Technische Universität München

forum 86

Newsletter of the Chair of Urban Water Systems Engineering

ANNUAL REPORT OF THE CHAIR OF URBAN WATER SYSTEMS ENGINEERING

2015

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Foreword

February 2016

Dear Friends,

I'm happy to present to you our most recent issue of our newsletter **forum** to provide you with an update regarding exciting recent activities at the Chair of Urban Water Systems Engineering at TUM.

Congratulations to Dr.-Ing. Mohamad Rajab, who successfully defended his doctoral dissertation in July 2015. We also congratulate Stefan Böhm, who received the Max-von-Pettenkofer Award of the German Association of Water, Wastewater and Waste (DWA) for his master thesis and Therese Burkhardt, who was awarded the Laura Bassi Frauenförderpreis at TUM.

After more than 9 years of highly valuable contributions to the Chair of Urban Water Systems Engineering, Dr. Elisabeth Müller moved on to a new position last October. We are very thankful to Lisa for her dedication and her leadership in establishing and directing the research group ‚Microbial Systems'. Starting Jan. 1, 2016 Dr. Bastian Herzog, who just completed a two-year post-doc appointment in Canada, took over to direct the microbiological laboratory and the ‚Microbial Systems' research group. Unfortunately, due to health issues Mrs. Petra Frömel had to step down as the administrative assistant of our foundation last year. On behalf of the board of directors, we are very thankful for her support over the years, in particular for organizing our annual conference on Wastewater Treatment (Abwassertechnisches Seminar – ATS). We are also happy that we were able to hire Mrs. Raphaela Hofmann, who will take over these duties in February 2016.

In July 2015, we hosted our 43rd Conference on Wastewater Treatment focusing on *„Energy-efficient Processes to Remove Nitrogen"*, which has been organized by Dr. Konrad Koch. For this event, we managed to line up internationally leading experts on the topic from Switzerland, Austria and Germany. This year's conference, scheduled for July 14, 2016, will focus on *„Energy transition – the role of wastewater treatment facilities in providing energy on demand".* You can find copies of the technical program in this annual report and on our website. We appreciate your interest in this exciting event and would be delighted to see you at this event.

In 2015, we completed a productive year in research and acquired a couple of new grants, for example the project FOR-IDENT (led by Prof. Thomas Letzel) funded by the German Ministry of Research (BMBF), a project on microbial methanation (led by Dr. Konrad Koch) funded by the Bavarian State Ministry of Economy and Energy, and a large instrument grant of the German Science Foundation (DFG) to fund a new LC-MS/MS Q-Trap system. With more than 40 peer-reviewed journal articles in print in 2015, we continued to translate our research into publications at a high level.

Last year, TUM launched a new initiative, the TUM Water Cluster, to better coordinate water research at TUM across three colleges (Civil, Geo and Environmental Engineering, Life Sciences and Chemistry), and to engage in strategic research areas. You can learn more about this initiative at the new website http://www.water.tum.de. Jörg Drewes is currently serving as the speaker of the TUM Water Cluster.

Staff members of the chair continued to deliver substantial shares of the curriculum for the education of bachelor students in Civil and Environmental Engineering and master students in Environmental Engineering, Civil Engineering, Environmental Planning and Engineering as well as Sustainable Resource Management. Beside a large number of lectures and laboratories, we advised a total of more than 90 master thesis, master study projects and bachelor thesis last year.

On behalf of my colleagues, I'd like to thank you for your interest in our students and our research. In particular, we are grateful for your support to our foundation. These funds are used to assist our PhD candidates and graduate students regarding travel support to participate in conferences and as seed funds for new research ideas.

Please enjoy reading about the latest developments at the Chair of Urban Water Systems Engineering.

With 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 both for 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 collaborations with industry, 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 Wastewater Treatment Plant Garching (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).

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).

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

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 in different 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.

Chemical-physical, Analytical and Microbiological Laboratory

A central facility of the chair and the research center is the affiliated laboratory, with three areas of activities: the chemical-physical laboratory led by Karin Hellauer, the analytical and microbiological laboratories led by Prof. Dr. Letzel and Dr. Müller, respectively.

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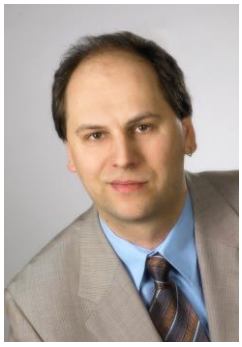

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The chemical-physical laboratory is equipped with state-of-the-art analytical apparatus. This enables the investigation of all standard parameters relevant in drinking water and wastewater. The determination of general parameters in water is performed for instance through application of an atomic absorption spectrometer (Figure 2), for the analysis of metals and an ion chromatograph for the analysis of relevant anions. For quantification of organic carbon the laboratory has the equipment for the determination of sum parameters like BOD, COD, and TOC, but also for the analysis to further characterize organic matter using 3-D fluorescence and UV spectroscopy.

Figure 2: Graphite furnace AAS for the analysis of metals

In the analytical laboratory, GC-MS, (LC-)LC-TOF-MS, (TOF-MS in Figure 3) as well as LC/MS-MS systems are available for target, suspected target und non target screening measurements. These are applied for characterization and identification of organic molecules in water matrices. New and established strategies, data workflows as well as methods enable the investigation of various molecules in variable water matrices.

Figure 3: TOF-MS system for trace analysis

The microbiological and molecular biological laboratory provides conventional cultivation techniques to detect fecal indicator bacteria (*E. coli* and enterococci) and pathogen bacteria (e.g. *Pseudomonas aeruginosa*, *Legionella* spp.) to monitor water quality. Furthermore, molecular biological techniques e.g. Fluorescence in situ Hybridization (FISH) combined with fluorescence microscopy are established and used for semi-quantitative analysis of different bacteria groups relevant in the biological wastewater treatment process (e.g. nitrifiers, ANAMMOX bacteria, methanogenes and sulfate reducing bacteria). Specific bacteria groups e.g. enterococci can be detected quantitatively by real-time polymerase chain reaction (PCR, Figure 4). In addition, PCR combined with denaturing gradient gel electrophoresis (DGGE), as well as next-generation sequencing (amplicon sequencing on MiSeq Illumina) is used to characterize microbial community structure and function in natural and engineered systems.

Figure 4: Thermal Cycler Real-Time System CFX96: quantitative PCR (qPCR)

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COOPERATION:
EAWAG, SWITZERLAND;
STANFORD UNIVERSITY, USA;
BAVARIAN STATE RESEARCH CENTER FOR AGRICULTURE, GERMANY

Research Group
Anaerobic Technologies & Energy Recovery

Reliable treatment of municipal and industrial wastewater for discharging with no harm to the environment remains the main goal of wastewater treatment. However, wastewater treatment plants (WWTPs) are one of the major municipal energy consumers, while currently only little energy is recovered (mainly as methane). Using different approaches, options to enhance energy recovery from wastewater streams is investigated.

Besides further increasing methane yields, innovative energy-saving treatment techniques, aiming on the allocation of valuable products, are developed and tested at lab and pilot scale. One approach for instance, is the so-called CANDO process, which results in the intentional production of nitrous oxide from ammonia-rich water and has been developed by our collaborators at Stanford University. While economic aspects play an important role, threats to the environment (for instance by excessive emissions of greenhouse gases) are also considered. We view wastewater as a resource that can help converting WWTPs into “energy autarchies” in the future.

Due to an increasing amount of power generated from renewable resources in Germany, matching production and the highly fluctuating energy demand from industry and private households will become more and more challenging. Currently, various available energy conversion and storage technologies (e.g., batteries, pump storage hydro power systems) are only applicable as short- or midterm storage due to limited capacity. In contrast, the gas grid in Germany provides one of the largest long-term storage capacities available. In this context, one project aims to further study and develop the microbial generation of methane (as a storable gas) directly from hydrogen and carbon dioxide, which could be an efficient alternative to the well-known Sabatier reaction (chemical-catalytic process). The required hydrogen can be generated in times of excess power via electrolysis, the carbon dioxide streams could be used directly at the point of generation (e.g., industries, biogas plants). This research focusses especially on the investigation of flexible (on demand) and efficient operation of the microbial methanation process, being envisioned to be applied as a future energy conversion and storage technology.

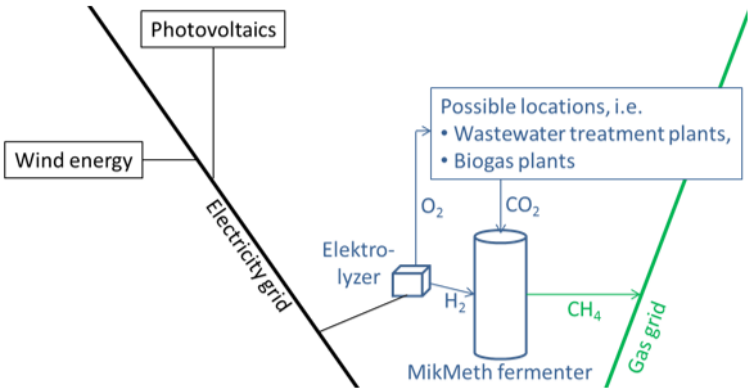

Figure 5: Power-to-gas concept

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Nitrous oxide – an innovative ressource for energy recovery from wastewaters (PANOWA)

Nitrous oxide (N_2O) is emitted in biological nitrogen removal processes and considered an undesired intermediate or side-product. With a greenhouse gas potential 300 times higher than carbon dioxide, an atmospheric resistance time of 114 years and its potential of ozone depletion, N_2O emissions should be reduced as much as possible to mitigate their negative influence on the environment. However, nitrous oxide can also be used as an energy source and is a common co-oxidant in rocket engineering and car racing. Thus, we investigate the potential for the intended production of nitrous oxide with as well as extraction strategies.

An experimental setup built upon design experiences at Eawag (Switzerland) had been established. This set-up consists of six fully automated reactors with a volume of 13 L each (Figure 6). The lab-scale research facility is automatically controlled by the software CitectSCADA, which is not only controlling the automation, but also acquires and logs all online measurements (including oxygen, ammonium, nitrate, redox potential, conductivity, pH, water level, temperature and N_2O) (Figure 7). For the online measurement of N_2O, an innovative laser-based photoacoustic cell with high temporal resolution developed by the Chair of Analytical Chemistry (TUM) is employed.

Figure 6: Experimental setup

The investigative focus is on process stability and sludge specific process kinetics, the applicability of real and local carbon sources as well as the characterization of the microbial community and determination of key organisms within the process.

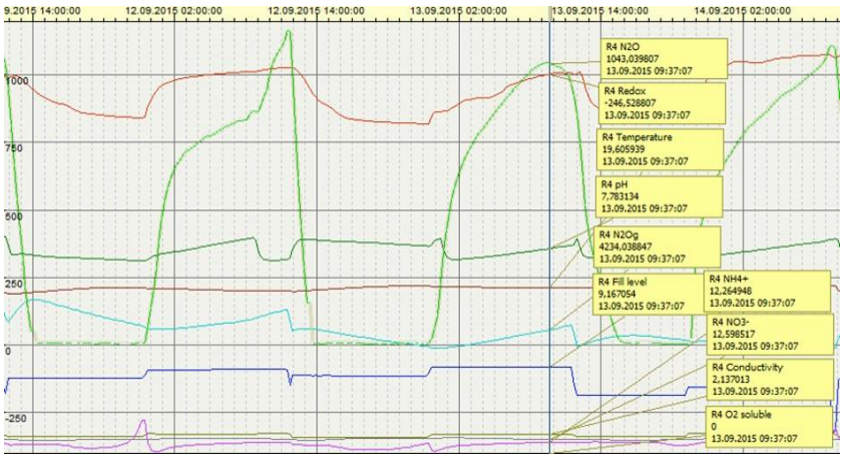

Figure 7: Visualization of all online measurements in CitectSCADA

Development of innovative strategies to minimize nitrous oxide emissions during deammonification

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High-strength ammonium loaded process water may be efficiently pretreated during a sidestream deammonification process in order to reduce the nitrogen back load of a mainstream wastewater treatment plant. Advantages of this approach compared to conventional nitrification/denitrification are significantly reduced cost for additives, energy and sludge disposal.

