treatment or biogas plants, CHP, industry) and is not emitted as a greenhouse gas. The carbon is recycled and used only as a carrier for renewable energies (e.g. from wind power, photovoltaics). The implementation of microbial methanation can thus lead to reducing the consumption of fossil fuels, contributing to decarbonization and achieving climate protection goals. The possibility of making excess energy storable and providing energy when required is a decisive component of an efficient energy policy ("efficiency first"). As an efficient technology for biogas upgrading, it also opens up possibilities for the continued operation of existing biogas plants in the post-EEG era.

Figure 15: Trickling biofilter

Microbial methanation has been investigated and established in thermophilic trickle bed reactors in pilot scale. These reactors provide a low-cost alternative to energy-intensive gas injection, which is used in similar approaches for microbial methanation.

Based on these results, the main focus of the OptiMeth project was to further investigate microbial methanation in different process states. These investigations aimed for the improvement of process flexibility, robustness and efficiency for the application of trickle bed reactors in various future energy conversion and storage scenarios. The Bavarian State Research Center for Agriculture as our project partner investigated the microbial composition, focusing on enriching dominant species of hydrogenotrophic methanogenic archaea during long-term and intermittent operation as well as on micro and macro nutrient requirements.

FUNDING:
BAVARIAN MINISTRY OF ECONOMIC AFFAIRS, REGIONAL DEVELOPMENT AND ENERGY

COOPERATION:
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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 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. A particular challenge to ensure an efficient and sustainable energy supply, is the fluctuating and intermittent generation of renewable energies. Conversion and storage technologies can be used to balance the power supply network in times of undersupply or overproduction.

A promising approach is the power-to-gas technology. During energy overproduction, excess electricity is used to produce hydrogen by electrolysis. Subsequently, hydrogen can be converted into storable biomethane by synthetizing it with carbon dioxide. In previous projects, methanation in anaerobic thermophilic trickle bed reactors at pilot-scale already demonstrated a high performance with methane production rates of up to 15.4 $LCH_4/(L_{trickle\ bed}*d)$ at methane concentrations in the product gas above 96 %. This allows a direct injection of biogas into the natural gas network without gas purification.

The project DemoMeth aims to further increase the gas conversion rates while maintaining a methane concentration suitable for grid injection by optimizing the methanation process and the reactor design. Furthermore, the use of biogas as an alternative CO_2 source will be investigated in order to enable the upgrading of biogas at the point of origin to grid injection gas quality. An upscaling of the trickle bed reactor to pilot-scale with a reaction volume of 1 m^3 will demonstrate the applicability of the concept at semi-industrial level.

FUNDING:
BAVARIAN MINISTRY OF ECONOMIC AFFAIRS, REGIONAL DEVELOPMENT AND ENERGY

COOPERATION:
BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE

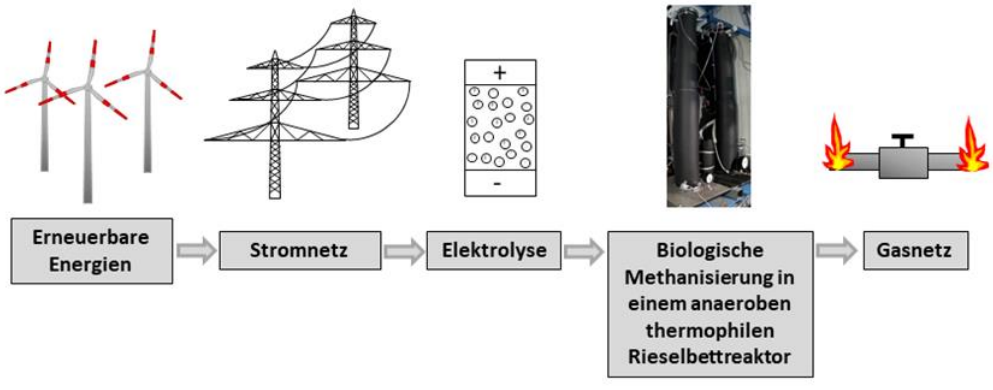

Figure 16: Simplified PtG process chain

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Increase of energy-efficiency of wastewater treatment by means of 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 pre-treatment.

The target of the research project 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. However, practical experience has shown that conventional sonotrode-based systems are relatively susceptible to interference. Therefore, an innovative split reactor is investigated as an alternative within this project..

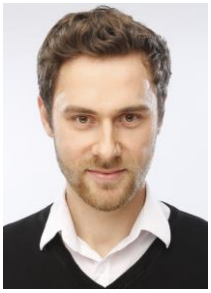
Figure 17: Continuously operated biogas test system

To ensure a design that is as efficient as possible with respect to increasing the methane yield, laboratory tests regarding reactor design optimization and energy-efficient reactor operation are conducted (Figure 17). A computer-based simulation of the fluid dynamics and the sound field within the reactors accompanies the lab tests to find an ideal design. For a holistic performance assessment of the novel reactor type, the impact of the treatment on sludge dewaterability, sludge viscosity and sludge bulking in the digesters is evaluated as well.

Besides the experiences in lab-scale, full-scale implementation on selected wastewater treatment plants including scientific support will deliver valuable information on the performance of the novel reactor concept in practice.

FUNDING:
FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY

COOPERATION:
BANDELIN ELECTRONIC;
GFM BERATENDE INGENIEURE



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Highly efficient ultrasound systems for the pre-treatment of wastewater sludge

The energy-efficient treatment of sewage sludge is a central challenge for modern wastewater treatment plants. Mechanical desintegration using ultrasound is one way of doing this. For this purpose, systematic investigations of the digestion performance of ultrasound-induced cavitation in highly viscous media, such as sewage sludge, are carried out. The ultrasonic energy, produced by piezo-ceramic ultrasonic systems, is intended to rupture the particles in anaerobic processes to increase biodegradability and consequently, increase biogas production. To obtain a positive energy balance, ideal ultrasonic configurations must be determined, to achieve highest sonication efficiency of different viscosities of sludge, by identifying the optimal ratio of amplitude, field size, ultrasonic frequency and power density in the configuration.
For this purpose, the effectiveness of tube and sonotrode reactors for the sonication of waste activated sludge (WAS) and digester sludge (DS) under identical conditions was compared for the first time. While the use of a sonotrode proved to be particularly advantageous for the treatment of WAS (+25% methane yield at 300 kJ/kg$_{TS}$), the use of a 2-inch tube reactor achieved the highest enhancement for low-intensity sonication in DS (+22% methane yield at 300 kJ/kg$_{TS}$) in a batch test (Figure 18).

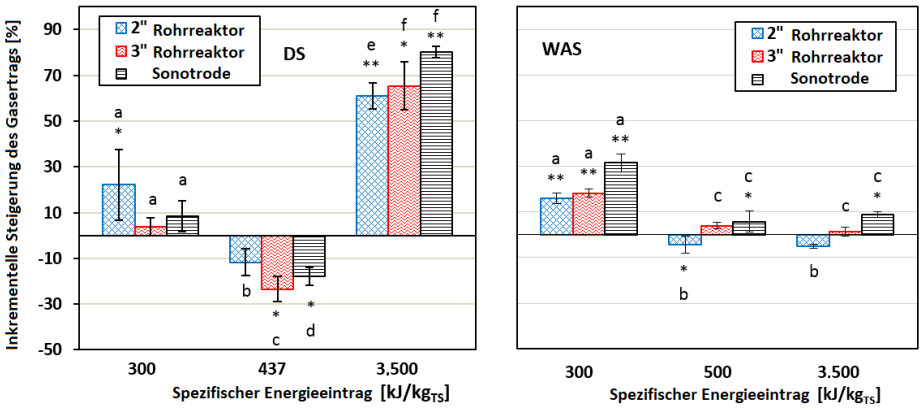

Figure 18: Incremental increase of specific methane yield of DS (left) and WAS (right) relative to the untreated sample after 28 days incubation time. Error bars denote standard deviation from the average of the three repetitions. Significant differences to the untreated samples according to the Student's t test are marked with one asterisk at $p < 0.05$ and with two asterisks at $p < 0.01$. Letters indicate significant differences according to a Student's t test at 5% significance level

Based on the results of the lab experiments, a complete ultrasonic systems consisting of tube reactors was installed at the wastewater treatment plant Traunstein for full-scale testing. Beside the process engineering considerations of the various ultrasonic concepts, the cost-effectiveness with regard to production costs and life time will also be determined.

FUNDING:
FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY

COOPERATION:
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Increasing 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. The following assumptions of possible effects leading to the bioconversion of CO_2 to methane have been stated in recent studies:

1. Increased substrate turnover
2. Redox reactions
3. Change in the carbon acid equilibrium
4. Reduced ammonia inhibition

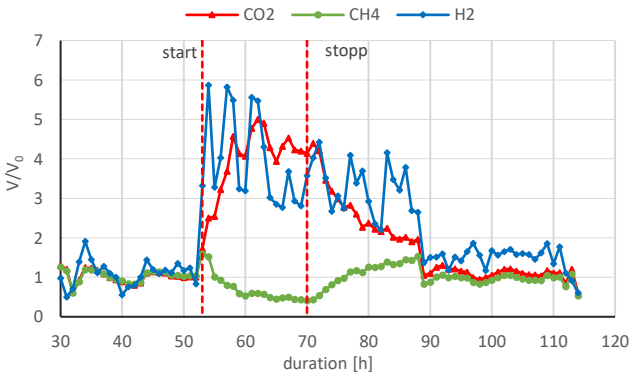

Figure 19: Development of biogas composition after CO2 enrichment

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. First discontinuous CO_2 enrichment tests showed an increased H_2 formation possibly resulting from an enhanced substrate turnover (Figure 19). In current continuous CO_2-injection experiments, the organic loading rate is gradually increased to further investigate the role of an elevated substrate availability as a prerequisite for the conversion of excess CO_2 to CH_4.

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 energy transition.

FUNDING:
GERMAN RESEARCH FOUNDATION

COOPERATION:
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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, personal care products, industrial chemicals)
- pathogens (bacteria, viruses, protozoa)
- antibiotic resistant bacteria and resistance genes and
- nutrients at low concentration (P, N).

Discharge from WWTP poses potential risk to aquatic ecosystems and human health. The work of this research group focuses on the evaluation and optimization of advanced water treatment processes and concepts for mitigation of these emerging contaminants.

Figure 20: Bench-scale ozonation system

Our research includes the evaluation of efficiencies, kinetics, reaction mechanisms and the formation of by-products and transformation products in oxidative treatment processes (e.g. ozonation, advanced oxidation processes ((AOPs)) as well as the elucidation of key factors driving the removal of emerging contaminants in natural and biological treatment systems.

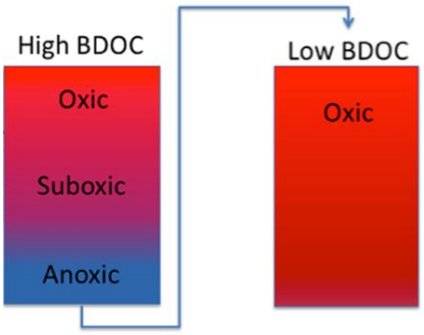

Figure 21: Principle of Sequential MAR Technology

Fundamental process understanding will be translated into the development and optimization of novel concepts for advanced water treatment. In addition, we investigate the fate and transport of chemicals, pathogens and antibiotic resistance in hybrid systems involving a combined oxidation, microbial degradation and sorption. Such multi-barrier concepts are needed as alternatives to membrane systems to provide save water quality especially for potable and non-potable reuse purposes without the constraint of concentrate disposal.

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

The diffusion-driven gas exchange 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. From the combination of ozone with hydrogen peroxide as advanced oxidation process, we expect an effective removal of monocyclic, aromatic compounds (BTEX) from polluted groundwater. Within this new 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. Different operating conditions (flow velocity, pressure, water constituents) shall provide more insights into options and limitations of the proposed technology. Different porous media layers after membrane ozonation can contribute to this assessment. 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. Further, we aim to identify suspected aliphatic products of BTEX oxidation (see Figure 22) by using HILIC-MS. Our partners in Tel Aviv will conduct experiments on a larger scale to optimize the membrane system and its operation (Figure 23). The proposed setup will finally be tested at full-scale to assess the effectivity of the concept for remediation of a contaminated site.

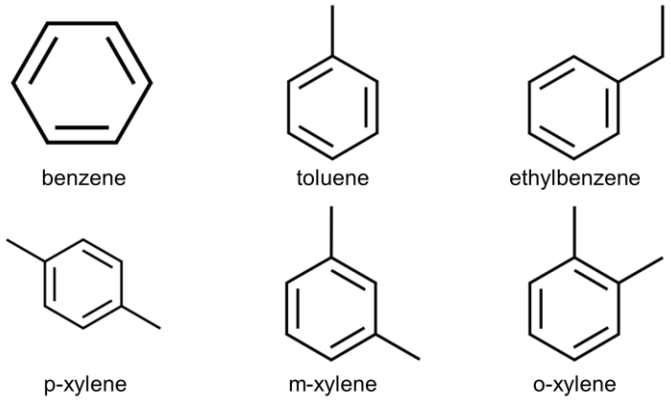

Figure 22: BTEX compounds

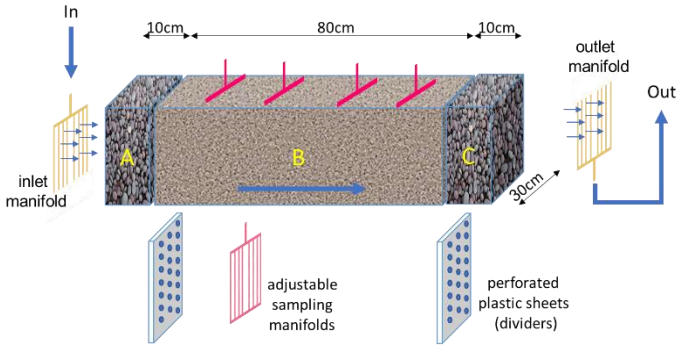

Figure 23: Experimental setup with porous media and passive gas introduction

FUNDING:
FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COOPERATION:
TEL AVIV UNIVERSITY

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Functional group specific reactivity, transformation and persistence of CECs and EfOM during wastewater ozonation

Chemical oxidation by ozone is an established technology for the efficient oxidation of contaminants of emerging concern (CEC) in water treatment. A major disadvantage of using ozone is the formation of stable and potentially toxic ozonation products (OPs). Biologically stable OPs are particularly critical due to their longevity in the environment. It is impossible to examine all relevant CECs for their reactivity towards ozone, the resulting OPs and their biological stability. Rather, it is necessary to generate knowledge based on the systematic study of functional groups that can be transferred to other substances.

The knowledge gap for effluent organic matter (EfOM) is even larger. The ozone consumption of EfOM proves its reactivity to ozone, but which functional groups react, which products are formed and how biologically stable they are, has not been investigated for EfOM especially with heteroatoms (N, S). This project aims to fill both gaps by a complementary analytical and experimental approach, with the common methodological approach of introducing a label into the OPs and the subsequent detection and identification of the OPs by means of (ultra-high-resolution) mass spectrometry.

The project is based on the central hypothesis that the reaction of ozone with certain functional groups of CECs as well as with equivalent functional groups of the EfOM leads to a predictable formation of OPs. It aims to i) improve our understanding of the reactivity of different functional groups to ozone, focusing on the identification of non-biodegradable functional groups within the OPs, ii) identify and quantify ozone-reactive functional groups in the EfOM based on existing knowledge on the transformation of CECs, with the focus on N- and S-containing functional groups which form potentially chemically stable OPs, and iii) assess the significance of the EfOM with respect to the formation of biologically stable OPs in wastewater ozonation in comparison to CECs.

To that end, the biological degradation of the OPs will be investigated using their specific functional groups in column degradation experiments. With the new labeling approach, we are able to reliably detect CEC and EfOM OPs, identify them and track their stability in biological systems.

The project generates a systematic and transferable understanding of the formation of stable OPs based on functional groups of organic molecules, both of CECs and EfOM. Only when the stability of the possible OPs has been investigated a systematic toxicological evaluation of ozonation as a water treatment method will become feasible.

FUNDING:
GERMAN RESEARCH FOUNDATION

COOPERATION:
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FUNDING:
FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COOPERATION:
UBA, BFG, BGS UMWELT, COPLAN AG, BWB, DHI WASY, TUB, UO, TZW

Development of a non-membrane based innovative treatment approach including comprehensive assessment criteria for indirect potable reuse in urban water cycles

TrinkWave aims to innovate a multi-barrier treatment concept for indirect potable water reuse based on sequential managed aquifer recharge technology (SMART). Proposed monitoring concepts will consider emerging water quality issues, including detection of viruses, antibiotic resistance genes, trace organic chemicals and transformation products, in the interest of human health protection.

Major tasks of TUM within this project include the development and testing of a novel treatment concept for inactivation of pathogens, removal of antibiotic resistant bacteria and genes, and health relevant chemicals at pilot-scale, the identification of novel bio-molecular parameters for assessing biofilm-based treatment systems, as well as quantitative microbial and chemical risk analysis to assess reuse strategies.

The novel concept SMARTplus builds upon knowledge and experiences from SMART, aiming to manipulate sequential redox changes and primary substrate availability to stimulate microbial biodegradation. Important research questions include selection of oxidizing agents (i.e., reactive barriers) for in-situ aeration, longevity of system functionality, compatibility with downstream purification processes, and attunement of operational flow rate for optimum removal of target substances at minimal hydraulic retention times. The results from the pilot scale system will be incorporated in the design of a demonstration scale SMARTplus application, planned by the Berlin Water Company (BWB).

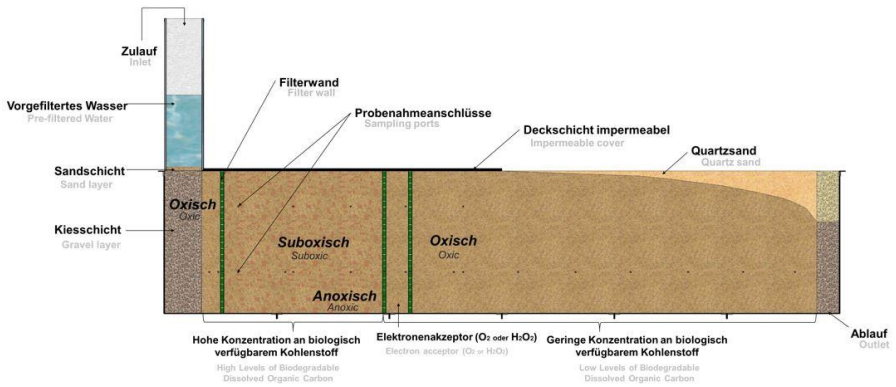

Figure 24: Schematic of the SMARTplus semi-industrial scale test facility at TUM

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Fate of antibiotic resistant bacteria and their resistance genes during advanced wastewater treatment

Spread of antimicrobial resistance (AMR) by horizontal gene transfer represents a new class of emerging concern, with adverse effects not only to the environment and often referred to as the most serious threat to public health of the 21st century. Despite the high treatment efficiency of conventional wastewater treatment plants (WWTPs), further spreading of antimicrobial resistance in urban aquatic environments is reported by many studies.

This study aims to improve understanding of the fate of ARB and their respective ARGs during oxidative wastewater treatment (i.e. ozone treatment and UV disinfection) at different operational conditions, and assess potential selection pressure on relevant pathogens. The experiments were performed with cultures of environmental isolates of susceptible and resistant bacteria of interest. The inactivation of microorganisms was evaluated by plate counting and monitoring of cell membrane integrity. The influence of ozone and UV on microbial cells and genes was also evaluated by quantitative polymerase chain reaction (qPCR), by quantifying the numbers of ARGs and 16S rRNA gene copies (as a proxy for total cell numbers). In addition, this study focuses on the elimination of ARGs based on different lengths of the amplified DNA fragments.

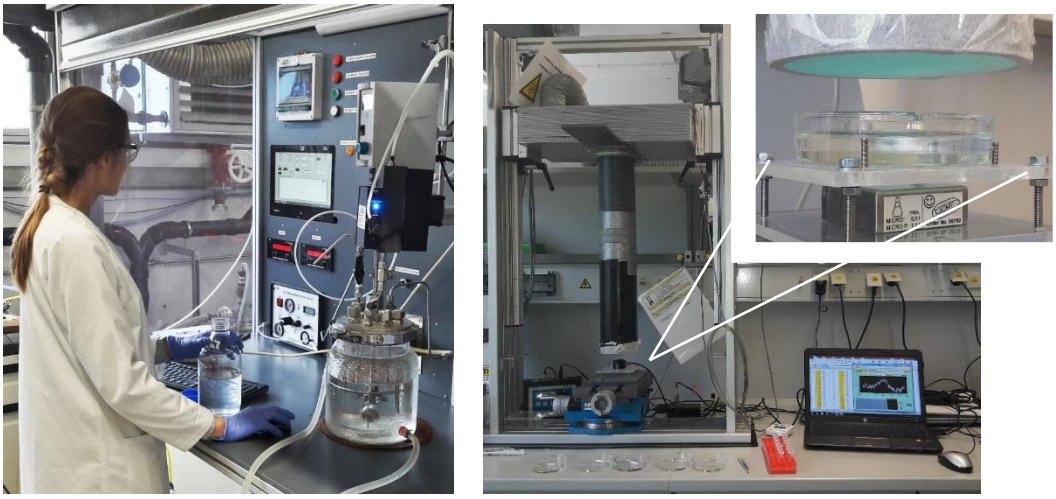

Figure 25: Expertimental setup of the ozone experiment (left) and the UV experiment (right)

FUNDING:
GERMAN FEDERAL ENVIRONMENTAL FOUNDATION

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Development of adaptive advanced methods and systems for the removal of recalcitrant perfluorinated compounds from water

The core activity of NOWELTIES is the research program (composed of 14 individual research projects) aimed at development of inventive water treatment technologies (advanced biological treatments, innovative oxidation processes, hybrid systems) that allow catering for the varied treatment demands for a plethora of interconnected streams arising from recycling loops

As a part of this network, this project focuses on developing a variety of methods and process optimizations for removing perfluorinated compounds (PFCs) from municipal or industrial wastewater. With various target goals, this project focuses on proven concepts, such as sonolysis, reverse osmosis, nanofiltration, and will experiment with the operational parameters of these treatment methods to achieve the lowest energy footprint and highest removal rate for these extremely recalcitrant compounds.

Additionally, in collaboration with the catalysis department of TUM, a novel material will be developed, with adsorption properties tailored specifically to fit the properties of these pollutants, and to extract these pollutants even at low concentrations without active energy input. Some obstacles in the material design are hydrostability and high cost of production. If successfully synthesized, these materials would provide a novel way of removing PFCs from water, while also providing a durable material which could be regenerated and reused many times, thus reducing the environmental impact on multiple fronts. Subsequently, treatment of the regeneration flow is mandatory in order to actually mineralize the pollutant. This will be done with a series of experiments first to determine which solvent is the best candidate for desorption of the compounds from the MOFs, and then a fitting process will be applied for the treatment of the organic solvent rich in PFCs. Current candidates are sonolysis, pyrolysis of both the solvent and pollutant or ideally distillation of the solvent for reuse and pyrolysis of the pollutant itself.

FUNDING:
EUROPEAN COMMISSION

COOPERATION:
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Bioenergetic Framework for Microbial Transformations of Trace Organic Chemicals

NOWELTIES is a Horizon 2020 Marie Skłodowska-Curie Innovative Training Network composed of 14 individual research projects. 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 microbial decomposition of TOrCs by coupling co-metabolism and mixed-substrate growth in a bio-energetic framework (Figure 26).

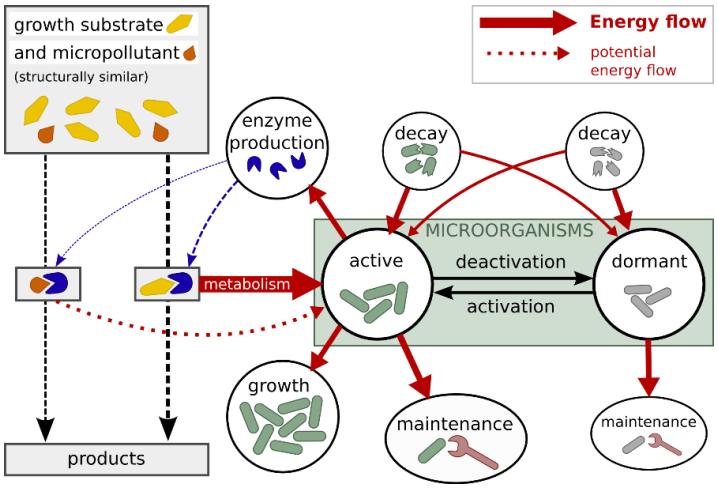

Figure 26: Illustration of the bioenergetic model developed at TUM and University of Tübingen

Results from research fields such as biofiltration systems, environmental chemistry and microbial omic technologies indicate that biological systems could achieve as good performance as advanced water treatment processes for TOrC attenuation, but with less energy demand and without generation of residuals. However, improvement of these biological technologies for water treatment requires deeper understanding of mechanisms driving microbial degradation of TOrCs. It is neccesary to elucidate fundamental processes related to microbial metabolism in natural environments.