However, nitrous oxide (N_2O) can be formed as an intermediate and undesired by-product during the biological nitrogen removal process with the potential to be emitted with the off-gas. Due to its higher global warming potential by a factor of 300 compared to carbon dioxide, its persistence for approximately 114 years in the atmosphere and the ozone layer-depleting effect, it has a highly negative long-term impact on the environment. These facts highlight the necessity to minimize nitrous oxide as much as possible. Therefore, the aim of the project is to develop effective prevention strategies without negatively affecting the performance of the removal process, thus, the overall nitrogen turnover rates of the deammonification.

The influence of different operational settings (pH value, aeration and feeding strategy) of a one-stage deammonification is investigated with regard to the nitrogen conversion rate as well as the nitrous oxide emissions. These findings will result in a model for the optimization of the process. Gaseous nitrous oxide is detected with a photoacoustic cell developed by the Chair of Analytical Chemistry at TUM. The dynamic production of nitrous oxide in the liquid phase is measured using microsensors (Unisense A/S, Denmark) in order to derive additional prevention strategies.

Furthermore, fluorescence in situ hybridization (FISH) for the visualization, characterization, and semi-quantitative specification of microorganisms involved in the process was established and carried out. Figure 8 depicts the strong dominance of the interacting microorganisms of ammonium oxidizing bacteria (AOB) and Brocadia fulgida as typical representative of the anaerobic ammonium oxidation (anammox) in the biological community of the biofilm.

Apart of single-stage deammonification, also the two-stage process is of significant interest for operation, which is why we also examine its potential to produce and emit nitrous oxide (see page 9).

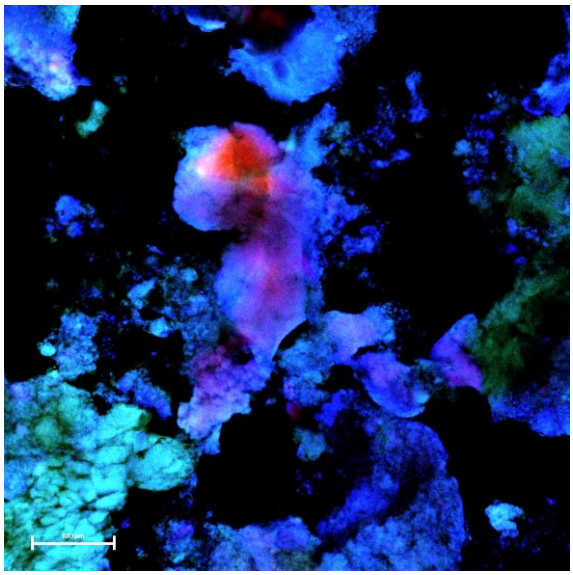

Figure 8: Bacteria (blue), AOBs (green), Brocadia fulgida (red), detected with FISH.

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Deammonification with SBR-Cascade and Granule-Loop-Reactor

With the operation of a SBR-Cascade including a Granule-Loop-Reactor since the beginning of 2015, we were able to demonstrate that a two-step deammonification process with separated biomass is more comfortable to maintain. Based on the total reactor volume needed, the performance of a two-step process compared to the one step approach is more than 30 % higher.

The first step of the two SBR´s with 31 L volume (Figure 9) is running without mixing as a simply aerobic treatment. After settling, the bottom-up feeding replaces the supernatant water. At a specified load of about 1,000 $g_N/(m^3 \cdot d)$, the process control is carried out controlling the intensity of aeration and surplus sludge removal. Because of the pH-drop, a limitation of efficiency is given in the first process step, which should be operated at pH values higher than pH 6.8. In the second step, granules (sieve residue > 0.2 mm) were accumulated after one year of operation up to 80 %.

Figure 9: SBR-Cascade with Granule-Loop-Reactor

Preliminary N_2O-measurements revealed that emissions from the second step can be reduced with an adequate anoxic reaction time. Thereby, the oxidation-reduction-potential provides a sensitive signal (Figure 10) at the absence of dissolved N_2O and is also useful for the control of excess sludge withdrawal.

Beside the online sensors for pH, conductivity, ORP, and temperature the other wastewater relevant parameters are analyzed once a week. In practice, it is highly recommended to equip a deammonification plant with a control for air volume.

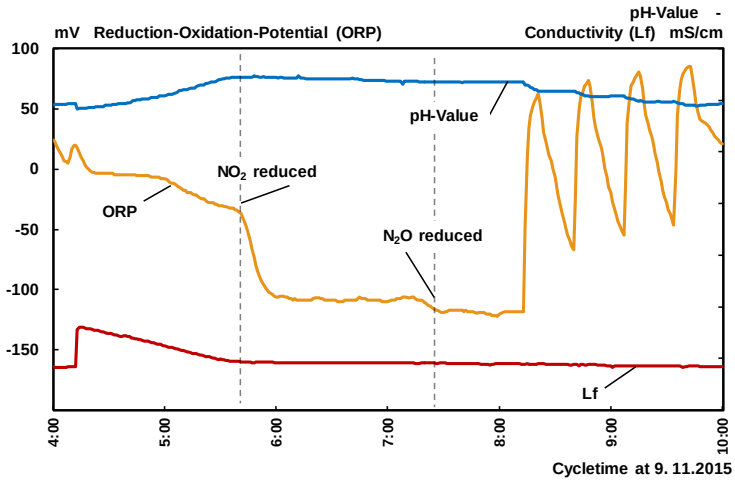

Figure 10: Online signals at one cycle in the second step

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Tailored energy supply by microbial methanation of H_2 and CO_2 using 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, one of the largest long-term storage capacities available, currently up to 230 billion kWh or 25% of the annual gas consumption can be stored. In this context, the project aims to further study and develop the microbial generation of methane as a storable gas. The only educts will be hydrogen, generated in times of excess power via electrolysis and carbon dioxide from different sources (e.g., industries, biogas plants).

Figure 11: Trickle bed reactor

By establishing this process within an anaerobic trickle bed reactor, the system can be operated without pressurized gas supply, possibly increasing the energy efficiency compared to previously studied systems. A methanogenic archaea biofilm will form on the trickle bed support material and due to a larger gas-liquid interface surface area an improved hydrogen mass transfer can be expected.

The experiments will be performed at pilot scale (50 L reactor volume; Figure 11). With regard to process efficiency and applicability the influence of different inocula, process temperatures as well as CO_2-sources will be investigated. Furthermore periods without gas supply and their impact on the microbial community and methane generation will be studied, being an essential criterion for a flexible "on demand" operation.

Our collaborator, the Bavarian State Research Center for Agriculture, will also investigate the microbial composition, focusing on enriching dominant species of hydrogenotrophic methanogenic archaea during long-term and intermittent operation and to better determine micro and macro nutrient requirements.

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ETHIOPIAN MINISTRY OF EDUCATION; GERMAN ACADEMIC EXCHANGE SERVICE

COOPERATION:
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Multi sectorial approach for management of wastewater in Addis Ababa, Ethiopia

Addis Ababa is the capital of Ethiopia with currently 3.2 million inhabitants and a total area of 530 km². Migration into the city causes continuous challenges for both water supply and wastewater drainage among others. The Addis Ababa Water Supply and Sewerage Authority provides services of potable water supply, collection and disposal of wastewater (mainly human excreta). However, only about 6% of the wastewater is currently collected and disposed properly by sewerage system (sewer lines), while about 80% of the wastewater is collected via trucks (Figure 12). Hence, 14% of the community's wastewater is not collected at all. Consequently, about 11,000m³ of wastewater per day are discharged untreated causing odor problems and representing a serious issue to public health. Furthermore, the existing treatment facilities have a capacity to treat only about 65% of the collected wastewater using relatively simple open pond systems (Figure 13).

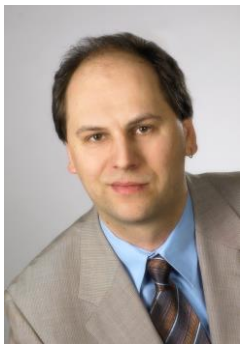
Figure 12: Wastewater collection in Ethiopia

This project aims to develop a suitable approach to reduce wastewater-related issues, such as health and environmental hazards. In a first step, the wastewater flow will be quantified and the major problems of the current wastewater management system in Addis Ababa will be identified. Based on a literature survey, simple, but robust approaches applied in other developing countries will be reviewed and assessed concerning its applicability for Addis Ababa. Due to the unique geography of Addis Ababa in a very mountainous region, decentralized treatments systems might be advantageous over centralized ones. For instance, a simple treatment system consisting of a combination of septic tank and upflow anaerobic sludge blanket reactor has been already successfully applied in Nepal.

Figure 13: Open pond system for wastewater treatment

The most suitable approach will be chosen and will be implemented at a small scale for demonstration, i.e. at the university campus. Finally, municipalities and stakeholder will be invited to discuss how the developed approach can be implemented in the near future.

Analytical Research Group (AFG)



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The Analytical Research Group (AFG) is currently comprised of - including external PhD students - 10 members (as well as practical students, bachelor and master students). The research group has received funding from third parties including DFG, BMBF, EU, BFS, AiF/BMWi, WiFö, foundations and private industry.

Currently, the key aspects in research are addressing the development of technological, analytical-methological and analytical-chemical approaches that can be applied in water and wastewater analysis as well as in other relevant environmental and food matrices. A special focus is on the chemical analysis with simultaneous functionality analysis using mass spectrometric detection.

Current topics of interest are:
1) Analytical platform development for targeted analysis of organic molecules in complex matrices (‚Target-Screening‘),

2) Analytical platform development for the analysis of expected organic molecules in complex matrices (‚Suspected-Target-Screening‘ including databases like 'STOFF-IDENT'),

3) Analytical platform development for the non-targeted analysis of organic molecules in complex matrices (Non-Target-Screening‘),

4) Analytical platform development for the analysis of organic molecules in complex matrices with simultaneous functionality analysis by mass spectrometric detection,

5) Software development of modular working tools for data analysis (‚Retention Time Index RTI', ‚Achroma‘ and ‚FOR-IDENT‘),

6) Application of analytical platforms (1-3) in the research area of oxidative and biological treatment of water and the development of sustainable strategies,

7) Application of analytical platforms (1-4) in the research area of ingredient analysis and the search for biofunctional active compounds in environmental samples, after treatment, in plant extracts and beverages.

Finally, our projects in our community service initiative ‚Wissenschaft vermitteln‘ are worth mentioning, with visits in the Kindergarten or basic schools via ‚Kinderuni on Road‘ or basic analytical courses for young apprentices (http://www.sww.bgu.tum.de/wissenschaft-vermitteln/).

Development of an e-learning platform in the area of analytical chemistry (Analytics+)

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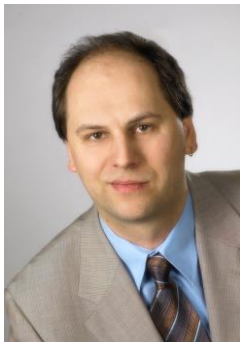

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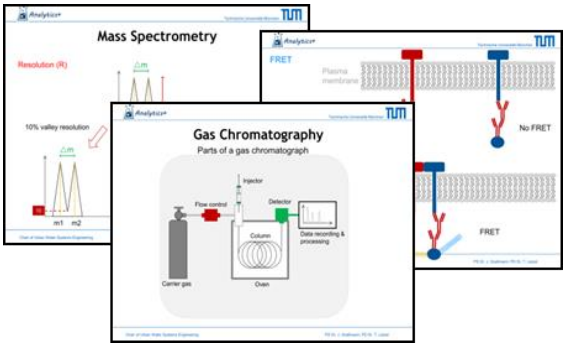
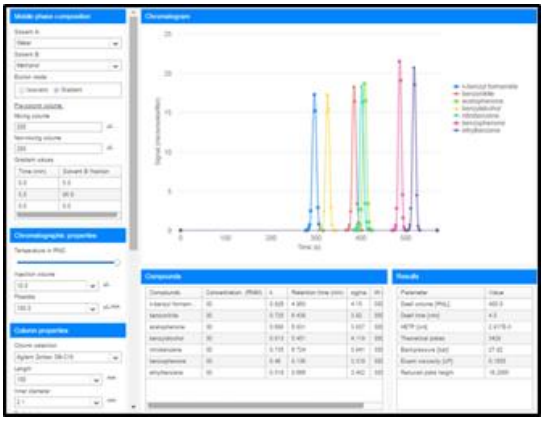
The e-learning platform Analytics+, which was already introduced in the last annual report, has been further developed during this year and will still be funded by TUM Lehrfond throughout 2016. The content is divided into three levels, which were further expanded to convey the provided knowledge in a sustainable and playful manner. The platform is designed for mainly students and trainees of TUM with interest in analytical and bioanalytical topics. A TUM access code is currently a prerequisite for the utilization of Analytics+.