Development of microbial communities under oligotrophic conditions will be studied in a retentostat bioreactor system. Generated data such as substrate transformation, microbial growth rate and gene expression will be used to calibrate the model. Experiments will be designed to address which environmental conditions induce expression of enzymes capable of TOrC removal. The expected outcome of the study is to develop a model to provide better prediction of TOrCs removal, especially under oligotrophic conditions.

FUNDING:
EUROPEAN
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COOPERATION:
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FUNDING:
BAVARIAN ENVIRONMENTAL AGENCY

Side effects of an Intensified Application of Coagulants for Phosphorous removal

In Germany, the realization of the European Water Framework Directive proceeds slowly. Despite reductions already achieved, slow realization is in part brought about by the exceedance of orientation concentrations for nutrients like phosphorous in inland surface waters. To avoid harmful effects to water bodies through the effluent of wastewater treatment plants, in March 2018, the requirements regarding the parameter phosphorous were been tightened with the forward projection of the leaflet Nr. 4.4/22 “Anforderungen an das Einleiten von Schmutz und Niederschlagswasser” and the definition of stricter requirements in Bavaria. Often stricter control values lead to an intensified application of coagulants in wastewater treatment plants for chemical phosphorus removal. Caused by the production or the utilized raw materials, the used coagulants, iron and aluminum salts/salt solutions can contain contaminants like heavy metals, which are released when coagulants are used. Furthermore, due to the application of phosphorus precipitation, active agents like iron and aluminum, as well as anions like chloride and sulfate (salts) dissolve in the wastewater stream.

Hence, the Chair of Urban Water Systems Engineering of the Technical University of Munich carried out a study on possible side effects of phosphate precipitation in Bavarian wastewater treatment plants on behalf of the Bavarian Environment Agency (LfU). The focus of this study was a model calculation to quantify the emissions of coagulant related active agents, salts, and heavy metals into Bavarian surface waters. Also, concentration increases in the effluents as well as in the surface waters at the discharge point of the 2,500 wastewater treatment plants related to coagulants were calculated. The calculated increases were assessed concerning the environmental quality standard and the orientation values of the Oberflächengewässerverordnung (OGewV 2016).

Based on data of the LfU for the year 2016, a current state scenario 2016, as well as the scenario according to the realized requirements of the leaflet Nr 4.4/22 (2018) were balanced. To evaluate the effects of a possible further tightening of the requirements for phosphorus removal in Bavarian wastewater treatment plants, two more scenarios were balanced. Currently, but no thresholds for the content of heavy metals in coagulants exist, only guidance values are provided. Hence, it was necessary to research the heavy metal contents based on data sheets and manufacturer information for coagulants primarily applied in Bavaria.

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Focus Area
Urban Water-Energy-Food (WEF) Nexus

The focus area "Urban Water-Energy-Food (WEF) Nexus," conducted at the chair since April 2017, is financed by the Bavarian State Ministry for Environment and Consumer Protection.

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

Figure 27: Water-Energy-Food Nexus diagram

The Urban WEF Nexus approach is one way for cities to devise more sustainable development pathways. The approach advocates that supplying water to cities and treating water takes much energy, and that much water is also needed to produce energy and food. Planning these three sectors in conjunction can support water, energy and food security and achievement of the Sustainable Development Goals (SDGs). Water reclamation with integrated resource recovery is a key synergy opportunity for operationalization of the WEF Nexus approach.

The aim of the Urban WEF Nexus focus area is to study the interaction between the sectors water, energy and food and devise alternative future urban development scenarios to support the development of decentralized pilot projects. Further, a dialogue is being conducted with local partners including government, NGOs and industry e.g. through regular workshops to discuss the implementation of such pilot projects. The project takes Leh, the capital of Ladakh, a semi-arid high-altitude region in the Indian Himalayas, as a case study, as well as other cities in India and Africa.

FUNDING:
BAVARIAN STATE MINISTRY FOR ENVIRONMENT AND CONSUMER PROTECTION

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Research Group Membrane Filtration

Membrane processes play a central role in the closure of in-house water cycles, the reuse of municipal wastewater as well as in seawater desalination. The focus of research, however, is not only the removal performance of membrane processes with respect to unwanted water constituents but also their energy efficiency and the aspect of the recovery of useful resources. After all, the theoretically usable energy of wastewater is about 2.52 kWh m^{-3}.

For example, it has been shown that a conventional activated sludge process in combination with a further purification stage (microfiltration, reverse osmosis and final UV-H_2O_2 treatment) has a net energy requirement of 1.09 kWh m^{-3}. Alternative process concepts utilizing membrane processes, such as combinations with anaerobic membrane bioreactors, have higher levels of energy recovery and consequently lower net energy requirements of up to 0.22 kWh m^{-3}.

In another project, since the end of 2018, we have been addressing the question of how much unwanted biofouling on the membrane, which affects the energy efficiency of the membrane process, can be reduced. Through the use of UV-C LEDs, we develop UV membrane hybrid processes in which the formation of biofouling is delayed and, by UV-induced effects in microorganisms, the properties of the biofilm formed positive with regard to its permeability and UV-induced by pretreatment To influence cleanability.

The feed spacer is an important component of a spiral wound membrane module and is responsible for the transport of the feed water to the membrane surface. The better this succeeds, the less, for example, the influence of fouling on the performance of a membrane module. In a structural analysis of various commercial feed spacers in combination with numerical hydrodynamic modeling, we were able to establish important constraints (e.g., spatial resolution constraints on the numerical model) under which to later numerically optimize the design of novel feed spacers.

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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 UV-C-LEDs to mitigate biofouling in reverse osmosis (RO) membrane processes by UV pre-treatment. UV-C-LEDs have many advantages over conventional mercury vapour lamps, which makes them environmentally friendly and, due to their size, easy to physically integrate into membrane modules.

The membrane filtration research group investigates the efficiency of the novel UV-C-LED system in lab- and pilot-scale experiments (Figure 28). 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 UV-C-LED system will be characterized with regard to its UV-dose by using actinometry and biodosimetry. A further research focus of this collaborative project is to evaluate the efficiency of the innovative UV-C-LED system on the basis of typical membrane module performance parameters, such as permeability decline, feed channel pressure drop, and UV-induced changes of relevant biofilm properties, such as removability during membrane cleaning.

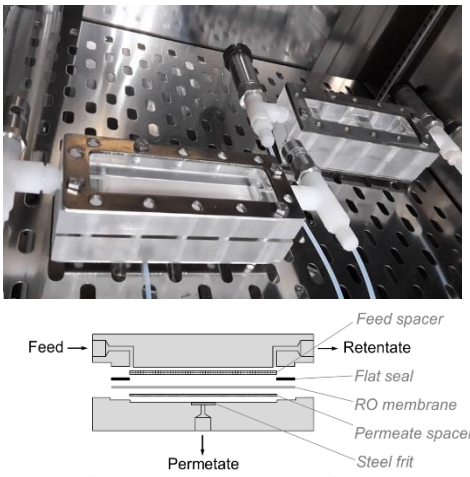

Figure 28: Lab-scale RO biofouling simulator

FUNDING:
FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COOPERATION:
UV-EL GMBH;
DELTA UMWELT-TECHNIK GMBH

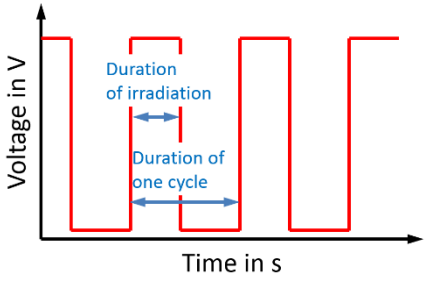

Figure 29: Pulsed power supply of UV-C LEDs

When applying an intermittent current as power supply, UV-C-LEDs can generate pulsed irradiation (Figure 29). Through fundamental investigations, we plan to determine the inactivation efficiency and mitigating effects on biofouling of pulsed UV-C irradiation at a large range of duty cycles (0 – 100 %) and pulse frequencies (1 – 100 Hz).

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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.

FUNDING:
FEDERAL MINISTRY OF EDUCATION AND RESEARCH

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Research Group Microbial Systems

The Microbial Systems Research Group focuses on the investigation of microbial processes in aquatic and engineered systems, ranging from biological wastewater treatment to surface water ecosystems. We are looking for new ways to better understand microbial functions and their enzymatic potential. One focus of our research is the diversity and interaction of various organisms within microbial biofilms. This year, the research group was rewarded with an Emmy Noether Junior Research group fellowship, which will start in January 2020.

Microbes possess an array of enzymes for the degradation of all kinds of substances ranging from high molecular weights polymers to low molecular weight aromatic compounds. Fungi are one group of microorganisms that produces very efficient exoenzymes that breakdown recalcitrant organic matter. Aquatic fungi in particular are largely unexplored and thus an interesting target. These aquatic fungi may facilitate enzymatic transformations of pollutants in wastewater reactors. Further research addresses the characterization of taxonomic and functional diversity of microbial communities with very specific functions, such as micropollutant degrading communities, or antibiotic resistance genes bearing microbes in surface waters. Often molecular methods are applied quantitatively (qPCR) or qualitatively (high throughput sequencing) (Figure 30).

Figure 30: qPCR Analysis targeting antibiotic resistance genes, and a third generation sequencing based USB sequencer for analyzing marker genes, genomes and metagenomes

Figure 31: Traditional and new minimal model community based microbiological cultivation

Moreover, we are currently establishing a small culture collection by using a high throughput mixed model cultivation with the goal to target the untapped potential of mixed cultures from urban waters (Figure 31). These functional minimal communities may facilitate the removal of pollutants such as trace organic chemicals, and thus may hold the key for applied treatment processes.

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Removal of trace organic chemicals (TOrCs) by functional microbial model communities

Trace organic chemicals (TOrCs) such as residuals of pharmaceutical products are increasingly found in the water cycle. Since TOrCs and their biotransformation products can have adverse ecological effects, it is necessary to reduce them as much as possible before they enter surface waters, i.e. during wastewater treatment. For many polar trace compounds, biotransformation through microbial communities has great potential. In order to further improve the biotransformation process, it is therefore necessary to investigate the basics of the composition, interactions and functional enzymes of microbial communities, and thus to understand and control the biotransformation rates and pathways during biological treatment.

My project aims to establish low complexity microbial model communities capable of removing TOrCs. These communities originate from biologically active sand filters, which allows us to link biotransformation efficiency with the quantity and quality of microbial interactions and their respective functional enzymes. The transformation potential of the model communities is then analyzed using high-resolution mass spectrometry and high-throughput sequencing of metagenomes and metatranscriptomes, allowing the elucidation of biotransformations at the molecular level. Finally, these model communities will be implemented in bioreactors to assess their potential to treat wastewater with TOrCs.

This project will contribute to a more comprehensive understanding of TOrC biotransformation. This would allow us to predict biotransformation rates and pathways based on the composition of microbial communities.

FUNDING:
CHINA SCHOLARSHIP COUNCIL

COOPERATION:
STOCKHOLM UNIVERSITY, BFG

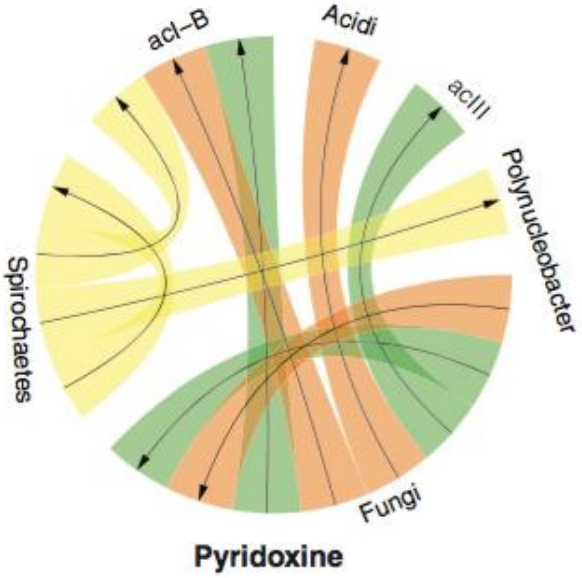

Figure 32: Potential metabolic complementarity among major members of each model community (from Garica et al. 2018).

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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) include contain classes of (crude-)oil, pesticides, and industrial chemicals, as well as household chemicals and pharmaceuticals (analgetics, 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.

Figure 33: Pharmaceuticals

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:

- Develop new methods to quantify known TOrCs (target screening)
- Develop new hybrid methods to identify biologically active TOrCs by combining analytical separation techniques and effect assays
- 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.