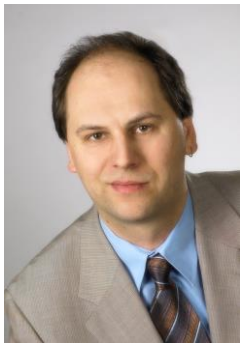
The content of **level 1** is presented clearly and comprehensively in textual and graphical form and contains basic chemical knowledge and learning content about (bio-) analytical topics. This level provides chromatographic methods as well as slides regarding e.g. mass spectrometry, electrophoretic separation methods and immunoassays. The self-made content is furthermore augmented with external content like tutorial videos of analytical techniques, altogether supporting the acquisition of a broad knowledge.



Level 2 allows the recapitulation and deepening of the acquired knowledge. For one this is achieved by the implementation of a glossary, which briefly and concisely explains the most important terms. Furthermore a “HPLC simulator” software tool is provided, which allows to directly observing the effects of manually adjusted HPLC parameters on a chromatogram. The software tool features were customized to be applicable and comprehensible for Analytics+ users, aiming for an easy understanding of HPLC parameters and their respective effects on chromatographic separation. Adjustments of the tool were made in collaboration with the Applied University of Weihenstephan-Triesdorf. The content of **level 3** includes a quiz, which encourages the user to test their acquired knowledge. Simultaneously it provides the possibility to solidify the understanding of the subject matter. Furthermore, HPLC simulator tool allows the planning and conduction of a virtual HPLC experiment by applying the understanding obtained in level 2, beginning with the solubility of different analytes. Thus, level 3 creates a test situation, which provides instantaneous feedback for each step of the experimental planning of a chromatographic separation to strengthen the learning effect.



FOR-IDENT – New strategies and workflows in the ‘Hidden-Target-Screening’ approach



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COLLABORATION:
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LFU;
LW;
TUM

The project FOR-IDENT is a project funded by the BMBF for two years building upon the activities of the precursor RISK-IDENT project relating to the establishment of guidelines and the integration of the database STOFF-IDENT in an extended working platform. Additional software-tools and databases are developed as part of the working platform ‘FOR-IDENT’. Furthermore, tools are linked to provide data analysis workflows for the evaluation of LC-MS data. New strategies and workflows may help the user of non-target screening approaches to identify molecules much easier and faster. 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 nonpolar molecules (RPLC).

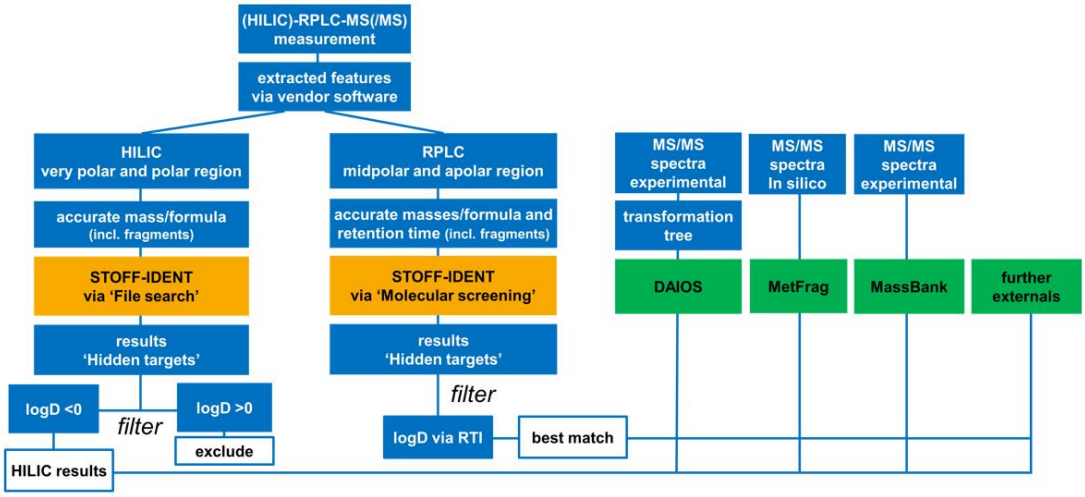

Figure 14: Illustration of two established workflows in Non-Target-Analysis on the FOR-IDENT platform

The core of FOR-IDENT is the database STOFF-IDENT, which was developed within the RISK-IDENT project. Hereby, molecules -suggested in water samples by STOFF-IDENT- can be identified by different analytical approaches. Furthermore, analytical MS/MS-databases like MassBank and MetFrag are integrated as well. This allows the usage of chemical, physico-chemical and analytical metadata at the same time. In addition, a database, called DAIOS, will be integrated into the platform as well. This database contains transformation products identified in environmental samples and in water treatment processes. The FOR-IDENT project will further implement additional features, for example an ecotoxicological database.

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Analytical Strategies in the Non-Target, Suspects and Target Screening using RPLC-HILIC-API-MS

Analytical chemistry has improved greatly the last decade, however, a comprehensive identification of the organic content in waters is still challenging, especially if one considers not only the thousands different possible water contaminants, but also their metabolism and transformation products.

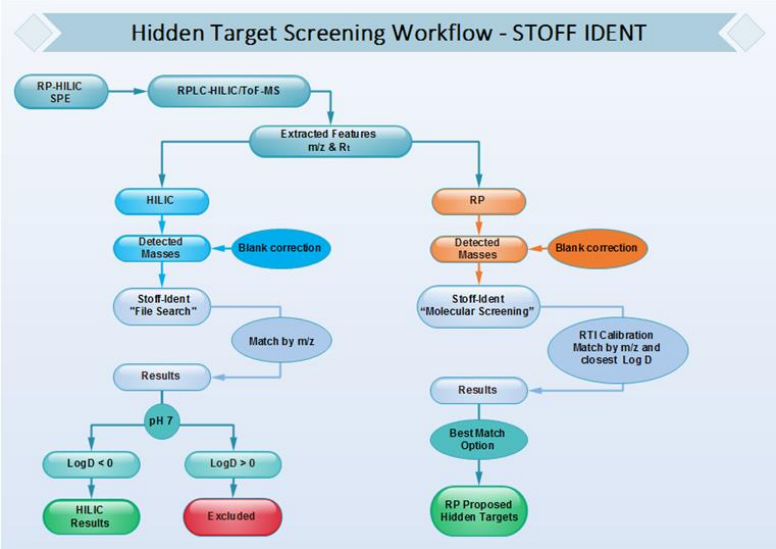

Figure 15: Hidden Workflow Strategy using HILIC-RPLC-MS.

Until now most of the compound screening that were applied on water samples have been targeted. Only due to recent advances in accurate and high resolution mass spectrometry, the idea of non-target screening by LC-MS of samples has become popular in order to provide a more complete view of the organic contents of different water bodies. These organic compounds that are present in a sample are defined as “Hidden Targets”, as they are known in the chemical literature or MS reference databases, but unknown to the researcher regarding a specific sample. Surface water samples - like from thirteen sampling locations along the river Isar (Bavaria) and its tributaries - are analysed by RPLC-HILIC-API-MS in order to detect various highly polar, mid-polar and nonpolar organic compounds. Subsequently, the Non-Target Screening data analysis is applied with the help of the STOFF-IDENT database and various other tools performing specific data analysis workflows. For example, extracted exact masses from the very polar compounds (logD<0) eluting from the HILIC column were analysed in this database. The returned results were then filtered and any suggested compounds with a positive logD were rejected. For the compounds with a positive logD the results were obtained from the database by not only using the exact mass, but also a Retention Time Index (RTI), which takes advantage of the known retention time and logD correlation in RPLC, giving much more probable results. Currently, the results of the STOFF-IDENT database can be classified by categories, like industrial chemicals, pharmaceuticals, transformation products and others.

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Parallel detection of very polar and nonpolar trace organic compounds in water samples by SFC-MS

Detection of trace organic compounds are of emerging concern for the analysis of water samples. These compounds are residues of pharmaceutical, everyday-chemicals, pesticides or others and can be found in waterbodies in a concentration range from ng/L to µg/L. For the analysis of trace organic compounds, mainly reversed phase chromatography, coupled to mass spectrometry is commonly utilized. This technique is well suitable for the detection of medium to nonpolar compounds, but not for very polar to polar ones. The more knowledge about trace organic compounds and their origin increases, the more obvious it becomes that also very polar compounds are likely to occur in waterbodies and influence water quality.

Since current analytical tools are hardly capable of detecting these compounds, alternative techniques have to be established and evaluated. One option here is supercritical fluid chromatography (SFC), a separation technique, which uses carbon dioxide above or near the critical point as mobile phase. Analytical SFC is commercially available for only several years by now, and the technique is not completely understood yet.

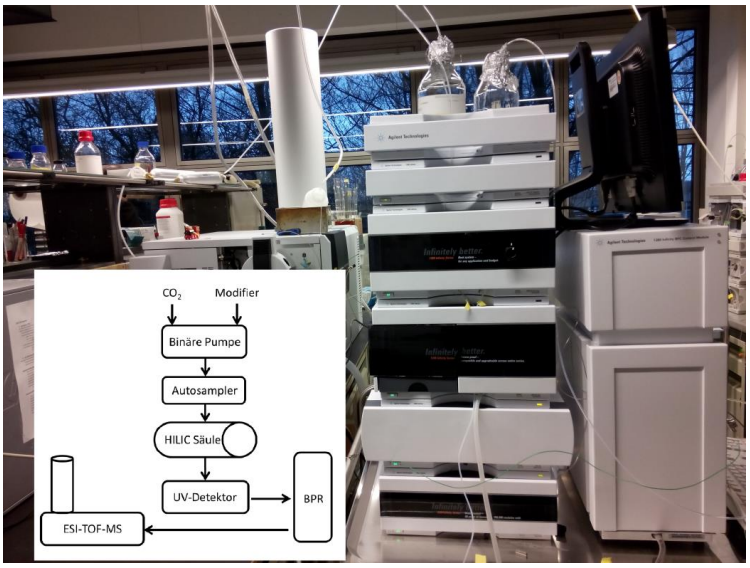

Figure 16: SFC with mass spectrometric detection in our lab

At the Chair of Urban Water Systems Engineering, SFC coupled to mass spectrometry (Figure 16) has been introduced for the detection of trace organic compounds in water samples. It could be shown that SFC offers significant benefits over commonly used separation techniques. Besides compounds, which can already be detected by reversed phase chromatography, SFC can also be used to detect compounds that are considerably more polar. In addition, SFC offers further advantages – separations are cheaper and do not produce hazardous waste. In order to intensify knowledge of this technique, studies are currently conducted, which will lead to an increased understanding of the basic mechanisms of SFC separations.

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Electrochemical oxidation of trace compounds – investigation of oxidative transformation pathways

Electrochemical flow-through cells can be used to degrade trace compounds by oxidation. Compounds passing electrodes with high voltage can be degraded or transformed in aqueous solution and detected with a subsequently coupled mass spectrometric detector. The generation of certain transformation products can be promoted by voltage variation. The reaction mechanism is strongly depending on the nature of the flow-through cell.

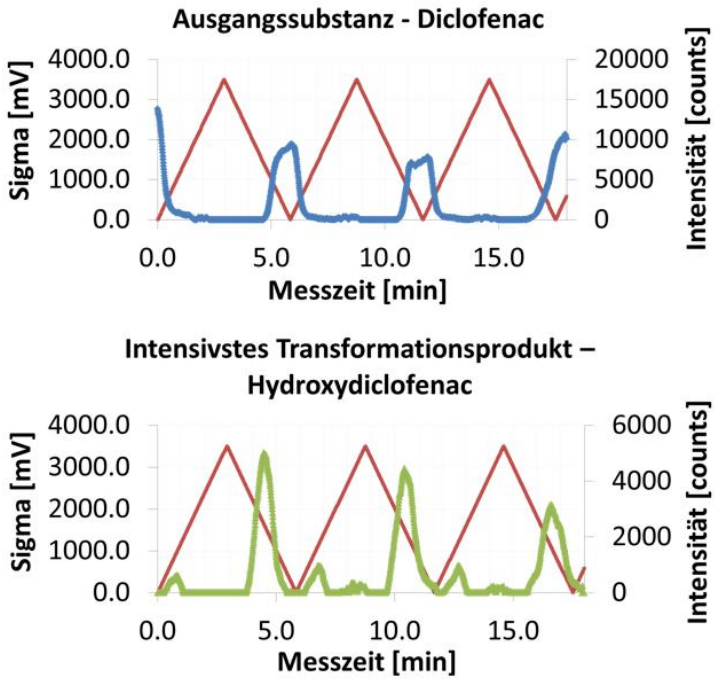

Figure 17: Voltage variations and resulting intensity changes for diclofenac and hydroxy diclofenac

The cell, which was utilized in this study, mainly produces OH radicals, which can react with trace compounds. By coupling the flow-through cell to a mass spectrometer, newly formed transformation products can directly be measured. With the example of diclofenac, it could be shown that, among others hydroxy-diclofenac is generated by oxidation. The formation rate is strongly depending on the applied voltage (Figure 17). The intensities of diclofenac (blue) and hydroxy-diclofenac (green) were recorded for three scan cycles (red). Within a scan cycle, the voltage was altered from 0 to 3 volts. In a voltage range between 1 and 3 volts, diclofenac is completely degraded. Hydroxy-diclofenac was detected in the voltage range from 2-3 volts. As a consequence, other transformation products must exist, which are generated in the range from 2 to 3 volts.

Besides direct measurement, the transformation products can also be collected and further analyzed or identified by liquid phase chromatography. The information, gained from these experiments can further be used, to detect these compounds in environmental samples.

Mass spectrometric detection of enzymatic reactions – characterization, miniaturization and the application for environmental samples

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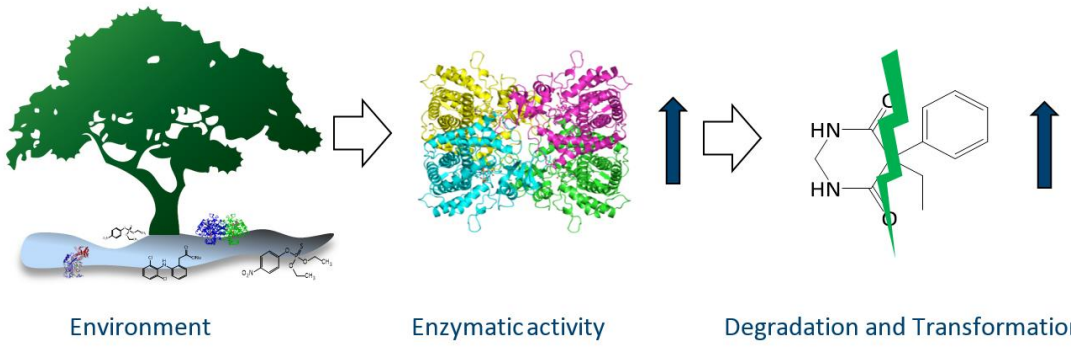
Trace organic chemicals (TOrC) are compounds which can be found ubiquitously in the aquatic environment in quantities between 10 and several 100 ng/L. The spectrum of these substances is broad and includes TOrCs derived from pharmaceuticals, health care products, flame retardants or pesticides. Due to their persistence, bioaccumulation potential, and toxicity there is a need to develop efficient and economic removal techniques. For these purposes the target use of enzymes can be a convenient approach, since they often possess a broad substrate spectrum and are able to catalyze versatile reaction types. Thus, enzymes offer a widespread application spectrum and open up new possibilities for environmental technologies, especially for biological water treatment processes. Some studies already utilized the potential of oxidative enzymes such as peroxidases or laccases to degrade TOrCs. Very recently it was shown that enzymes such as amidases, monooxygenases and carboxylesterases seem to be involved in degradation of those compounds.



In addition to spectroscopic methods, e.g. photometric or fluorescence detection there is also the possibility to couple enzymatic reaction with mass spectrometric detection. The direct coupling allows cost-efficient and simultaneous mass spectrometric characterization of all ionizable assay components in particular substrate(s), product(s) and intermediate(s).

Determination of the enzymatic activity in environmental samples (Therese Burkhardt)

In order to take advantage of these enzymatic activities, first there is a need to measure their activity in environmental samples. Thus, the objective of the present work is to combine an optimized extraction method with photometric and mass spectrometric measurements to investigate the activity of the intra- and extracellular enzymes in environmental samples. This approach will be designed as a rapid test that furthermore allows for a differentiation of enzymes by means of substrate

specificities. Until now two different extractions methods using diverse substrates were investigated in order to establish a sensitive, easily applicable approach. Results indicate that substrate oxidation in the probed sample is affected by the applied methods, pH, substrates and co-substrates. Those observations imply that the differentiation of enzymes or enzyme classes might be possible. However, further experiments are in progress in order to clarify which components impair the enzymatic activity and to establish a method to measure the "real" enzymatic activity in those environmental samples.

Enzymatic transformation of TOrCs (Lara Stadlmair)

A further objective is to investigate the potential of selected enzymes to degrade and transform TOrCs using MS-based *in vitro* enzyme assays. Two assay procedures are established to determine enzymatic reactions. The single enzyme-substrate assay establishment can enable the characterization of particular enzymatic reactions to determine transformation mechanisms, products and the kinetics. In a multiplex enzyme assay more than one enzyme and substrate are used. Utilization of multiple TOrCs simulates the complexity of biological samples and therefore offers the advantage of performing the assay under more realistic conditions. Moreover, a mixture of enzymes can potentially achieve higher transformation efficiencies. The evaluation of degradation potential and efficiency of enzymes can contribute to optimize suitable removal techniques to diminish TOrCs. Furthermore, the characterization of reaction mechanisms will help to understand chemical behaves of TOrCs especially in WWTPs.

Miniaturization and methodological approach (L. Stadlmair & T. Burkhardt)

To enable high sample throughput using different enzymes and substrates a miniaturized and automated robotic NanoESI is currently being optimized. Thus, this technology represents a promising new and fast tool to screen for enzymatic conversion of TOrCs. In the context of miniaturization, a microfluidic chip device will be established for the analytical, zero-death-volume analysis of enzymatic activities and their respective regulation. It was designed in a manner to enable a direct hyphenation to a mass spectrometer. Enzymatic reactions have already been assigned to this chip device. Nevertheless, for a complete validation and assessment further investigations are necessary.

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Investigation of Perilla frutescens extracts on their effect on cell proliferation and gene expression of a porcine jejunal epithelial cell line

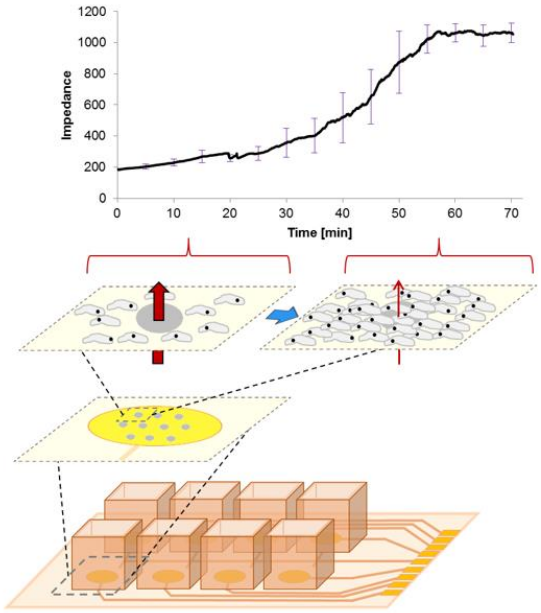

Figure 18: Analytical strategy to investigate the proliferation

Perilla frutescens is already known to contain a wide range of beneficial compounds, which possess health-promoting properties, e.g. associated with their capability to scavenge potentially harmful reactive oxygen species. Therefore, a collaboration with the Chair of Plant Physiology was established to investigate the effects of Perilla extracts from Vital Solutions and Amino Up Chemicals on the cell proliferation and gene expression of a porcine jejunal epithelial cell line. For this purpose, several extracts were prepared with solvents ranging from polar, i.e. 100% H_2O to non-polar, i.e. 100% ethanol, which allowed to investigate the effect of different "polarity fractions" on the cells. After extract application the proliferation was continuously detected during a time span of several days using electric cell-substrate impedance sensing (ECIS). By determining the expression of genes relevant for the progression of cell cycle or apoptotic events, the obtained proliferation results could be verified.

Since phenolic substances tend to generate toxic H_2O_2 concentration and are furthermore known to partly possess only limited stability in cell culture medium, appropriate control experiments were conducted as well. The applied amount of all PF extract "polarity fractions" was found to instantaneously downregulate the cell proliferation. However, a significant reduction was merely detected with polar H_2O and semi-polar 50% ethanol extract. The effect of both extracts was also found to be reflected in the expression of relevant genes. However, the most consistent and distinct regulation of gene expression was detected with the 50% ethanol extract.

The effect on the cells can be ascribed to compounds contained in the extract and no H_2O_2 generation was observed. Beyond that, the stability of compounds was assessed and was found to be varying. Some were detected to be stable over the entire experimental time, whereas others, which often contain ortho-hydroxyl groups, tend to degrade rapidly within only a few hours. A fast decrease was observed for e.g. rosmarinic acid or luteolin, both possessing adjacent OH-groups.

An innovative method to distinguish between gushing and non-gushing samples

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The term gushing describes the spontaneous uncontrolled release of carbon dioxide when opening a bottle. Gushing may not only lead to a damage of the affected companies image, but also to financial losses especially for brewing industry.
By means of LC-LC-UV/Vis-ToF-MS in this project for the first time comprehensive information were obtained about the composition of potentially gushing and non-gushing samples.
By using coupled chromatographic RPLC-HILIC separation, molecules ranging from "very polar" to "very unpolar" can be separated and detected. This technique results in a characteristic pattern of low as well as high molecular weight molecules, a so called molecular fingerprint. Each sample is characterized by such a fingerprint and by using those fingerprints samples containing several hundred different substances can be compared and statistically differentiated.

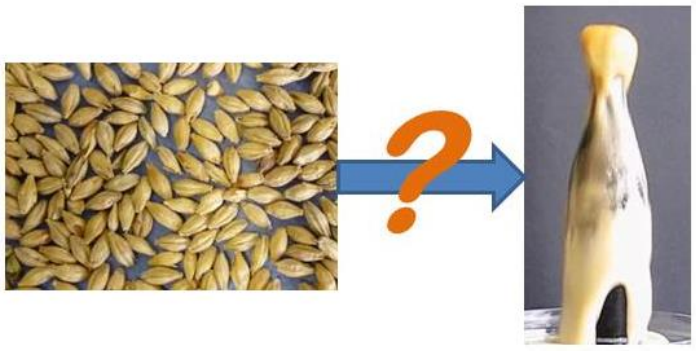

Figure 19: Do malt composition or processing induce gushing?

A workflow was developed to find marker substances out of the plethora of compounds characterizing the properties "associated to gushing" and "not associated to gushing". The main challenge was to filter the large amount of data in a way that they firstly were processable in a reasonable time and secondly provided interpretable results.

Applying the finally acquired strategy indeed allowed for filtering marker substances for defined groups of compounds. With this result the aim of the project, i.e. the development of an innovative method to distinguish between potentially gushing and non-gushing cereal and malt samples was reached.

However the marker substances are related to the property „potentially gushing" or „non-gushing", respectively, based on quite controversial gushing tests (i.e., the Modified Carlsberg Test and the Donhauser Test). To what extent the samples are really associated with gushing has to be clarified in further investigations. For doing so in a follow-up project, the marker molecules will be verified in samples with known and ascertained gushing potential.