Figure 34: Triple-Quad mass spectrometry

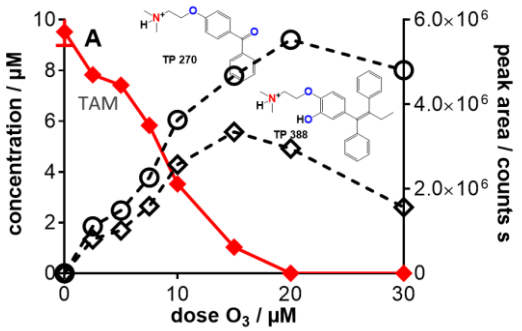

Figure 35: Loss of the starting material and formation of transformation products in ozonation

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Validation of Analytical Methods for Microplastic Particles in Environmental Matrices

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. Inorganics can be removed by salt-based density separation techniques, whereas organics have a similar density to microplastics and needs to be removed via chemical digestion methods, such as oxidation, alkali, acids, and enzymatic reactions. These reactions may inadvertently alter the microplastics being investigated. Alongside the sampling and analysis techniques, the employment of different sample preparation methods is one of the main factors impeding direct comparability of the results from different studies dealing with the determination of microplastic particles.

The goal of this study is to optimize and validate a standardized sample preparation method to remove organic matter without altering the microplastics. The Fenton reaction was determined to be a fast and suitable digestion method when tested against seven common polymer types (PS, PE, PP, PET, PVC, PA and PLA) in the size range of 63-200 µm. For reproducibility, the sample preparation protocol is to be clearly detailed when published. Such details are often missing from many previous studies, which impedes the reproducibility of their results. Hence, various parameters in this study are being monitored and documented to enhance the understanding of relevant parameters for reproducibility.

The next step is to validate the protocol for particles < 5 µm as those have increased surface area and thus potentially increased reactivity compared to larger particles.

FUNDING:
BAVARIAN
RESEARCH
FOUNDATION

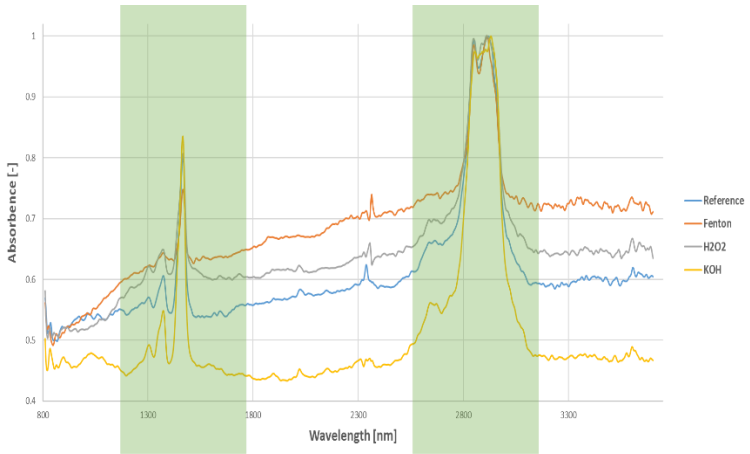

Figure 36: FTIR Spectra of PE

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Analysis of (sub)microplastic particles and sorbed trace substances with TD-Pyr-GC/MS

More than 8 million tons of microplastics are transported from land to the oceans every year. Primary microplastics are used, for example, in detergents or body care products. So-called secondary microplastics arise from large macroplastics caused by weathering, UV radiation or friction. Microplastic is defined as particles with a size between 5-1 mm. It is assumed that smaller particles have greater toxicological relevance due to their larger specific surface area. The concern about the possible harmful effects of microplastics relates not only to the particles themselves but also to their ability to transport pollutants.

The interdisciplinary research project "SubµTrack" focuses on the analysis of sub-microparticles (50 nm -100 µm) and adsorbed pollutants such as pesticides or insecticides. By means of a newly developed thermodesorption - pyrolysis - gas chromatography / mass spectrometry (TD-Pyr-GC/MS) the trace substances can first be identified in a coupled procedure. In the second step, the plastic is pyrolyzed and identified by means of characteristic substances.

By sorption of selected trace substances on different reference microplastic particles a method is first developed and then validated. By this method the sorption properties can be characterized depending on the polymer type, polymer size and polymer form.

By analysis using Stir Bar Sorptive Extraction (SBSE, Gerstel Twister®), TD-Pyr-GC/MS can not only be used to determine the sorbed substances on the particles, but also to quantify the substances remaining in the water phase. In this way, a mass balance of the sorbed and non-absorbed substances can be established and sorption kinetics can be investigated.

In cooperation with project partners, ecotoxicological samples are also investigated. Reference particles contaminated with trace substances are tested on aquatic organisms. After defined times, samples are taken and analyzed using TD-Pyr-GC/MS (particles) and TD-GC/MS (aqueous phase).

FUNDING:
FEDERAL MINISTRY OF EDUCATION AND RESEARCH

Figure 37: Particle analysis with TD-Pyr-GC/MS (left) and with Gerstel Twister® (right)

SubµTrack

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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 the mass measurement of the unfragmented analyte molecule. Additionally, the high amount of solvent in the sample after the LC separation does not interfere with ESI due to its working principle. 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 only 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 to rapidly decide which substances require detailed analysis.

As the ESI ionization rate depends on a large number of parameters, such a prediction is currently only possible to a very limited extent. To develop a method which allows the prediction of ESI ionization rates in real time, the ionization rate of a number of different substances shall be measured over a large variety of measurement conditions. The generated data shall subsequently be used to develop and train a machine leaning model that enables the ionization rate prediction based only on the properties of the analyte and measurement conditions.

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FOR-IDENT – Nachhaltigkeit: The final year

The project FOR-IDENT (FI) is a multiple year BMBF-funded project and furthers the activities of the former RISK-IDENT project (2012-2014) related to the establishment of guidelines and the integration of the database STOFF-IDENT in an extended platform. In this 'FOR-IDENT' platform further software tools and databases are implemented providing workflows for the evaluation of LC-MS/MS data. New strategies and workflows should support non-target screening approaches, for an easier and faster identification of organic molecules.

Currently two established workflows are integrated in the platform. The liquid-chromatography coupled to mass spectrometry for polar and very polar molecules (HILIC) and mid- to apolar molecules (RPLC).

Figure 38: Illustration of the FOR-IDENT platform info in current research journals

The database STOFF-IDENT, which was developed within the RISK-IDENT project, plays a key role (see also https://www.lfu.bayern.de/ stoffident/#!home). Hereby, suggested molecules in water samples can be reduced by different filter possibilities in STOFF-IDENT. In the last two years the databases were extended by the biogenic compound database PLANT-IDENT, the PFC-IDENT from the LfU, the DuftSTOFF-IDENT and the GC STOFF-IDENT. Furthermore, analytical MS/MS-tools like MassBank and prediction tools like MetFrag and EnviPath are already integrated. This allows the application of biological, chemical, physico-chemical and analytical metadata at the same time. Within the FOR-IDENT project further linkages are planned, for example with ecotoxicological databases.

The project was finally completed at the end of 2019 and will be transferred to an independent association. After completing the project, Thomas Letzel will continue to be associated with the chair and co-supervise several doctoral theses.

FUNDING:
FEDERAL MINISTRY OF EDUCATION AND RESEARCH

COOPERATION:
BWB, HSWT, LFU, LW, TUM

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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 to be 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.

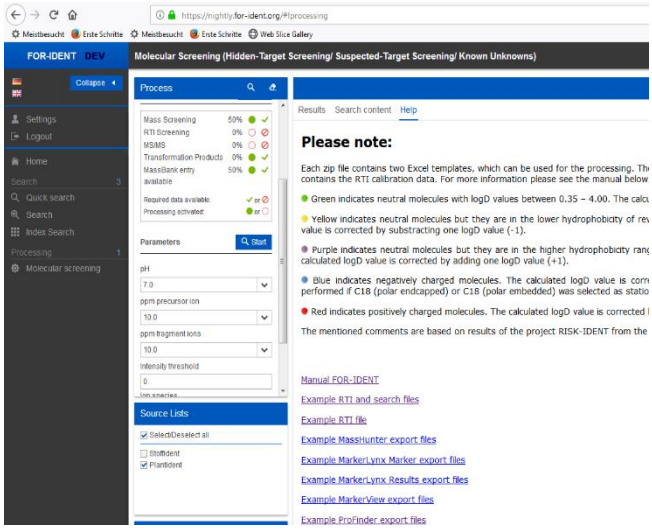

Figure 39: Screenshot of the developed tool

The project (which started in late 2016) focuses on the plant metabolomic pathways, the possibly involved enzymes and the resulting transformation products. In addition, whether the pollutant changes the plant biosynthesis cycle and whether the pollutants can push the biosynthesis cycle in specific direction by generating several substrates to specfic pathways is investigated. Plants can uptake the pollutants into their biosynthesis cycle. Thus, our major aim was to figure out whether the biological degradation pathways can be reflected by the analytical data obtained from polarity extended RPLC-HILIC-ESI-ToF-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-ESI-ToF-MS technique. The project is conducted through the following steps: first, an extraction method validated which will be applicable to extended-polarity chromatography analysis via target and non-target screening. Second, the dataset was interpreted to investigate the changes in plants metabolites and pathways changes behind them through statistical strategies.

Finally, the open access database PLANT-IDENT was filled with more than 1,000 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.

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

KOOPERATION:
HELMHOLTZ ZENTRUM MÜNCHEN

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Polarity-extended HRMS screening for (very) polar molecules in the aquatic environment

Trace organic compounds (TOrCs) in the aquatic environment are of public interest as they can have negative chronic effects on the local flora and fauna. They enter surface waters via sewage treatment plants, surface runoff or contaminated precipitation. Moreover, some of them have already been detected in low concentrations in groundwater and drinking water. Especially highly polar TOrCs are able to pass technical as well as biological barriers and spread along half-closed water cycles.

In order to be able to analytically encompass the variety of TOrCs, several chromatographic separation techniques are combined with high-resolution mass spectrometry (HRMS). For example, a broad polarity range can be covered by serial coupling of reversed phase liquid chromatography (RPLC) with hydrophilic interaction liquid chromatography (HILIC). Data of the RPLC-HILIC-HRMS system is collected by using a non-target screening approach. In combination with the compound database STOFF-IDENT at the open-access platform FOR-IDENT, a candidate list of potentially new and environmentally relevant compounds can be generated.

Non-target screening of environmental samples using HRMS generates complex data sets, for the evaluation and statistical interpretation of which new and comprehensive workflows are necessary. In the past project phase such a strategy for the processing of RPLC-HILIC-HRMS data was developed. The deconvolution of chromatographic peaks and their componentization to so-called molecular "features" was optimized. With the help of the compound database STOFF-IDENT, the accurate masses of these molecular features could be assigned to possible substances. Some of the physicochemical properties stored in the database were used for additional filtering steps. The condensed list of proposed substances could then be confirmed via reference standards. The workflow was applied to a set of samples taken in a sessional study at the river Isar and resulted in new identifications.

Susanne Minkus is an external PhD student and works at the AFIN-TS GmbH in Augsburg. The company develops non-target screening approaches and establishes them within and outside of academia. Susanne's doctoral thesis is supervised at TUM by Jörg Drewes and Thomas Letzel.

FUNDING:
AFIN-TS GMBH

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Identification and behavior of polyfluorinated precursors in the environment

Due to chemical policy restrictions for longchain perfluorinated substances, an increasing number of per- and polyfluorinated substitutes are used in industrial and consumer products. So far only insufficient information about these substances is available. Often neither the chemical structure nor analytical standards and methods are available to allow analysis of these substances. The objective of this work is to use different approaches to get information about the polyfluorinated precursors in the aquatic environment that are degraded long-term into the perfluorinated substances.

The total concentration of per- and polyfluorinated substances (PFASs) in the aquatic environment can be detected with the TOP-assay (total oxidizable precursor assay). The unknown polyfluorinated precursors are converted to the measureable 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. In the first phase of the project, the TOP-assay is validated for different matrices (ultrapure water, soil eluates and wastewater).

However risk assessment for polyfluorinated precursors can only be carried out if the single compound is known. For this reason 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 includes more than 4,600 substances so far. Recently, it was integrated into the FOR-IDENT platform. First environmental samples were analyzed by high resolution and accurate LC-MS/MS and are currently evaluated with this platform and databases.

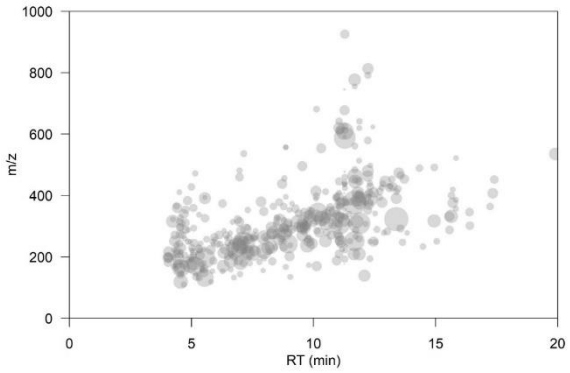

Figure 40: Substances detected in a surface water sample by high resolution mass spectrometry

Hanna Ulrich is an external PhD student and works at the Bavarian Environment Agency. Hanna's doctoral thesis is supervised at TUM by Jörg Drewes and Thomas Letzel.