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Research Group Sewer Systems and Rainwater Management

Figure 20: Copper roof runoff for testing treatment plants

In this year, the focus of the research group "Sewer Systems and Rainwater Management' was on decentralized treatment plants for traffic area runoff and metal roof runoff. In a research project funded by the Bavarian Research Foundation, the influence of de-icing salts on the remobilization of heavy metals from decentralized treatment plants for traffic area runoff was investigated. In this context, we have also published three studies on the occurrence of heavy metals and de-icing salts for winter road services and their importance for decentralized treatment systems for road runoff. In collaboration with the Frankfurt University of Applied Sciences (Prof. Antje Welker) we summarized the state-of-the-art of decentralized treatment systems for metal roof and road runoff as volume 213 of our book series. In this book, we provide an overview of the design of systems and their removal mechanisms, the different catchment areas and target compartments, the legal requirements, the approval processes, and current research results.

In an article published in the journal gwf water/wastewater, we presented an overview of the heavy metals copper and zinc in metal roof runoff and the possibilities for decentralized treatment. As a result, additional research is needed addressing service and maintenance requirements of decentralized treatment systems and compliance issues regarding implementing the proposed federal contaminated soil ordinance (Mantelverordnung).

At the end of the year, we have launched a survey with the manufacturers of decentralized treatment plants. The results will contribute to the development of the new DWA Standard M 179. We'd like to take this opportunity, to thank all of the producers for their active participation. We also like to offer you our support concerning developments and verifications of decentralized treatment plants for both metal roof runoff and road runoff.

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Effect of de-icing salts on the remobilization of previously retained pollutants on filter materials for treating traffic area runoff

The aim of this research project was the scientific description and determination of the remobilization behavior of heavy metals previously retained on filter materials by various de-icing salts. These filter materials are used in decentralized treatment systems for traffic area runoff. Until now, a test specification is missing in the approval process of the German Centre of Competence for Construction (Deutsches Institut für Bautechnik), that can be used to completely investigate the remobilization behavior. Therefore, no decentralized treatment plant for road runoff is available, for which the filter stability considering all relevant de-icing salts is proven.

To elucidate the effect of de-icing salts, an experimental setup was built on a laboratory scale at the Chair of Urban Water Systems Engineering. First, six selected filter materials were loaded in column experiments with the five heavy metals copper, zinc, cadmium, lead, and nickel with defined concentrations on the basis of real traffic area runoff water concentrations. After preloading, different de-icing salt experiments were carried out with pure sodium chloride, with a defined mixture of sodium chloride and calcium chloride, and with a defined mixture of sodium chloride and magnesium chloride, wherein each remobilization test is preceded by a new loading experiment.

Advanced analyzes such as particle size distribution, pore volume, pore size distribution, content of heavy metals, specific surface areas, and surface properties, were used to identify different removal mechanisms and to determine the behavior of the filter materials under application of de-icing salts in realistic conditions. Concerning the de-icing salt experiments, the behavior of each filter material, each heavy metal, and each de-icing salt was very heterogeneous regarding the risk and the amount of remobilization.

Figure 21: Experimental setup

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COOPERATION:
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Reduction of hydrocarbons and other organic trace materials by a decentralized road runoff treatment system

In collaboration with the Chair of Water Quality Control and Environmental Technology at Ruhr University of Bochum (RUB) and the company Dr. Pecher AG, a decentralized stormwater treatment system had been developed and modified for the retention of hydrocarbons and other organic trace materials from traffic area runoff.

Lab experiments were conducted in order to evaluate filter materials and filter material combinations for the retention of organic pollutants such as PAH (Polycyclic Aromatic Hydrocarbon), PH (Petroleum Hydrocarbons), ETBE (Ethyl-tert-butylether), and MTBE (Methyl-tert-butylether). Batch and column experiments were carried out to determine the maximum sorption capacities and sorption kinetics of several filter materials. Moreover, the suitability of the modified filter material combination, which was developed during this project, was evaluated for the retention of heavy metals and the influences of de-icing salt applications.

In addition, the developed filter material combination was subsequently tested in two large-scale treatment plants in the cities of Wuppertal and Mönchengladbach to monitor its operation by continuous sampling over a one-year period. Simultaneously, further studies were performed at pilot scale to determine the influences of further ions and real preloaded columns on the removal of pollutants. Maintenance intervals of the treatment plants were also evaluated. As a result, a guideline was developed with the aim of implementation and improvement of existing decentralized stormwater treatment systems for the reduction of pH and other organic trace substances from road runoff. Furthermore, the expected operational and investment costs were calculated.

Figure 22: Sampling site in the city of Wuppertal

For the service time, the retention of dissolved zinc was the limiting factor concerning the lab experiments, whereas the risk of clogging was crucial in the field, where the differences between the two locations were reflected.

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SWM, MÜNCHEN;
CSM, COLORADO SCHOOL OF MINES, USA

Microbial Systems Research Group

The Microbial Systems Research Group investigates microbial processes in aquatic and engineered systems, e.g. biological wastewater treatment or the application or biological active filtration in water purification. One focus is the identification of relevant functional bacteria groups and the detection of their specific activities, e.g. nitrogen conversion (nitrifiers, ANAMMOX bacteria), anaerobic processes (sulfate reducing bacteria, methanogens) and microbial induced corrosion (e.g. sulfide and sulfur oxidizing bacteria). The characterization of taxonomic and functional diversity of micropollutant degrading microbial communities in wastewater treatment and drinking water purification using state-of the art biomolecular tools (metagenomics and metatranscriptomics) represents further research topics.

The detection of fecal indicator organisms (*E. coli* und Enterokokken) or specific pathogen bacteria, e.g. *Pseudomonas* spp. und *Legionellen* spp., is established as routine methods. These techniques were used to monitor hygienic pollution of surface water, to track disinfection efficiency of oxidative treatment processes, and the elimination capacity of biological active filter (e.g., in wastewater treatment and drinking water purification).

Both classical microbial cultivation techniques (Figure 24) and molecular biological methods (Fluorescence in situ Hybridization, FISH applied with Confocal Laser Scanning Microscopy, CLSM, Figure 23; Polymerase Chain Reaction combined with Denaturing Gradient Gel Electrophoresis, PCR-DGGE; real-time PCR; metagenomics and metatranscriptomics) are applied to answer the various research questions.

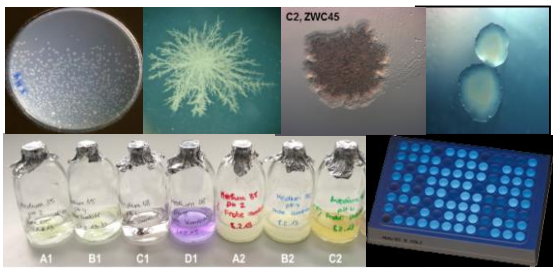

Figure 24: Classical microbiological cultivation on agar plates and liquid media (serum bottles and microplates; e.g. detection of E. coli, Most Probable Number counts, MPN)

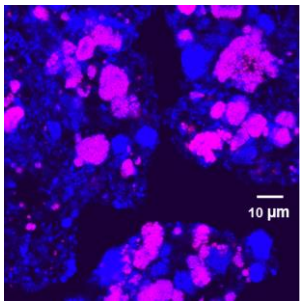

Figure 23: CLSM image of activated sludge floc after the application of FISH. Nitrospirae (magenta, nitrite oxidizing bacteria, NOB) and DAPI stained bacteria cells (blue signals)

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COOPERATION:
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Analysis of Biogenic Sulfuric Acid Corrosion in Sludge Digesters

In wastewater treatment facilities and sewer systems, biological produced sulfuric acid (H_2SO_4) often causes concrete deterioration (Figure 25). For the corrosion process, the activity of sulfate reducing and sulfur/sulfide oxidizing bacteria (SRB and SOB) is necessary which leads to the formation of H_2SO_4. Through the reaction of H_2SO_4 with the cement stone components of concrete, gypsum is formed (Figure 26). The formation of gypsum leads to a volume increase, internal cracks and finally to structural failure of the concrete. The main aim of this research project was to identify the microbial communities involved in the corrosion process (SRB and SOB) in sludge digesters. In addition, the corrosion potential of different SOB was investigated and the influence of chemical and biological H_2SO_4 on cement stone and concrete was studied.

Figure 25: Concrete corrosion within a digester headspace © Rolf König

To test, if there are differences between biogenic and chemical H_2SO_4 attack, specific corrosion experiments were performed. Therefore, 3-4 mm thick cement stone disks were exposed to chemical (pH value 1.0 and 2.0) and biological (pH value 1.5-2.0) generated H_2SO_4. After 28 days of incubation in the corresponding solutions, the extent of damage was evaluated by common visual-physical parameters. To analyze the element distributions in the corrosion layers, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was used as novel assessment tool. The results revealed a pH-value dependent degree of damage. The 4 mm thick disk at chemical H_2SO_4 at pH 1 was completely corroded. For the disks at chemical H_2SO_4 (pH value 2) and in biogenic H_2SO_4, an intact cement stone core remained with a similar thickness of the corrosion layers (1.8-2.0 mm) and sulfuric acid penetration depths (1.1-1.3 mm). Since the element distributions in the corrosion layers were similar, independent of applying chemical or biological H_2SO_4, no differences concerning the corrosion mechanisms between the two acid attacks were observed within this study.

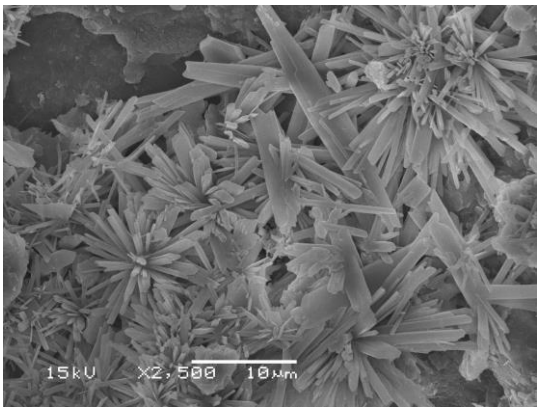

Figure 26: Formation of gypsum crystals on a concrete surface. SEM- picture.

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Research Group
Engineered Natural Treatment Systems

The removal of emerging trace organic compounds (TrOCs) in ground-, surface and drinking water is of increasing interest to reduce potential adverse effects on aquatic life and human health. Natural treatment processes, such as riverbank filtration, soil aquifer treatment or biologically-active filters, are used in water treatment for many decades. Major research objectives of this research group include

- an assessment of key factors for the removal of trace organic chemicals in microbial systems,
- the transitioning of passive natural treatment systems into active processes with predictable water quality,
- the development of new innovative treatment concepts for advanced water treatment and reuse based on biological processes, and
- the integration of natural processes into hybrid processes with advanced treatment such as ozonation, advanced oxidation or membrane processes.

In order to actively steer the attenuation of TrOCs, a basic understanding of predominant removal processes is essential. Previous research revealed an optimized compound removal under oxic, carbon limiting conditions. The role of refractory organic carbon as primary substrate for co-metabolic degradation, however, is not yet fully understood. Different column systems (Figure 27) are operated to evaluate the effects of concentration and composition of humic substances on chemical removal in natural treatment processes. In these systems, advanced analytical tools and next generation sequencing are used to quantify trace organic chemicals, characterize bulk organic carbon and to elucidate structure and functions of the microbial community key factors for compound removal in natural treatment systems.

Figure 27: Different setups for soil column experiments

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UNIVERSITÄT OLDENBURG

Sequential Managed Aquifer Recharge Technology (SMART)

Managed aquifer recharge (MAR) systems, such as riverbank filtration (RBF), soil aquifer treatment and artificial recharge and recovery, have been used for decades to improve the availability of localized water supplies by the utilization of less desirable water sources like storm water, impaired surface water and reclaimed water. During infiltration of water through the vadose and saturated zones, microbial degradation and assimilation is playing a dominant role for the attenuation of organic contaminants.

The innovative Sequential Managed Aquifer Recharge Technology (SMART) concept actively manipulates subsurface conditions and combines two MAR systems with an in between aeration step to provide favorable aerobic, carbon limited infiltration in the second system (Figure 28). This concept has already been successfully tested for treatment of wastewater-impacted surface water at a utility in the United States. In May 2015, a joint collaborating project with the TU Berlin (TUB), the University of Oldenburg (UO), and the Berliner Wasserbetriebe (BWB) was launched to assess the applicability of SMART for drinking water treatment in Berlin.

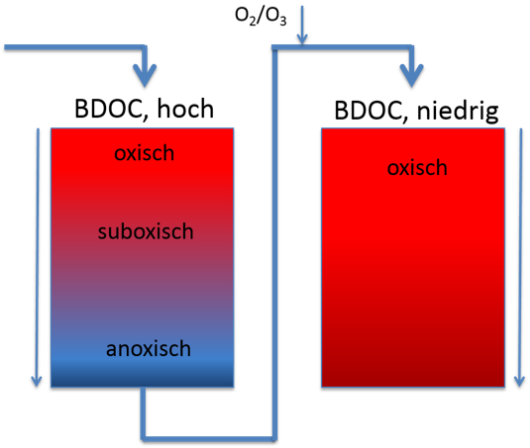

Figure 28: Principle of Sequential MAR Technology

Figure 29: Infiltration basin on the island Baumwerder, Lake Tegel

In addition to laboratory-scale column experiments operated with secondary effluent (at TUM) and surface water (in Berlin), full-scale validation was started in 2015 using bank filtered water for infiltration at a groundwater recharge facility in Berlin-Tegel. Redox conditions and water quality parameters are monitored using *in-situ* oxygen sensors and lysimeters. Besides chemical analyses, 16S rRNA sequencing and Metagenomic analyses will be used in order to identify composition and function of microbial communities responsible for biodegradation of trace organic compounds.

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FUNDING:
JPI WATER

COOPERATION:
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IRSA, ITALY;
ISS, ITALY;
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BRGM, FRANCE;
GÉO-HYD, FRANCE

A Novel Framework to Assess and Manage Contaminants of Emerging Concern in Indirect Potable Reuse (FRAME)

Within the research project FRAME, which started in January 2015, a cluster of seven European research institutions aims to develop an overall evaluation scheme to comprehensively assess and manage contaminants of emerging concern (CECs) and pathogens in Indirect Potable Reuse (IPR) systems.

Within the project, TUM is responsible for the development of novel treatment combinations to be integrated in IPR schemes. Therefore, the research group Engineered Natural Treatment Systems conducts pilot-scale studies to evaluate reliable and cost efficient treatment strategies. Besides oxidation, adsorption and membrane processes, enhanced biofiltration is a promising technology for the mitigation of CECs in tertiary wastewater treatment plant effluents. The novel concept aims to combine the benefits of a high microbial diversity in low rate biofilters and the high throughput in rapid media filters. The experimental setup integrates experiences made in sequential aquifer recharge systems. The setup consists of two filter columns operated in series with an in-between aeration to establish oligotrophic conditions in a sequential biofilter. These conditions favor the establishment of a highly diverse microbial community, capable of degrading CECs. The experimental setup with four independently operating filtration trains allows for a large variety of filtration modes.

Figure 30: Experimental setup

First results reveal that oligotrophic conditions were successfully established in the second stage filter, which is indicated by a reduced DOC and oxygen consumption. CEC measurements show compound dependent differences in the system's removal efficiency. However, several compounds show an increased removal during sequential biofiltration. Further studies aim to optimize the system and evaluate the influence of hydraulic retention time on system performance. Also potential combinations of sequential biofiltration with oxidation processes (ozone, AOP) and adsorption onto activated carbon will be investigated.

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BAVARIAN STATE MINISTRY OF THE ENVIRONMENT AND CONSUMER PROTECTION

COOPERATION:
BAVARIAN ENVIRONMENT AGENCY (LFU); MÜNCHNER STADTENTWÄSSERUNG (MSE)

The use of UV-based advanced oxidation processes (AOP) for the removal of trace organic chemicals from wastewater treatment plant effluents

In recent years, several trace organic chemicals (TOrC) have been detected in the aquatic environment. Besides urban and agricultural run-offs, wastewater treatment plant effluents are the most significant TOrC emitters. It is not unlikely that environmental quality standards for specific TOrCs, such as diclofenac, will be implemented at European level in the future requiring advanced treatment options for wastewater treatment plant (WWTP) effluents.

As part of a joint research project with the Bavarian Environment Agency and Münchener Stadtentwässerung, funded by the Bavarian State Ministry of the Environment and Consumer Protection, TUM started in 2015 to assess the applicability of the advanced oxidation process UV/H_2O_2 as an alternative to ozonation and adsorption onto activated carbon for the removal of TOrCs from WWTP effluents. Major objectives are to test i) whether and to what extent established UV disinfection systems at WWTPs can be upgraded for UV/H_2O_2 treatment, ii) whether UV/H_2O_2 reaches comparable removal efficiencies to ozonation, and iii) whether UV/H_2O_2 is an economically and operationally viable alternative compared to existing systems for TOrC removal from WWTP effluents.

As a first step, parallel lab experiments are conducted using a Collimated Beam Device (CBD, Figure 31) and a semi-batch ozonation system. The CBD setup allows UV irradiance of a water sample in a petri dish under standardized conditions, verified using a UV-radiometer. In 2016, pilot scale UV/H_2O_2 experiments (approximately 35 m^3/h) will be conducted at the WWTP Gut Marienhof in Munich.

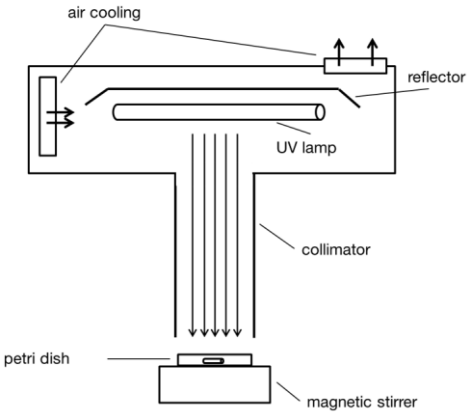

Figure 31: Collimated beam device

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FUNDING:
LFU,
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Optimization of treatment capacity from combined wetland systems in rural communities

Two different wastewater treatment plants from small communities were investigated over a longer time period within a research project funded by the Bavarian Environment Agency (LfU) to demonstrate the treatment efficiency of wetland systems. The first studied system consisted of a pond system combined with a vegetated soil filter. In the second system, combined vertical and horizontal reed bed filter effluent recirculation was tested to enhance denitrification.

The combination of pond and horizontal reed bed was set up to treat combined wastewater and resulted in a COD reduction by more than 90 % and an effluent BOD_5 below 3 mg/L throughout the year, when operated at 87 % of treatment capacity. Almost complete nitrification was achieved in wintertime with the soil filter providing nearly 30 % of the total NH_4-N removal. However, the denitrification is not effective on cold days and the NO_3-N concentration exceeded 30 mg/L at water temperatures below 8 °C.

In the combined reed bed system for treatment of a separate sewer system almost complete nitrification was already achieved in the first, vertical soil filter even in winter times. For advanced denitrification, the effluent of the vertical filter was recirculated with a reflux ratio of > 1 and the influent of the second, horizontal filter was mixed with some raw wastewater as carbon source. These adjustments enabled to increase the total nitrogen removal from below 40 % up to more than 70 %.

In general, it is possible to achieve an effective nitrification and denitrification of the effluent from pond systems by subsequent operation of a horizontal flow reed bed. Because wastewater quantity and quality from rural communities is highly variable based on local discharge, e.g. from dairy farming or breweries, the plant design always needs to consider local conditions. Major recommendations from this study for plant design and optimization are related to desludging, adaptation of reaction volumes for denitrification as well as flush batch feeding for optimal distribution of wastewater to the soil filters.

Research Group Advanced Water Treatment and Water Recycling

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The research group ‚Advanced Water Treatment and Water Recycling' is jointly directed by Profs. Drewes and Helmreich. The group is comprised of four research teams: Advanced Oxidation Processes – Dr. Uwe Hübner; Deammonification – Dipl.-Ing. Claus Lindenblatt; Membrane Processes – Prof. Dr. Drewes; and Water Recycling – Prof. Dr. Drewes.

Current foci of research are investigations to improve alternative processes for nitrogen removal (deammonification) and process optimizations for advanced treatment processes in particular targeting trace organic chemicals and pathogens. These hybrid systems combine modified biological filtration, advanced oxidation processes (UV/H_2O_2; nanomodified diamond electrodes; ozone), granular activated carbon and membrane filtration (ultrafiltration, nanofiltration, reverse osmosis), which can be employed in centralized and decentralized settings.

An additional focus are treatment processes facilitating water recycling to augment drinking water supplies and industrial water needs. A particular emphasis is on the development of more energy-efficient processes and water reclamation with integrated energy recovery. Improved performance control through new monitoring strategies are embedded in all these applications.

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OSWALD-SCHULZE-FOUNDATION

COOPERATION:
COLORADO SCHOOL OF MINES, USA;
TU DELFT, THE NETHERLANDS;
UNIVERSITÉ DU LUXEMBOURG, LUXEMBOURG;
UNIVERSITY OF NEW SOUTH WALES, AUSTRALIA

Energy-efficient Treatment Schemes for Water Reuse - Drinking Water Augmentation

Population growth, demographic changes (urbanization), climate change, lack of conventional freshwater supplies, and more frequent and severe drought conditions are stressing the availability of conventional freshwater resources. Water reuse is one option to close local water cycles and conserve local water resources. In semi-arid and arid regions, including European regions with water scarcity the utilization of municipality wastewater for water reuse purposes is well established. A significant disadvantage of many treatment schemes in water reuse is the high energy demand and generating waste streams, which are difficult or expensive to dispose of. Alternative treatment schemes for water reuse are required to overcome these issues and guarantee a sustainable (water supply) development worldwide. Alternative treatment scenarios are developed and are being tested at laboratory and pilot scale to determine optimal operational conditions (Figure 33). Due to an integrated energy recovery approach by improved pretreatment and physical separation of organic matter (results in higher biogas yield), the overall energy footprint can be substantially decreased. Additionally, an integrated energy recovery is provided by the intended production of nitrous oxide from concentrated nitrogen process water streams (see project *PANOWA*). The nitrogen removal from the wastewater can be coupled via the aerobic-anoxic nitrous decomposition operation (CANDO) with the production of nitrous oxide as an additional energy source. Membrane processes will play a major role within the alternative treatment approach. In particular, fouling and scaling effects will be analyzed. With the help of modeling software, we are analyzing the hydrodynamic and solute transport effects within the membrane cell-holders/modules (Figure 32) and are developing fouling and scaling mitigation strategies.

Figure 33: Ultrafiltration test-skid for municipal wastewater treatment

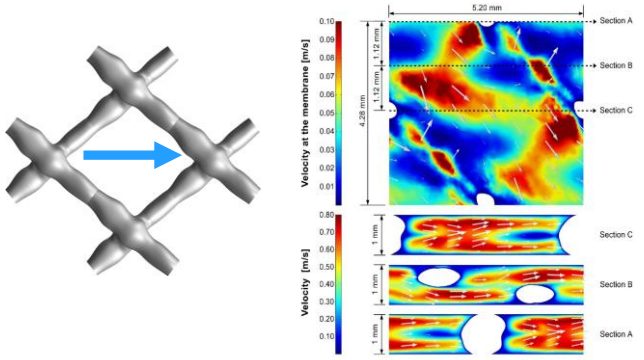

Figure 32: Hydrodynamic simulation of a feed spacer specimen

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FÖRDERUNG:
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KOOPERATION:
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Developing a Decision Making Framework for Upgrading and Operation of Wastewater Treatment Plants for Trace Organic Chemical Removal

During the recent past, anthropogenic trace organic chemicals (TOrCs) have moved into the focus of regulatory authorities. In contrast to conventional biological wastewater treatment systems, a more complete removal of these contaminants can be achieved by various advanced treatment processes. However, all these treatment approaches usually come with a higher energy footprint. Therefore, this PhD-Project focuses on the heuristic optimization to remove TOrCs while also considering the local discharging situation into a receiving stream.