FUNDING:
BAVARIAN
ENVIRONMENT
AGENCY

Visting Scientists

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Dr. Nirina Khadgi did her PhD at the Hohai University in Jiangsu, China, and focused on the photocatalytic remediation of trace organic compounds and the control of the transfer of antibiotic resistances. Within the Green Talent Awards, funded by the German Ministry for Education and Research (BMBF), she visited the chair from October till December 2019. During her stay, she investigated the photolysis and product formation of the antibiotic ciprofloxacin. A special focus was on the determination of the remaining antibiotic activity of the formed transformation products.

Renato Liguori
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Renato Liguori is a biotechnologist specialized in biochemistry with strong interest in bioinformatics investigating the potential usage of microbial communities for treatment of contaminated sites. His PhD research is conducted at the University Parthenope in Napoli, Italy, and is supervised by Prof. Vincenzo Pasquale.

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

Moreover, Renato Liguori investigates the microbial communities of water infiltration systems for urban street water runoff. This study examined the as yet unknown microbial communities of urban street water infiltration system. In particular, how the microbiology may influence the retention of pollutants such as heavy metals or antibiotic resistance genes was investigated.

International Cooperation Partners

Last year, we further expanded our international partner network! (Figure 41)

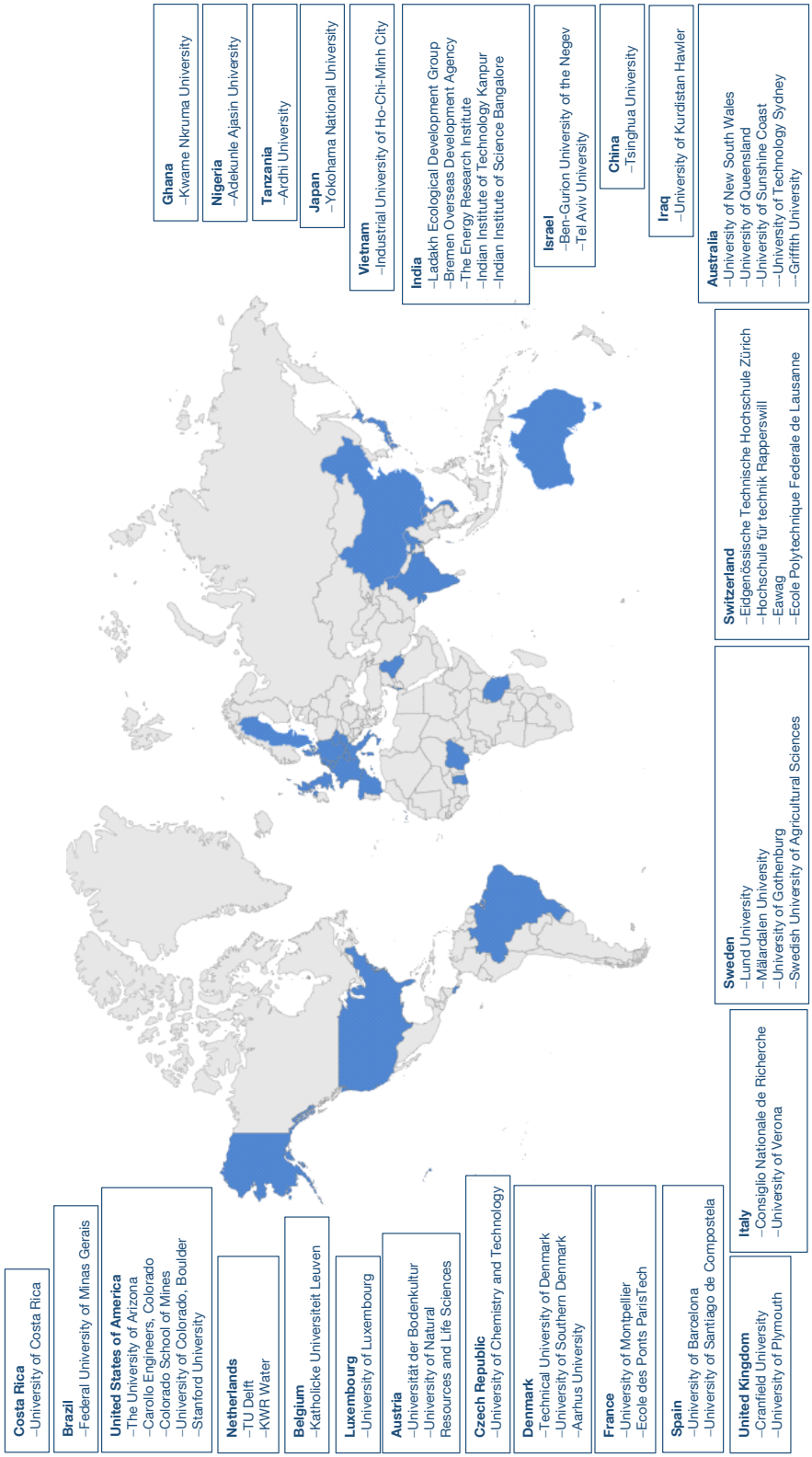

Figure 41: International partners

National & International Committees

DWA Working Groups

Brigitte Helmreich 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 leaflet **DWA-M 179** "Decentralized plants for rainwater treatment" (ES-3.7). 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**. "Waste water from the starch industry".

This year, she was appointed as the spokesperson of the **DWA Working Group ES-3.1** "Percolation of Rainwater" and member of the DWA Committee of Experts **ES-3** "Plant-Related Planning,", where she was elected as the deputy chairman.

Figure 42: from left: Prof. Theo Schmitt (Obmann DWA-ES-2), Prof. Brigitte Helmreich (stellv. Obfrau DWA-ES-3), Prof. Helmut Grüning (stellv. Obmann DWA-ES-2), PD Dr. Stephan Fuchs (DWA-ES-3) (Source: DWA)

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".

IWA Strategic Council

Jörg Drewes has been elected to the Strategic Council of the **International Water Association** as the representative of the Specialist Groups.

Figure 43: Meeting of the committee in Portugal.

IWA Water Reuse Specialist Group (WRSG)

After six years of service, **Jörg Drewes** stepped down as chair of **Water Reuse Specialist Group**. He will continue to serve as past-chair on the Strategic Board of WRSG.

Journals – Editors

Jörg Drewes continues to serve as editor of the Journal of Water Reuse and Desalination.

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 has been a special editor of the journals **MycoKeys** and **Biodiversity Data Journal** since 2016.

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.

Workshops & Other Activities

30th Water Technology Seminar (WTS)

On the 13th of February an audience of roughly 100 people met at the Oskar-von-Miller-Forum to get information on groundwater contaminations due to per- and polyfluorinated compounds (PFCs) and discuss the associated problems. The audience consisted of representatives from local and federal governmental institutions, industry, (environmental) engineering offices, airport associations, and interested citizens.

The focus of the seminar was on perfluoroalkyl carboxylic acid (PFCA) and perfluoroalkyl sulfonic acids (PFSA), as well as precursor compounds. PFCs are used in a wide range of applications due to their unique physical properties. Unfortunately, they also have a high persitance and mobility in the environment. Additionally they tend to bioaccumulate. Due to known toxicological effects and their high mobility of some PFCs, they represent a substantial thread for groundwater as drinking water source.

During the seminar, the toxicological data were elucidated and the estimated risk of exposition via drinking water supply was presented as well as possible treatment options were discussed.

Furthermore, sources, distribution and occurrence of PFCs in the environment were shown and specific individual cases were considered in detail. Especially firefighting training areas of airports or large industry facilities show a high contamination due to the use of PFC containing firefighting foams.

Hence, possible remediation strategies for contaminated soils were presented and discussed. The disposal of contaminated soils is also difficult, as landfills often do not have the necessary leachate treatment facilities.

Figure 44: Attendees of the WTS.

47th Wastewater Technology Workshop (ATS)

On 3 July 2019, more than 80 participants from research and practice followed the invitation of the Chair of Urban Water Management to the 47th Wastewater Technology Workshop (ATS) in the Hainhalle Ismaning with the topic "Advanced wastewater treatment - requirements, financing and implementation".

According to a recent survey conducted as part of the 'ZeroTrace' project, more than 80 % of the experts surveyed see trace substances as the most important challenge water management is currently facing. Based on the survey, the introduction of a regulation for the removal of trace substances in municipal wastewater treatment plants is expected for the period 2021-2025. But what will these regulations look like? Which wastewater treatment plants must be equipped with a further treatment stage? What are the most effective treatment methods and how can implementation be financed in practice?

The first speakers of the workshop discussed the current strategy to address the problem of trace organic chemicals (TOrCs) in Germany and its implementation by the State of Bavaria. It turned out that in particular operators at hotspots will soon have to reckon with new requirements for the elimination of trace substances. Subsequently, the relevance of the removal of trace substances for water bodies and, in some regions, also for the protection of drinking water supply was discussed. A further presentation dealt with the topic of antibiotic resistance and its removal in conventional processes for advanced water treatment.

After the lunch break, speakers from Switzerland and Aachen gave an insight into the implementation in practice before alternative approaches (i.e. biological treatment) for the elimination of trace substances were discussed. The seminar ended with a comprehensive session on costs and financing strategies for the elimination of trace substances.

Figure 45: 47th ATS in the Hainhalle, Ismaning

Young Water Reuse Professionals (YWRP)

Mitarbeiter des Lehrstuhls unter Federführung von Frau Sema Karakurt-Fischer engagieren sich in der 2015 gegründeten **Young Water Reuse Professionals (YWRP)** Gruppe der IWA Water Reuse Special Group (WRSG). Ziel ist die internationale Vernetzung der "Jungwissenschaftler" untereinander sowie der Austausch mit "Seniorwissenschaftlern" und Industrievertretern im Bereich des Wasser Recyclings. Die Aktivitäten beinhalten die Unterstützung von Plattformen und Strukturen für den gegenseitigen Austausch (IWA Connect), WRSG Newsletter sowie Mitarbeit bei der Planung der IWA Water Reuse Specialist Conferences.
Interessierte wenden sich bitte an Sema Karakurt-Fischer: sema.karakurt@tum.de

Sciencecyclists

In 2019, we collectively biked over 26,300 kilometers to and from the chair. This equates to 3.8 tons of CO2 saved in comparison to an average car, and 10 tons of CO2 in comparison to an economy flight. We aim to increase overall and individual contribution in 2020!

Institute Outing – Summer 2019

This year our chair outing on September 17th, 2019 took us over the Höllentalklamm to the Höllentalangerhütte. The tour started in Hammersbach, where we took the railway towards Zugspitzplatt. After a picturesque and somewhat wet ascent through the Höllental, we arrived at the Höllentalangerhütte at noon. With refreshing drinks, a meal and sunshine, we relaxed wonderfully after the hike. Afterwards we learned about the wastewater treatment plant of the Höllentalangerhütte from Steffen Rommel, who worked there for some time.