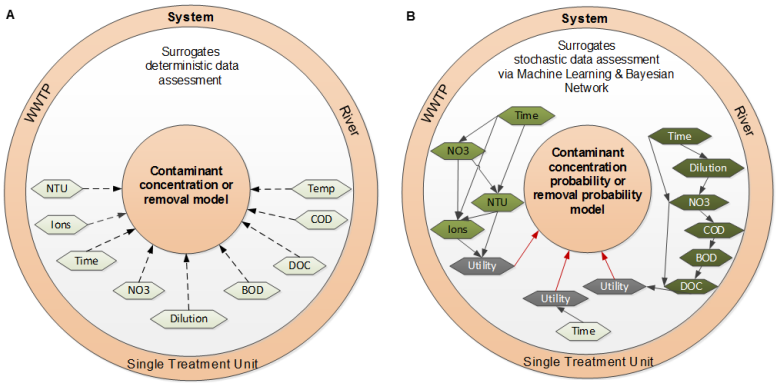

Figure 34: Surrogate-Model to remove trace organic chemicals by engineered systemste

The traditional concept of regulating contaminants is rather linear in nature (Figure 34 A) and usually assumes a rather direct correlation between surrogate parameters and the mostly deterministic contaminant fate model. Especially regarding the prediction of TOrC this is not very promising, because given the wide variety of different TOrCs there is currently not a single strong surrogate that correlates with removal of TOrCs. The proposed novel approach (Figure 34 B) uses the power of statistics and machine learning to define specific surrogate clusters, which are resilient enough to act as more suitable surrogates. Furthermore, the individual surrogates are data sets with a specific probability distribution considering the incoming conditions. This concept even allows real-time monitoring of surrogates and combined with static data sets these can result in a comprehensive dynamic monitoring approach. This concept offers a large potential to optimize current wastewater treatment system through more flexible operational regimes. Adjusting the treatment system to the individual contaminant load probability will result in significant energy savings.

In 2015, the main focus was to write a review paper, which discusses common and alternative regulatory tools and controls for a dynamic water quality risk profile in water quality management. In addition, the basis for the following statistical work with Bayesian Belief Network modeling was developed. Finally, a long-term sampling campaign along the river Isar was performed to establish an initial data set for statistical evaluations and to study the potential for photolytic degradation processes of selected TOrCs in receiving streams.

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FUNDING:
ALEXANDER VON HUMBOLDT-STIFTUNG;
GEORGE-FORSTER-FELLOWSHIP

Preparation and Characterization of Metal ion Incorporated Diatomite for Groundwater Defluoridation

Prof. Abiola Nurudeen Oladoja visited the chair in 2015 and was funded by a George Forster Fellowship for experienced researchers for two years at our Institute. In his research, he has developed and evaluated materials for the removal of fluoride from groundwater. In several developing countries fluoride polluted groundwater is a serious issue. Due to the high dependence on groundwater supplies and the negative impact of F^-, efforts are now focused on the development of simple and low cost functional reactive materials that can scavenge F^- from the aqua stream for applications in the developing world and remote areas of the developed world. The abilities of oxides and hydroxides of trivalent and tetravalent metal ions in aqua defluoridation are recurrently scrutinized because of their strong affinities for F^-. Majority of these oxides and hydroxides have their point zero charge (PZC) above the natural water pH of 7. Therefore, at the pH of natural water, the surfaces of these materials are predominated by positive charges, which favor the adsorption of the negatively charged aqua F^- species.

Thus far, in our laboratory, different single (aluminum and nano-magnesium) and binary metal (calcium aluminate, Mg-Al layer double hydroxide) ions have been incorporated into diatomaceous earth and silica sand to prepare reactive, permeable filter materials for groundwater defluoridation. These materials were characterized and the defluoridation potentials were appraised in a batch reactor. Premised on the results obtained from the batch defluoridation studies, the design and operating parameters for groundwater defluoridation were obtained from fixed bed operation in a column reactor (Figure 35). The performance efficiencies of the developed materials were tested using groundwater, spiked with fluoride, and the regeneration potential of the column was evaluated using different regenerating solvents.

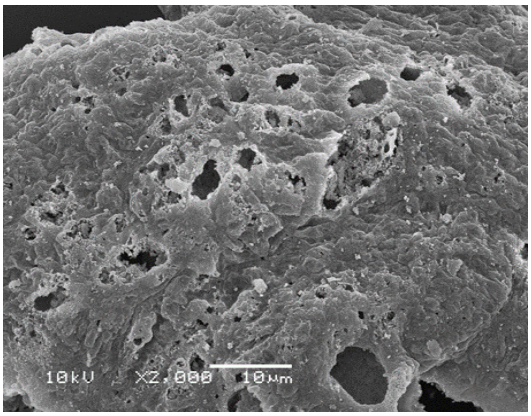

Figure 35: Surface structure of a nanomaterial

Further Research Activities

NeXus of Water, Food and Energy

The Chair of Urban Water Systems Engineering is part of the project **NeXus of Water, Food and Energy**, which is funded by the German Academic Exchange Service (DAAD). The project focuses on interaction of the limited resources of water, food and energy. Together with the Ardhi University in Dar es Salaam, Tanzania we analyzed within a study project the behavior of a constructed sandfilter (Figure 37). The aim of this project was the improvement of wastewater disposal and treatment along the river as well as the implementation of targeted water reclamation for irrigation (urban farming). In particular in dry season the river is contaminated with high amounts of wastewater (Figure 36) and needs treatment before using it for irrigation purposes. In 2016, we will continue to work together with the Ardhi University on improvements of the local water and wastewater situation.

Figure 37: Sandfilter for treatment of river water (Foto: Tim Fettback / Nils Horstmeyer)

Figure 36: Mlalakua-River in Dar es Salaam, Tanzania (Foto: Tim Fettback / Nils Horstmeyer)

Young Water Reuse Professionals (YWRP)

During the *10th IWA International Conference on Water Reclamation and Reuse* in Harbin, China, the *Young Water Reuse Professionals (YWRP) Group* was established. The purpose of this group is to facilitate networking between the YWRP and professionals within the IWA Water Reuse Special Group (WRSG), who are more advanced in their career and provide the possibility to establish their own subgroup within the YWP and the *Water Reuse Special Group (WRSG)*. We intend to develop activities for YWRPs in the near future by featuring YWRPs prominently both in the WRSG Newsletter and on the IWA Water Wiki site (www.iwawaterwiki.org).
If you are interested in being featured as an „YWRP of the month" or using the opportunity to have your work being showcased on the IWA Water Wiki site, please contact us (Nils Horstmeyer: nils.horstmeyer@tum.de).

External PhD Candidates

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Vasilis Dandikas is a scientific assistant and doctoral candidate at the Institute of Agricultural Engineering and Animal Husbandry of the Bavarian State Research Center for Agriculture in Freising, Germany.
In his PhD, he deals with the question whether the biogas yield of different energy crops can be predicted by their chemical composition. For that purpose, the plants are characterized by fodder analysis (so-called Weender analysis with van-Soest fraction), for instance concerning their content of crude protein, crude lipids, fiber and non-fiber carbohydrates. Additionally, the biogas yield is determined in an anaerobic batch test.
By a principal component analysis, statistical correlations of the parameters and the biogas yield as well as among each other are identified in order to select those parameters, which are most suitable for the prediction of the biogas yield. Based on those, global (enabling the prediction over different plant species, but with higher prediction error of about 10%) and local (is only valid for a specific group or species, but with high accuracy) models are developed. They can then be used for calculating the biogas yield at known chemical composition.

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Sebastian Hien is a research associate at the Chair of Urban Water Management and Hydraulic Engineering at the University of Luxembourg. His PhD thesis is supervised by Professor Joachim Hansen and co-supervised by Dr.-Ing. Konrad Koch from the Anaerobic Technologies and Energy Recovery group at TUM.
The dissertation is investigating possibilities to predict biogas and methane production rate in digesters at biogas plants and wastewater treatment plants to support their integration in the concept of virtual power plants. In particular, parameters influencing the prediction of biogas formation above average should be identified. Therefore, data from different digesters are collected and used within the framework of modelling dynamic simulations. The simulation results are analyzed by means of machine learning approaches like “random forest” or “artificial neural networks” to find the most important parameters and develop a prediction tool on that base.
In the near future, this tool should provide reliable biogas production rate predictions in a short- and medium term perspective.

Visiting Scientists

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Associate Professor Mike Manefield, University of New South Wales, Sydney, Australia

Prof. Dr. Mike Manefield joint our department as the August-Wilhelm-Scheer Visiting Professor from July to December 2015. Mike Manefield is an Associate Professor in the School of Biotechnology and Biomolecular Sciences at the University of New South Wales, Australia.

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Associate Professor Stuart Khan, University of New South Wales, Sydney, Australia

Prof. Dr. Stuart Khan is a Hans-Fischer Fellow at TUM and joint us from January to July 2015. Stuart Khan is Associate Professor in the School of Civil and Environmental Engineering at the University of New South Wales. As Hans-Fischer Fellow at TUM, Stuart receives support through a 3-year fellowship and is planning to visit again in the summer of 2016. He is co-supervising with Prof. Drewes our PhD candidate Philipp Michel.

International Cooperation Partners

Last year, we could further expand our network with international partners Figure 38).

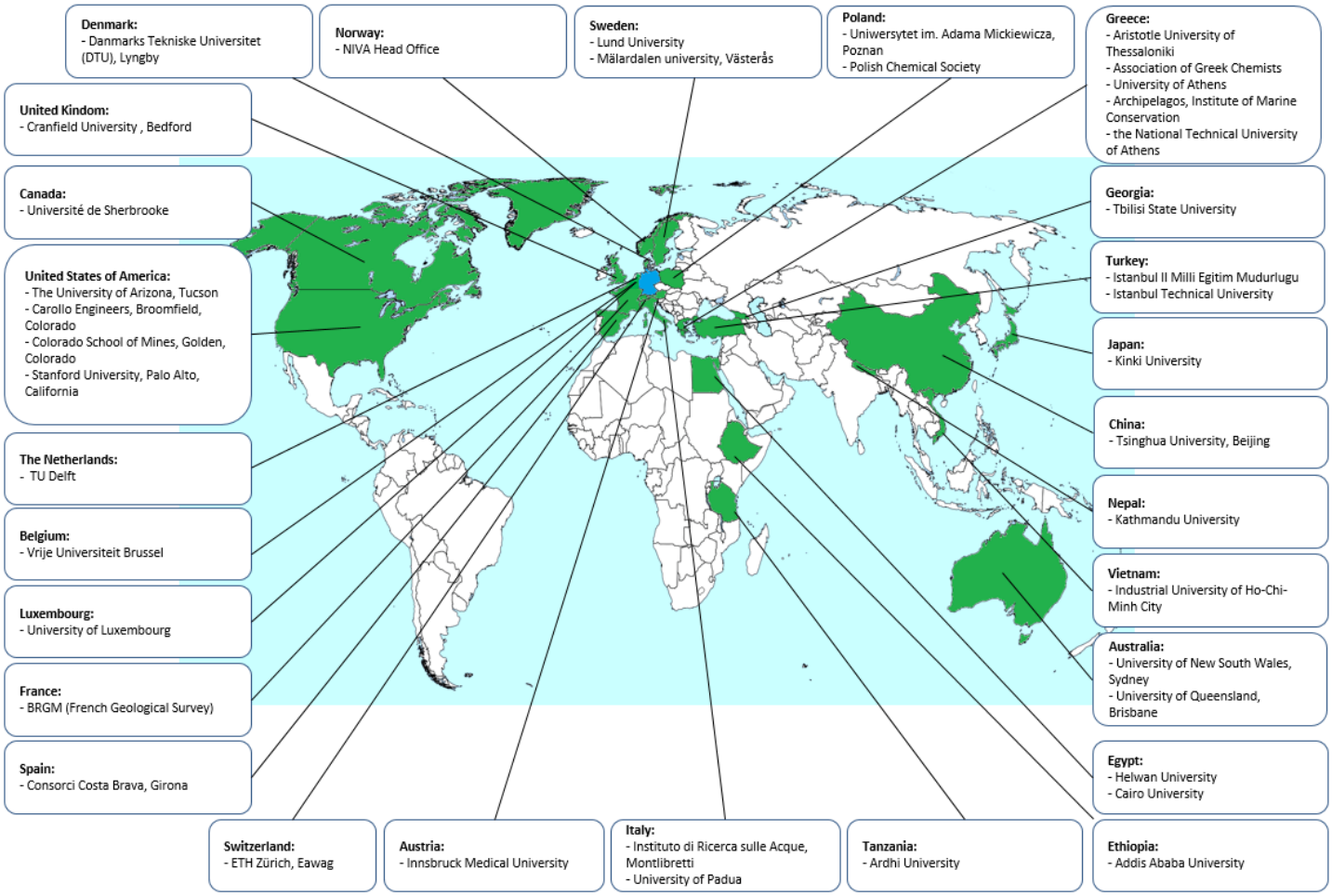

Figure 38: Overview of international collaboration partners

National/International Committee

Water Reuse Specialist Group (IWA)

Since 2013, **Jörg E. Drewes** is serving as chair of the **Water Reuse Specialist Group (WRSG**) of the **International Water Association (IWA)**. With more than 2,700 members, the WRSG is the largest specialist group within IWA with specialists in water reclamation and reuse from more than 110 countries.
As prime conference of the WRSG, the 10th International Conference on Water Reclamation and Reuse was held in Harbin, China from 5-9 July, 2015. Currently, preparations are underway for the 11th International Conference on Water Reuse in Long Beach, California, scheduled for July 24-27, 2017.