Figure 46: Chair outing to Höllentalklamm

Upcoming Events

48th Wastewater Technical Seminar (WWTS) on July 15th, 2020

Currently, cities are experiencing above-average growth. In numerous urban centres 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 aim of the seminar is 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.sww.bgu.tum.de/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) Bajón Fernández, Y., Soares, A., Vale, P., Koch, K., Masse, A.L., Cartmell, E., 2019. Enhancing the anaerobic digestion process through carbon dioxide enrichment: initial insights into mechanisms of utilization. Environ. Technol. 40, 1744–1755. https://doi.org/10.1080/09593330.2019.1597173
2) Barros, L.B.M., Andrade, L.H., Drewes, J.E., Amaral, M.C.S., 2019. Investigation of electrodialysis configurations for vinasse desalting and potassium recovery. Sep. Purif. Technol. 229, 115797. https://doi.org/10.1016/j.seppur.2019.115797
3) Grossart, H.-P., den Wyngaert, S., Kagami, M., Wurzbacher, C., Cunliffe, M., Rojas-Jimenez, K., 2019. Fungi in aquatic ecosystems. Nat. Rev. Microbiol. 17, 339–354. https://doi.org/10.1038/s41579-019-0175-8
4) Heeger, F., Wurzbacher, C., Bourne, E.C., Mazzoni, C.J., Monaghan, M.T., 2019. Combining the 5.8S and ITS2 to improve classification of fungi. Methods Ecol. Evol. 10, 1702–1711. https://doi.org/10.1111/2041-210x.13266
5) Heerenklage, J., Rechtenbach, D., Atamaniuk, I., Alassali, A., Raga, R., Koch, K., Kuchta, K., 2019. Development of a method to produce standardised and storable inocula for biomethane potential tests – Preliminary steps. Renew. Energy 143, 753–761. https://doi.org/10.1016/j.renene.2019.05.037
6) Hellauer, K., Martínez Mayerlen, S., Drewes, J.E., Hübner, U., 2019. Biotransformation of trace organic chemicals in the presence of highly refractory dissolved organic carbon. Chemosphere 215, 33–39. https://doi.org/10.1016/j.chemosphere.2018.09.166
7) Hermes, N., Jewell, K.S., Schulz, M., Müller, J., Hübner, U., Wick, A., Drewes, J.E., Ternes, T.A., 2019. Elucidation of removal processes in sequential biofiltration (SBF) and soil aquifer treatment (SAT) by analysis of a broad range of trace organic chemicals (TOrCs) and their transformation products (TPs). Water Res. 163, 114857. https://doi.org/10.1016/j.watres.2019.114857
8) Hien, S., Hansen, J., Drewes, J.E., Koch, K., 2019. BioTOOL—a Readily and Flexible Biogas Rate Prediction Tool for End-users. Environ. Model. Assess. 24, 87–94. https://doi.org/10.1007/s10666-018-9609-3
9) Hiller, C.X., Hübner, U., Fajnorova, S., Schwartz, T., Drewes, J.E., 2019. Antibiotic microbial resistance (AMR) removal efficiencies by conventional and advanced wastewater treatment processes: A review. Sci. Total Environ. 685, 596–608. https://doi.org/10.1016/j.scitotenv.2019.05.315
10) Jensen, M.B., Strübing, D., de Jonge, N., Nielsen, J.L., Ottosen, L.D.M., Koch, K., Kofoed, M.V.W., 2019. Stick or leave – Pushing methanogens to biofilm formation for ex situ biomethanation. Bioresour. Technol. 291, 121784. https://doi.org/10.1016/j.biortech.2019.121784
11) Karakurt, S., Schmid, L., Hübner, U., Drewes, J.E., 2019. Dynamics of Wastewater Effluent Contributions in Streams and Impacts on Drinking Water Supply via Riverbank Filtration in Germany - A National Reconnaissance. Environ. Sci. Technol. 53, 6154–6161. https://doi.org/10.1021/acs.est.8b07216
12) Koch, K., Hafner, S.D., Weinrich, S., Astals, S., 2019. Identification of Critical Problems in Biochemical Methane Potential (BMP) Tests From Methane Production Curves. Front. Environ. Sci. 7. https://doi.org/10.3389/fenvs.2019.00178
13) Lahmouri, M., Drewes, J.E., Gondhalekar, D., 2019. Analysis of Greenhouse Gas Emissions in Centralized and Decentralized Water Reclamation with Resource Recovery Strategies in Leh Town, Ladakh, India, and Potential for Their Reduction in Context of the Water–Energy–Food Nexus. Water 11, 906. https://doi.org/10.3390/w11050906
14) Lindenblatt, C., Drewes, J.E., 2019. N_2O-Vermeidung bei der Behandlung hoch stickstoffreicher Abwässer. Chemie Ing. Tech. 91, 1460–1467. https://doi.org/10.1002/cite.201900071
15) Lippert, T., Bandelin, J., Schlederer, F., Drewes, J.E., Koch, K., 2019. Impact of ultrasound-induced cavitation on the fluid dynamics of water and sewage sludge in ultrasonic flatbed reactors. Ultrason. Sonochem. 55, 217–222. https://doi.org/10.1016/j.ultsonch.2019.01.024

16) Macintosh, C., Astals, S., Sembera, C., Ertl, A., Drewes, J.E., Jensen, P.D., Koch, K., 2019. Successful strategies for increasing energy self-sufficiency at Grüneck wastewater treatment plant in Germany by food waste co-digestion and improved aeration. Appl. Energy 242, 797–808. https://doi.org/10.1016/j.apenergy.2019.03.126
17) Miklos, D.B., Wang, W., Linden, K.G., Drewes, J.E., Hübner, U., 2019. Comparison of UV-AOPs (UV/H2O2 , UV/PDS and UV/Chlorine) for TOrC removal from municipal wastewater effluent and optical surrogate model evaluation. Chem. Eng. J. 362, 537–547. https://doi.org/10.1016/j.cej.2019.01.041
18) Müller, J., Drewes, J.E., Hübner, U., 2019. Investigating synergies in sequential biofiltration-based hybrid systems for the enhanced removal of trace organic chemicals from wastewater treatment plant effluents. Environ. Sci. Technol. Water Res. Technol. 5, 1423–1435. https://doi.org/10.1039/c9ew00181f
19) Müller, J., Jewell, K.S., Schulz, M., Hermes, N., Ternes, T.A., Drewes, J.E., Hübner, U., 2019. Capturing the oxic transformation of iopromide - A useful tool for an improved characterization of predominant redox conditions and the removal of trace organic compounds in biofiltration systems? Water Res. 152, 274–284. https://doi.org/10.1016/j.watres.2018.12.055
20) Müller, J., Levai, S., Titzschkau, L., Popovic, N., Carevic, D., Drewes, J.E., Hübner, U., 2019. Role of reduced empty bed contact times and pre-treatment by coagulation with Fe (III) salts on the removal of trace organic compounds during sequential biofiltration. Sci. Total Enviroment 685, 220–228. https://doi.org/10.1016/j.scitotenv.2019.05.361
21) Oladoja, N.A., Bello, G.A., Helmreich, B., Obisesan, S. V, Ogunniyi, J.A., Anthony, E.T., Saliu, T.D., 2019. Defluoridation efficiency of a green composite reactive material derived from lateritic soil and gastropod shell. Sustain. Chem. Pharm. 12, 100131. https://doi.org/10.1016/j.scp.2019.100131
22) Ricci, B.C., Skibinski, B., Koch, K., Mancel, C., Celestino, C.Q., Cunha, I.L.C., Silva, M.R., Alvim, C.B., Faria, C. V, Andrade, L.H., Lange, L.C., Amaral, M.C.S., 2019. Critical performance assessment of a submerged hybrid forward osmosis - membrane distillation system. Desalination 468, 114082. https://doi.org/10.1016/j.desal.2019.114082
23) Rojas-Jimenez, K., Rieck, A., Wurzbacher, C., Jürgens, K., Labrenz, M., Grossart, H.-P., 2019. A Salinity Threshold Separating Fungal Communities in the Baltic Sea. Front. Microbiol. 10. https://doi.org/10.3389/fmicb.2019.00680
24) Rommel, S.H., Ebert, V., Huber, M., Drewes, J.E., Helmreich, B., 2019. Spatial distribution of zinc in the topsoil of four vegetated infiltration swales treating zinc roof runoff. Sci. Total Environ. 672, 806–814. https://doi.org/10.1016/j.scitotenv.2019.04.016
25) Sembera, C., Macintosh, C., Astals, S., Koch, K., 2019. Benefits and drawbacks of food and dairy waste co-digestion at a high organic loading rate: A Moosburg WWTP case study. Waste Manag. 95, 217–226. https://doi.org/10.1016/j.wasman.2019.06.008
26) Skibinski, B., Uhlig, S., Müller, P., Slavik, I., Uhl, W., 2019. Impact of Different Combinations of Water Treatment Processes on the Concentration of Disinfection Byproducts and Their Precursors in Swimming Pool Water. Environ. Sci. Technol. 53, 8115–8126. https://doi.org/10.1021/acs.est.9b00491
27) Strübing, D., Moeller, A.B., Mößnang, B., Lebuhn, M., Drewes, J.E., Koch, K., 2019. Load change capability of an anaerobic thermophilic trickle bed reactor for dynamic H2/CO2 biomethanation. Bioresour. Technol. 289, 121735. https://doi.org/10.1016/j.biortech.2019.121735
28) Vitas, S., Beckmann, P., Skibinski, B., Goldhahn, C., Muff, L.F., Cabane, E., 2019. Rejection of micron-sized particles using beech wood xylem. Environ. Sci. Water Res. Technol. 5, 944–955. https://doi.org/10.1039/c8ew00774h

Conferences

Oral presentations

1) Achermann, S., Mansfeldt, C.B., Hübner, U., Drewes, J.E., Fenner, K., 2019. Analysis of micropollutant biotransformation kinetics and products reveals reaction-type-specific behavior, in: TransCon 2019. Ascona, Switzerland.
2) Burke, V., Greskowiak, J., Sanz-Prat, A., Rhode, C., Schröter, I., Drewes, J.E., Hübner, U., Sperlich, A., Schimmelpfennig, S., Dünnbier, U., Massmann, G., 2019. Coupling bank filtration to pond infiltration – a usefil option in terms of quality improvements, in: 10th International Symposium on Managed Aquifer Recharge (ISMAR). Madrid, Spain.
3) Drewes, J.E., 2019. Innovationen – Von der Forschung in die Praxis, in: DWA Dialog Berlin 2019. Berlin, Deutschland.
4) Drewes, J.E., 2019. Understanding microbial biotransformation of contaminants in natural and engineered systems - The past, present and future, in: TransCon 2019. Ascona, Switzerland.
5) Drewes, J.E., Hellauer, K., Karakurt, S., Zhiteneva, V., Müller, J., Hübner, U., 2019. Next-generation Managed Aquifer Recharge for Enhanced Trace Organjc Chemical and Pathogen Removal, in: 10th International Symposium on Managed Aquifer Recharge (ISMAR). Madrid, Spain.
6) Drewes, J.E., Schramm, E., Jungfer, C., 2019. Risikomanagement zur Hygiene bei der Wasserwiederverwendung (BMBF-Schwerpunkt), in: DWA Hygienetag. Karlsruhe, Deutschland.
7) Drewes, J.E., Schwaller, C., Helmreich, B., 2019. Möglichkeiten der Stützung lokaler Wasserressourcen, in: IESP Workshop – Bewässerung in Ländlichen Und Urbanen Räumen. Garching, Deutschland.
8) Fajnorova, S., Hübner, U., Wurzbacher, C., Wanner, J., Drewes, J.E., 2019. Fate of antibiotic microbial resistance during ozonation of wastewater treatment plant effluent, in: 11th International Water and Health Seminar. Cannes, France.
9) Hafner, S., Justesen, C., Mortensen, J., Thorsen, R., Koch, K., Weinrich, S., Astals, S., 2019. Sell your GC: Simple and accurate BMP measurement with a scale and syringe, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.
10) Helmreich, B., 2019. Bestandsaufnahme bestehender technischer Maßnahmen und Umsetzung der weitestgehenden Phosphorelimination, in: Seminar Weitergehende Abwasserreinigung. Wien, Österreich.
11) Helmreich, B., Ebert, V., Rommel, S., 2019. Performance of vegetated infiltration swales for treatment of zinc roof runoff, in: Novatech 2019. Lyon, France.
12) Helmreich, B., Rommel, S.H., 2019. Dezentrale Behandlung von Straßenabflüssen im urbanen Raum – wohin geht die Reise?, in: Kolloquium Kommunales Verkehrswesen. Kassel, Deutschland.
13) Holliger, C., de Laclos, H., Koch, K., Hafner, S., 2019. International inter-laboratory studies for standardizing biomethane potential tests, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.
14) Hübner, U., Hellauer, K., Müller, J., Drewes, J.E., 2019. Development of novel treatment concepts based on sequential biofiltration for indirect potable reuse, in: 12th IWA International Conference on Water Reclamation and Reuse. Berlin, Germany.
15) Hübner, U., Hellauer, K., Müller, J., Karakurt, S., Drewes, J.E., 2019. New water treatment concepts to take advantage of functionally-modified microbial communities for enhanced biotransformation of trace organic chemicals, in: TransCon 2019. Ascona, Switzerland.
16) Hübner, U., Müller, J., Drewes, J.E., 2019. Biologische Verfahrensansätze zur Nachbehandlung auf Kläranlagen, in: 47. Abwassertechnisches Seminar: Weitergehende Abwasserbehandlung – Anforderungen, Finanzierung Und Umsetzung. Ismaning, Deutschland.
17) Karakurt, S., Sanz-Prat, A., Ergh, M., Rien, C., Selinka, H.C., Hübner, U., Drewes, J.E., 2019. Coupling high-rate infiltration trench technology with a plug-flow bioreactor (SMARTplus) for indirect potable reuse via groundwater recharge, in: 12th IWA International Conference on Water Reclamation and Reuse.

Berlin, Germany.
18) Karakurt, S., Schmidt, L., Hübner, U., Drewes, J.E., 2019. The status of de facto potable water reuse – A national reconnaissance of Germany, in: 12th IWA International Conference on Water Reclamation and Reuse. Berlin, Germany.
19) Kluge, M., Wurzbacher, C., Stenlid, J., Peura, S., 2019. Accessing poorly studied fungi from a thermokarst site in Abisko, Sweden, by culture and isolation, in: SAME 16 – 16th Symposium of Aquatic Microbial Ecology. Potsdam, Germany.
20) Knoop, O., 2019. Effektorientierte Analytik – Kombination von RP-HILIC-MS/MS mit genotoxikologischem Monitoring, in: Anakon 2019. Münster, Deutschland.
21) Knoop, O., Lutze, H. V, Schmidt, T.C., 2019. Remaining Effects After the Ozonation of Tamoxifen, in: Jahrestagung Der Wasserchemischen Gesellschaft. Erfurt, Deutschland.
22) Knoop, O., Sprafke, A., Hofmann, M., Drewes, J.E., 2019. Ozonation of Fluoroquinolone Antibiotics – Transformation Pathways and Genotoxic Effects, in: 8th Late Summer Workshop: "Chemical and Biological Transformation Processes and Analytical Tools for Their Investigation." Haltern am See, Germany.
23) Koch, K., Hafner, S., Weinrich, S., Astals, S., 2019. Identification of critical problems in BMP tests from methane production curves, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.
24) Koch, K., Strübing, D., Mößnang, B., Lebuhn, M., Drewes, J.E., 2019. Betriebserfahrungen mit der biologischen Wasserstoffmethanisierung im Rieselbettverfahren unter thermophilen Bedingungen, in: Tagungsband Zu Den Biogasinfotagen. Ulm, Deutschland.
25) Koch, K., Strübing, D., Weißbach, M., Drewes, J.E., 2019. Mikrobiologische Methanisierung und der CANDO-Prozess - Neue Möglichkeiten zur Energierück-gewinnung und -speicherung, in: Fachtagung „Co-Vergärung – Chance Oder Risiko? Aktuelle Entwicklungen Aus Deutschland Und Österreich". Ottobrunn, Deutschland.
26) Rommel, S., Helmreich, B., 2019. Drei dezentrale Behandlungsanlagen für Verkehrsflächenabflüsse im Feldversuch – sind die Einzugsgebiete an der gleichen Straße vergleichbar?, in: Aqua Urbanica 2019. Rigi-Kaltbad, Schweiz.
27) Rommel, S., Helmreich, B., 2019. Are different catchment areas at one heavily trafficked road comparable as monitoring sites for stormwater quality improvement devices?, in: Novatech 2019. Lyon, France.
28) Strübing, D., Moeller, A., Mößnang, B., Lebuhn, M., Drewes, J.E., Koch, K., 2019. Anaerobic thermophilic trickle bed reactor as a promising technology for flexible demand-oriented H2/CO2 biomethanation, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.
29) Weißbach, M., Drewes, J.E., Koch, K., 2019. Technische Umsetzung und Entwicklung von Kontrollstrategien für die Integration des CANDO-Prozesses in Abwasserbehandlungs-systeme zur Entfernung von Stickstoff bei gleichzeitiger Energierückgewinnung, in: 52. Essener Tagung Für Wasserwirtschaft. Aachen, Deutschland.
30) Zhiteneva, V., Rodriguez, J., Ehre, M., Drewes, J.E., Hübner, U., 2019. Quantitative chemical exposure and risk assessments of sequential biofiltration within a potable reuse treatment train, in: 12th IWA International Conference on Water Reclamation and Reuse. Berlin, Germany.
31) Zhiteneva, V., Shehata, O., Rodriguez, J., Ehre, M., Drewes, J.E., Hübner, U., 2019. Quantitative exposure and risk assessments of a potable reuse treatment train, in: 11th International Water & Health Seminar. Cannes, France.

Poster presentations

1) Bandelin, J., Lippert, T., Drewes, J.E., Koch, K., 2019. Practical experience with full-scale ultrasonic pre-treatment using a novel reactor design, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.

2) Dandikas, V., Heuwinkel, H., Lichti, F., Drewes, J.E., Koch, K., 2019. Linear regression models for BMP prediction of energy crops, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.
3) Lippert, T., Bandelin, J., Drewes, J.E., Koch, K., 2019. Impact of pressure on the efficiency of ultrasonic sewage sludge pre-treatment, in: 16th IWA World Conference on Anaerobic Digestion. Delft, The Netherlands.
4) Zhiteneva, V., Rodriguez, J., Ehre, M., Drewes, J.E., Hübner, U., 2019. Quantitative chemical exposure and risk assessments on a non-membrane based potable reuse treatment train, in: Jahrestagung Der Wasserchemischen Gesellschaft. Erfurt, Deutschland.

Theses

Doctoral dissertations

1) Hellauer, Karin: Sequential Managed Aquifer Recharge Technology (SMART) – The role of dissolved organic carbon composition and concentration on trace organic chemical transformation
2) Horstmeyer, Nils: Integrating energy recovery concepts into potable water reuse schemes
3) Müller, Johann: Sequential biofiltration – a novel concept for enhanced biological attenuation of trace organic componds during wastewater treatment'

Master's theses

1) Andrianjafidago, Stéphanie: Rainwater management using natural and technical measures under different conditions in industrial areas
2) Bein, Emil: Modeling and performance analysis of gas/liquid membrane contactors for in-situ oxygenation in SMARTplus facility for indirect potable reuse
3) Bell, Birgit: Creation of a nitrogen balance and evaluation of operation data of partial nitritation at the sewage treatment plant Rosenheim
4) Bickert, Nadine: Preparation of a sampling plan for TroCs based on a risk assessment for a drinking water production facility
5) Bleicher, Daniel: Characterization and optimization of a soil column system comprising different redox conditions to assess the removal of trace organic chemicals
6) Ciofalo, Anna: Optimization of UF operating conditions for standard and high permeability membranes
7) Dominke, Martin: Pollution load calculation of the sewer system of the Ingolstadt-Nord wastewater administration - Data collection and processing for Eitensheim, Lippertshofen, Hepberg, Stammham and Appertshofen
8) Eckert, Jennifer: Effects on rainwater discharges from seperate sewer systems into surface waters using DWA-M 153 and DWA-A 102 at the example of Neuburg/Danube
9) Ehdan, Wardah: Tertiary Treatment of Paper Mill Wastewater by Biological Aerated Filtration
10) Eibach, Veronika: Development of a wastewater register to set up a strategy to eliminate existing operating problems of the local MBR plant of the Pharmazell GmbH in Raubling
11) Eibl, Alexandra: Investigation and evaluation of solutions for the prevention and elimination of odors in sewer systems, especially at the end of pressure pipes
12) Even, Max Ernst: Design of bubble column reactors and optimization of CO2 gassing processes in non-Newtonian fluids
13) Feickert Fenske, Carolina: Application of an ultrafiltration membrane for the concentration of biomass in a thermophilic anaerobic trickle bed reactor

14) Gall, Sarah: Gall, Sarah: Biochar filters for the removal of metals and trace organic contaminants from urban stormwater
15) Gillany, Sayd: Potential of UV Disinfection for Biofouling Mitigation in Spiral Wound Reverse Osmosis Membrane Modules
16) Gramm, Mario: Design, implementation and optimization of pre-treatment technologies for a pilot scale SMARTplus facility for indirect potable reuse
17) Hallsdóttir, Bryndís: Two-Fold Wastewater Treatment System Risk Assessment for the Protected Lake, Lake Mývatn in Iceland
18) Hasan, Md Nazmul: Investigation of nitrogen reduction on high salted industrial wastewater
19) Hendrik, Tyas: Real-time monitoring of anammox activity in a two-stage partial nitritation - anammox (PN/A) pilot reactor
20) Hentschel, Anton: Investigation of variants for the waste water management of an inner-city sewer rehabilitation project
21) Hesam Mahmoudinejad, Termeh: Anthropogenic antibiotic-resistance gene pollution in surface waters of Germany
22) Hofmann, Michael: Analysis of transformation products after the ozonation of trace organic compounds
23) Huber, Vinzenz: Development of an investigation concept for the assessment and evaluation of reinforced concrete structures in the drainage system of the Münchner Stadtentwässerung
24) Keller, Ivonne: Assessment of the agricultural irrigation demand in the area of Schweinfurt by using the CROPWAT model
25) Khan, Muhammad: To study the effects of varying proportions of trace element addition on biogas production from the anaerobic co-digestion of rice straw and cow manure
26) Kiesecker, Lea: Method development for simultaneous identification of sorbed pollutants and plastic types via TED-Pyr-GC/MS
27) Lutz, Simon: Development of a prototype of a multiplexed retentostat system for removal of trace organic chemicals in groundwater ecosystems
28) Mahmood, Ammad: Optimization of ultrasonic reactors: Impact of reactor height and pressure on the efficiency of ultrasonic pretreatment of sewage sludge
29) Moeller, Andreas: Fast response capability of anaerobic thermophilic trickle-bed reactors for dynamic H2/CO2 methanation
30) Prahtel, Marlies: Impact of Membrane Selection and Transmembrane Pressure on Micropollutant Removal, DOC Removal and Bromide Passage in Surface Water Treatment
31) Ribesmeier, Matthias: Statistical-stochastic sewer condition forecasts of stoneware sewers
32) Ruan, Pinpin: Investigation for optimization of biological degradation of wastewater from an industrial laundry.
33) Sahanoglu, Hazal: Biomass build up and transformation produce formation as indicators of biodegradation processes in biofilters
34) Schlederer, Felizitas: Design optimization by determination of the flake-related energy input in ultrasonic disintegration technology
35) Schnerider, Bernd: Development of a concept for the risk management of heavy rain for municipalities
36) Schütz, Manuel: Balancing of anthropogenic nutrient immissions at the river Glonn up to the town Petershausen as a basis of action planning to reduce eutrophication (UPIÖ)
37) Seidl, Martin: Maintenance of the German Sewer Infrastructure - Measures and Methods
38) Shehata, Omar: A probabilistic quantitative microbial risk assessment of water reuse: removal of pathogens within a sequential managed aquifer recharge technology for urban water reuse using Bayesian networks

39) Skiebe, Axel: Effects of different CO2 gassing regimes on reactor parameters pH value and ORP, biogas composition and methane production in sewage sludge anaerobic digesters
40) Skrobanek, Patrick: Role of hydrodynamic stresses occuring in GDM filtration in determining the composition and mechanical properties of the biofilm EPS matrix
41) Sprafke, Aileen: Genotoxic Potential Determination for Transformation Products of four Antibiotics by Ozone Degradation
42) Regmi, Ashed: Participatory Approach for Sustainable Water Management and Potential of Water Reclamation with Resource Recovery in Mahabodhi International Meditation Center, Leh, Ladakh, India
43) Templeton, Kathrina: Investigation of sorption processes of micro- and nanoplastic particles via TED-(Pyr)-GC/MS depending on particle size and polymer type
44) Voggenreiter, Ines: Emergency water demand planning for hospitals
45) Wei, Mengqing: Acrylamide removal in drinking water treatment
46) Weiß, Franz: Strategies for the efficient start-up of anaerobic thermophilic trickle bed reactors for H2/CO2 methanation
47) Werheim, Carolin: Investigation and Optimization of Antibiotic Resistance Retainment in Membrane Technology for Waste Water Treatment with Flow Cytometry and Biofilm Measurement
48) Willmes, Hannah: Per- und polyfluorinated compounds in the leachate of Bavarian landfills – survey and treatment options
49) Wörle, Nicole: Development of an adapted method to determine extraneous waters in the drainage area of the Münchner Stadtentwässerung
50) Wu, Zhaoqian: Condition prediction of sewer laterals in Hachinger Tal
51) Xu, Yunqi: Ultrasonic treatment of digested sludge as an alternative to sonication of waste activated sludge – a holistic performance assessment

Study projects

1) Ahmadi, Mohammad: Investigation of artifact formation and changes of relevant characteristics of polystyrene microparticles by various sample preparation and isolation methods
2) Andrianjafidago, Stéphanie: Potential of digester reject water as a cheap mineral medium for H2/CO2 methanation in an anaerobic thermophilic trickled bed reactor Alipour Tesieh, Zahra: Impact of ultrasonic pre-treatment on sludge digestion at the wastewater treatment plant Starnberg
3) Anwar, Ayesha: Effect of CO2 injection on volatile solids removal, COD concentration and methane production during anaerobic digestion of sewage sludge
4) Awais, Usama: CO2 enrichment during anaerobic digestion to increase CH4 productivity: A review on steady state analysis
5) Baba, Mohammed Majiya: Collection and processing (preservation) of urban water and sediment samples for identifying types of fungi: a case study of Munich and Freising
6) Bayram, Berfin: Operation of a sequential biofiltration system with intermediate ozonation for enhanced removal of trace organic chemicals from wastewater treatment plant effluent
7) Dorape Witharanage, Dinithi Bhagya Amarawardana: Integrating rainwater harvesting with water reclamation, nutrient recovery and energy production potential for the Himalayan Institute of Alternatives, Phyang, Leh, Ladakh, India
8) Fanger, Sami: Microplastics under the spotlight: a study of selective fluorescent staining methods for tracking microplastics
9) Gerber, Stefan: Overview of the umu Test for Genotoxicity Screening, Comparison with the Ames Test, and Establishment of a Standard Operating Procedure.
10) Gottfriedsen, Julia Embedding Entrepreneurship Education in the TUM curriculum for Environmental Engineering with regards to the WEF Nexus
11) Hasan, Md Nazmul: Fecal Sludge Management and Resources Recovery: A case Study in Dhaka, Bangladesh
12) Heck, David: Application Report and Benchmark of WTW OxiTop® System
13) Hergeth, Lisa: Development of a preliminary indicator set for the Water-Energy-Food Nexus
14) Khatri, Himani: Impact assessment of CO2 injection on FOS/TAC value and VFA composition as an indicator for changed microbial degradation activity during anaerobic digestion of sewage sludge
15) Liao, Kuan-Po: Ecological interactions between autochthonous microbiota and human viral pathogens in aquatic ecosystems
16) Liu, Dan: Microbial Community of Street Gutter Filtration Systems and Isolation of PAH-tolerant microbes
17) Looi, Shu Wei: Alternative positive control for the standardization of biomethane potential tests
18) Lutz, Jannik: Construction and Performance Testing of Clay Water Filtration Systems - Assessment of a Pilot Project in Ethiopia
19) Mahesh, Ragini Bal: Development and Validation of a Procedure for Accelerated Biofouling Studies Under Fully Controlled and Reproducible Conditions
20) Manghabati, Hamed: Impact of ultrasonic pre-treatment on sludge digestion at the wastewater treatment plant Freising
21) Mayer, Philipp: Parameters influencing trace organic chemical biotransformation in natural treatment systems
22) Moritz, Theresa: Remote sensing for the site potential assessment of decentralized Energy-Water-Food systems - Case study Nsutam, rural Ghana

23) Nguyen, Anh Thang: Physico-chemical chlarification of recycled paper storage yard effluent in a paper mill in Vietnam
24) Noceti, Luca: Analysis of particulate matter, alkalinity and heavy metal speciation in road runoff and stormwater quality improvement devices
25) Nwankwo, Joseph: Investigation of the Aging and Degradation potential of Microplastics (MPs) from various sample preparation methods
26) Rainer, Andreas: Impact of increased organic loading rate on carbon dioxide to methane bioconversion during anaerobic digestion of sewage sludge
27) Rodriguez Ramirez, Juan Miguel: Quantitative chemical risk assessment (QCRA) of water reuse: Trace organic chemical removal within a sequential managed aquifer recharge technology for urban water reuse
28) Ruf, Anastasia: Development and evaluation of concepts for optimizing water management in a market garden
29) Sadat, Sayed: Extended monitoring of biofilter removal performance
30) Schmelzig, Helene: Recommisioning of a SCADA-controlled bioreactor system and technical instructions for using it during the CANDO process.
31) Schott, Sebastian: Analysis of the increase in heavy metal and salt concentrations due to application of precipitants in the chemical phosphate precipitation
32) Shourov, Md. Mosheur Anaerobic digestion of cellulose using the OxiTop® batch system: Impact of headspace flushing on reaction kinetics and methane production
33) Stanojevic, Sarah; Planning and construction of an EcoSan-Toilette for the Toranam-Project in rural India
34) Stauner, Manoel: Stormwater reuse for agricultural irrigation purposes in the regions of Gochsheim and Schwebheim
35) Stinshoff, Philipp: Remobilization of metals under various leaching conditions present during dry periods in stormwater quality improvement devices for traffic area runoff.
36) Stoll, Clara: Analysis of Water-Energy-Food Nexus Tools for Simulation and Visualization
37) Thoma, Mario: Energetic optimization of a wastewater treatment plant

Bachelor's theses

1) Feder, Sandra: Data acquisition regarding molecules from the plant family Nymphaeaceae to create a database
2) Fischer, Moritz: Maintenance effort of decentralized treatment plants for road runoff
3) Galsterer, Susanne: Comparison of bioplastics with conventional plastics in terms of resources and biodegradability
4) Gensch, Christina: Heavy metal contamination in precipitants for chemical phosphorus removal in municipal wastewater treatment plants
5) Hirsch, Patrick; Removal of Antibiotic Microbial Resistance in Membrane Bioreactors
6) Jaafar, Sana: Data acquisition regarding family Brassicaceae metabolites for building up database
7) Kellner, Fabian: Comparative process description and process optimization of a treatment plant for industrial wastewater - focus on cyanide detoxification
8) Kellerer, Marion: Data acquisition regarding molecules from the plant family Vitaceae to create a database
9) Kriegsch, Severin: Deep groundwater use in the Ampertal
10) Kurz, Johannes: Standardization of anaerobic batch tests - Examination of freeze-dried inoculum under practical conditions
11) Manninger, Fabian: Ultrasonic pre-treatment of sewage sludge
12) Ng, Yi Li: The impact of pressure on the efficiency of ultrasonic disintegration of sewage sludge – a literature review
13) Nguyen, Phan-Anh: Microbial transformation of herbicides in soil
14) Reiser, Patrick: Economic considerations of the combined heat and power plant of the wastewater treatment plant Rosenheim
15) Satzl, Christoph: Application, extention and optimization possibilities of natural wastewater treatment systems
16) Vollmer, Jonas: Data acquisition regarding flavonoids to create a database
17) Weiss, Isabell: Pathogen removal in wastewater treatment: Ratios of indicators to reference pathogens
18) Wen, Tan Jun: The Impact of Ultrasonic Reactor Design on the Efficiency of Sewage Sludge Disintegration – A Literature Review
19) Wohlmannstetter, Sebastian: Development of N_20 emissions at nitogen reduction

Dissertations and Awards

Congratulations to **Dr.-Ing. Nils Horstmeyer** for successfully defending his dissertation, titled *‚Integrating energy recovery concepts into potable water reuse schemes'* on March 1st, 2019. His committee members included Prof. Joachim Hansen (University of Luxembourg), Prof. Stuart Khan (University of New South Wales) and Prof. Jörg Drewes.

Figure 47: Commitee of Dr.-Ing. Nils Horstmeyer

Figure 48: Commitee of Dr. rer. nat. Karin Hellauer

Congratulations to **Dr. rer. nat. Karin Hellauer** for successfully defending her dissertation, titled *'Sequential Managed Aquifer Recharge Technology (SMART) – The role of dissolved organic carbon composition and concentration on trace organic chemical transformation'* on March 23rd, 2019. Her committee members included Prof. Martin Jekel (TU Berlin) , Prof. Martin Elsner (TUM) und Prof. Jörg Drewes.

Congratulations to **Dr.-Ing. Johann Müller** for successfully defending his dissertation, titled *'Sequential biofiltration – a novel concept for enhanved biological attenuation of trace organic componds during waterwater treatment'* on December 9th, 2019. His committee members included Thomas Ternes (BfG), Prof. Martin Jekel (TU Berlin) and Prof. Jörg Drewes.

Figure 49: Commitee of Dr.-Ing. Johann Müller

Figure 50: Picture: Willy-Hager-Award for Dr.-Ing. M. Weißbach (Source: Wasserchemische Gesellschaft)

Dr.-Ing. Max Weißbach received the **Willy Hager Prize 2019** for outstanding work in the field of process engineering for (industrial) water or wastewater treatment for his doctoral thesis. He defended his thesis on June 24th 2018 with distinction (*summa cum laude*) and bears the title „Technical implementation and development of control strategies for the integration of the Coupled Aerobic-anoxic Nitrous Decomposition Operation (CANDO) into wastewater treatment schemes for the simultaneous nitrogen removal and energy recovery from nitrogen.“

Figure 51: Philipp Sperle (middle) with Dean Prof. Dr. Christoph Gehlen (right) and Prof. Dr. Gebhard Wulfhorst at Day of the faculty 2019 (Source: Andreas Heddergott)

Philipp Sperle, M.Sc., received this year's **H.P. Scholz Prize** for Special Study Achievements for his master's thesis titled "Development and Investigation of Vibration Based Membrane Fouling Mitigation and Cleaning Strategies." In 2018, Philipp finished the study program Environmental Engineering (Master) as the best in his year. He completed his master's thesis under the supervision of Prof. Jörg E. Drewes.

Figure 52: Picture: from right side: Michael Mall, Johann Lechner, Anastasia Ruf, Christian Rossmanith and Prof. Dr. Wulfhorst at the day of the faculty 2019 (Source: Andreas Heddergott)

The **Roland Mall Foundation** presented three gifted students from the field of water and environment each with a scholarship of €500/month for the entire standard period of study of the Master's program. The students (**Johann Lechner, Anastasia Ruf and Christian Rossmanith**) were selected based on their previous accomplishments. The scholarships were personally presented by Mr. Michael Mall, Chairman of the Foundation Board at the day of the faculty 2019.

We are delighted that the **German Research Foundation (DFG)** has awarded an Emmy Noether fellowship to one of our employees. From January 2020, **Assoc. Prof. Dr. Christian Wurzbacher** will begin the Emmy Noether Microbial Systems working group for an estimated period of three plus three years. We are pleased to welcome him as a TUM Junior Fellow in our ranks!

Figure 53: Picture: TUM Junior Fellow Dr. Christian Wurzbacher (Source: Andreas Heddergott)

Teaching

The Chair of Urban Water Systems Engineering offers a wide range of different courses for the Bachelor study program Umweltingenieurwesen and Bauingenieurwesen as well as for the Master programs Environmental Engineering, Civil Engineering, Environmental Planning and 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 2019, the following lectures were offered:

Summer Term

Bachelor

- Thermodynamic and Energy Technology (BSc): Hübner, Uwe
- Project Course Urban Water Systems Engineering (BSc): Drewes, Jörg
- Environmental Analyses (BSc): Knoop, Oliver
- Environmental Law (BSc): Spieler, Martin (external lecturer)

Master/PhD

- Advanced Water Treatment Engineering and Reuse (MSc): Drewes, Jörg
- Anaerobic Treatment and Energy Recovery (MSc): Koch, Konrad
- Hydrochemistry Lab (MSc): Helmreich, Brigitte; Knoop, Oliver; Hübner, Uwe; Petz, Susanne
- Industrial Wastewater Treatment and Reuse (MSc): Helmreich, Brigitte
- Planning of Sewer Systems and Rainwater Management (MSc): Helmreich, Brigitte
- Modelling of Aquatic Systems (MSc): Koch, Konrad
- PhD Seminar SiWaWi (PhD/MSc): Drewes, Jörg; Koch, Konrad
- Wastewater Treatment (MSc): Koch, Konrad
- Unit Operation Lab (MSc): Hübner, Uwe
- Colloquium for master and PhD students (MSc/PhD): Drewes, Jörg; Helmreich, Brigitte; Koch, K., Hübner, Uwe; Knoop, Oliver; Wurzbacher, Christian; Keilman-Gondhalekar, Daphne
- Riverwater Protection (MSc): Gschlößl, Tanja (TUM-Lehrbeauftragte)

Winter Term

Bachelor

- Basics of Process Engineering (BSc): Böhm, Bernhard (external lecturer); Koch, Konrad
- Microbiology (BSc): Wurzbacher, Christian
- Ecology (BSc): Wurzbacher, Christian; Knoop, Oliver
- Urban Water Systems Engineering - Base Module (BSc): Helmreich, Brigitte; Koch, Konrad

Master/PhD

- Engineered Natural Treatment Systems (MSc): Hübner, Uwe
- Hydrochemistry (MSc): Helmreich, Brigitte
- Hydrochemistry Laboratory (MSc): Helmreich, Brigitte; Knoop, Oliver; Hübner, Uwe; Petz, Susanne
- PhD Seminar SiWaWi (PhD/MSc): Drewes, Jörg; Koch, Konrad;
- Practical Aspects of Engineered Natural Treatment Systems (MSc): Hübner, Uwe
- Sanitation in the Global South (MSc): Drewes, Jörg; Hübner, Uwe; Karakurt-Fischer, Sema; Zhiteneva, Veronika; Lippert, Thomas; Muntau, Meriam; Bein, Emil; Aniol, Jonas; Sperle, Philipp; Al-Azzawi, Mohammed;
- Technical Communication Skills in Water and Wastewater Treatment (MSc): Drewes, Jörg; Koch, Konrad
- Modelling of aquatic systems (MSc): Koch, Konrad
- Water and Wastewater Treatment Engineering (MSc): Drewes, Jörg
- Colloquium for master and PhD students (MSc/PhD): Drewes, Jörg; Helmreich, Brigitte; Koch, K., Hübner, Uwe; Knoop, Oliver; Wurzbacher, Christian; Keilman-Gondhalekar, Daphne
- River Water Quality Management (MSc): Gschlößl, Tanja (TUM-Lehrbeauftragte)

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Friends of the Chair

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

Membership is open to anyone who supports the goals of the foundation. Funds of the foundation are used to:

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

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

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

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

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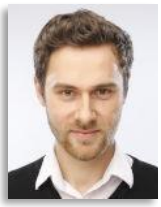

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