ESSEM-COST Action

Thomas Letzel is member of the **ESSEM COST Action ES1307** "*Sewage biomarker analysis for community health assessment*" and representing Germany in the Management Committee. He is leading the analytical subgroup 'Non-target screening strategies' established in 2015 and is an active member in the group "Finding biomarkers and stability of these biomarkers in wastewater". The action develops and expands an existing pan-European inter-disciplinary network, bringing together experts from relevant disciplines interested in the application and development of using quantitative measurements of human biomarkers in sewage to evaluate lifestyle, health and exposure at the community level. Current work and results (e.g., from the international Workshop in Zurich, Switzerland at October 15-16, 2015) can be found at the following URL: http://score-cost.eu/.

EU-COST Action

Brigitte Helmreich is serving as member of the **EU-COST Action** *„Conceiving wastewater treatment in 2020. Energetic, environmental and economical challanges"* (http://www.water2020.eu/) and active in working group 3 entitled *„Environmental and economic impact"*. „COST" represents „Intergovernmental framework for European Cooperation in Science and Technology". These networks are funded by the EU to coordinate national-funded research activities at the European level. COST working groups are meeting regularly to prepare joint research proposals and publications.

NEREUS-COST Action

Jörg Drewes serves as member of the **NEREUS-COST Action ES1403** *„New and emerging challenges and opportunities in wastewater reuse"* (http://www.nereus-cost.eu). Within this action, he serves as facilitator among the five working groups. NEREUS members met twice in 2015, in Barcelona and Luxemburg.

NORMAN Network

Thomas Letzel is representing our department in the **NORMAN Initiative** and serves as representative of the German research community in the group focusing on chemical analysis of organic compounds in water matrices. In that predominantly eco-political European group, we are active in the topics 'retention time index' (RTI), i.e. the harmonization of HPLC, in the 'introduction of the HILIC technique', and the 'realization of an international round robin'.
Current work and results (e.g., from the international Workshop in Rhodos on September 1-2, 2015 and the general assembly in Rome on December 3-4, 2015) can be found at the webpage: http://www.norman-network.net.

National Academies of Engineering, USA – Expert Panel on the Use of Stormwater and Graywater

Jörg Drewes served as a panel member of the **National Academies of Sciences, Engineering and Medicine** (USA) to prepare a comprehensive report entitled „*Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits"*. The final report is available free of charge using the following link: http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an.

Wasser Recycling in California, USA

Jörg Drewes serves as member of an expert panel entitled „*Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse"* for the State of California. This advisory panel assists in the assessment of direct potable reuse (DPR) as a future water supply option for the state of California.

DWA-Working Groups

At the national level, **Brigitte Helmreich** is an active member of two DWA-working groups: For several years, she is working for the **DWA-working group ES-3.1** "*Versickerung von Niederschlagswasser*" (Infiltration of Run-Off Rain Water). In October 2014, she was nominated to join the **DWA-working group S-3.7** „*Dezentrale Anlagen zur Niederschlagswasserbehandlung*" (Decentralized Installations for the Treatment of Rainwater). Since the beginning of 2015, she is also a guest at the DWA Committee of Experts IG-2 "*Sector-specific industrial effluent and waste*".

Jörg Drewes serves in the **DWA-Working Group KA-8** *„Advanced Wastewater Treatment"*, the **DWA-Working Group Biz 11.4** *„Water Reuse"* and **KA-8.1** *„Trace Organic Chemicals in the Water Cycle"*.

German Water Chemistry Society

Uwe Hübner is an active member of the Technical Committee "*Transformation products of biological treatment processes in wastewater treatment*" of the **German Water Chemistry Society**. The group is currently preparing a status paper to summarize current research on biological transformation processes with a publication envisioned in 2016.

‚FA Non Target Screening' – Committee II within the German Water Chemistry Society

Thomas Letzel is an active member in the committee of experts for the harmonization and adjustment of water analysis by LC-MS in Germany. In 2015, a round robin was organized to compare several analytical LC-MS(/MS) systems. During this effort, our department was responsible for the inter-laboratory normalization of retention times and delivered separate reference materials to all partners.

Journal *Water* – Guest Editor

Brigitte Helmreich was invited to serve as a guest editor of the **research journal Water** (impact factor 1.4) in 2015 for the special issue "*Urban Drainage and Urban Stormwater Management*"
(http://www.mdpi.com/journal/water/special_issues/urban_drainage_stormwater)

Journal *Chemosphere* – Associate Editor

In 2015, **Jörg E. Drewes** served as Associate Editor of the journal **Chemosphere**. Chemosphere is an international journal that is specializing on publishing papers on the fate and transport of chemicals in the environment. In 2015, its impact factor was 3.5 (http://www.journals.elsevier.com/chemosphere/).

Journal of Water Reuse and Desalination – Editor

In 2015, **Jörg E. Drewes** continued to serve as Editor of the new journal **Journal of Water Reuse and Desalination (JWRD)**. JWRD is an international journal that is publishing papers on issues related to water reclamation, reuse and desalination. In 2015, it had an impact factor of 0.277 (http://jwrd.iwaponline.com).

Promotion of Young Talents/ Workshops/ Other Activities

Meeting of the Research Assistants 2015 in Weimar

From September 16-19, 2015 the 36th international meeting of the German-speaking research assistants in the area of environmental engineering was held in Weimar (Weimar Bauhaus University, hosted by Professor Jörg Londong).

A total of 61 academic research assistants from Germany, Austria, Luxembourg and Switzerland participated (Figure 39). Our deaprtment was represented by **Therese Burkhardt** and **David Miklos**.
The first meeting of the research assistants was first held in 1980 at TUM and has since then been organized annually. The aim of the meeting is to foster the professional and personal contact through the establishment and expansion of networks between the institutions. Through a technical program during the meeting, themes related to urban water management and water pollution control are presented and discussed. In addition, workshops and specialized tours are organized. Special thanks to the organizers and hosts of the Bauhaus-Universität Weimar.

Figure 39: Excursion Wismut Ronneburg (Picture: Bauhaus-Universität Weimar)

The next meeting of the research assistants in September of 2016 will be organized by our department at TUM (hosted by Professor Jörg E. Drewes).

Team outing in summer 2015

This year's team outing took place on the 16th of June, 2015. We spent the day in the crag (Figure 41), followed by a boat trip on the beautiful lake Ammersee (Figure 40). The day concluded with beer and food at a local restaurant in Herrsching.

Figure 40: Team outing 2015

Figure 41: In the crag

Scienclisten

The team of the Chair of Urban Water Systems Engineering cycled more than 35,000 km in the year 2015. This was approximately 10,000 km more than in 2014. We saved approximately 5 t of CO_2 in comparison to using a car (144 g CO_2/km). For 2016, we are targeting to bike one time around the equator (40,070 km).

Aquamasters 2015

This year's 10th Aquamasters of the German Water and Waste Management Institutes took place on the 9th of May in Hamburg. The Chair of Urban Water Systems Engineering was represented by the team "TUM kickt gut!" (Figure 42). Eleven teams with more than 100 participants from Aachen, Berlin, Bochum, Hamburg, Hanover, Karlsruhe, Koblenz, Munich, Rostock and Stuttgart joined this meeting. In the final, the Hamburg Sielkicker were defeated with 1: 2 by the team 1. FC Turbine Testfilter Berlin.

The final ranking of the Aquamasters 2015 was as follows:

1. FC Turbine Testfilter Berlin (Technische Universität Berlin)
2. Sielkicker Hamburg (Technische Universität Hamburg-Harburg)
3. GULLIats HRO (Universität Rostock)
4. TZW Karlsruhe (DVGW-Technologiezentrum Wasser)
5. Kupferbolzen Aachen (RWTH Aachen)
6. Nach(t)klärung Bochum (Ruhr-Universität Bochum)
7. Abse(i)tzbecken Stuttgart (Universität Stuttgart)
8. TUM kickt gut! (Technische Universität München)
9. Hamburger Sturmflut Verein (Technische Universität Hamburg-Harburg)

10. Anaerob Koblenz (Bundesanstalt für Gewässerkunde)
11. ISAH 96 (Leibniz Universität Hannover)

Many thanks to the organizers from Hamburg. The TUM team also thanks *Ingenieurbüro GFM Beratende Ingenieure* for the kind sponsorship of tricot sets. For more information visit www.aquamasters.de.

Figure 42: Our team "TUM kickt gut!"

Publications

Books and Book Chapters

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- Müller, J., Villamayor, L., Hübner, U., Drewes, J.E.: Aufbau und Einlaufphase eines sequentiellen biologischen Filtersystems zur Entfernung von Spurenstoffen aus dem Ablauf kommunaler Kläranlagen. Jahrestagung der Wasserchemischen Gesellschaft, 2015, 11.-13.05.2015
- Stadlmair, L., Grassmann, J., Drewes, J.E., Letzel, T.: Enzymatic Transformation of Trace Organic Chemicals – Characterization of Reaction Mechanisms using Mass Spectrometric Technologies. ANAKON, 2015, 23.-26.03.2015
- Veloutsou, S., Christoforidis, C., Mitsika, E., Raikos, N., Fytianos, K., Letzel, T.:Amphetamines and amphetamine-like drug analysis in waste water using RP-UPLC-MS/MS & comparison with a HILIC-RP-HPLC-MS coupling separation. ANAKON, 2015, 23.-26.03.2015
- Weißbach, M., Koch, K., Drewes, J.E.: Emissions from Wastewater Treatment Plants – a Novel Technique for Online Monitoring of Nitrous Oxide. University of Queensland/TUM Research Symposium, 2015, 11.-12.06.2015

Conference Articles

- Helmreich, B.: Dezentrale Behandlungsanlagen für Metalldachabflüsse. 14. Regenwassertage der DWA, 2015, 01.-02.07.2015
- Horstmeyer, N., Stahlschmidt, M., Regnery, J., Drewes, J.E.: 3D-Fluorescence Excitation-Emission Spectroscopy for Water and Wastewater Samples. FluoroFest 2015, 2015, 29.06.-01.07.2015
- Horstmeyer, N., Vatankhah H., Drewes, J.E.: Alternative Energy-Efficient Treatment Schemes for Potable Water Reuse. IWA 10th International Conference on Water Reclamation and Reuse, 2015, 05.-09.07.2015

- Huber, M., Hilbig, H., Drewes, J.E., Helmreich, B.: Einfluss von Auftausalzen auf die Remobilisierung von auf Filtermaterialien zur Behandlung von Verkehrsflächenabflüssen zurückgehaltenen Schwermetallen. Aqua Urbanica 2015 (Stuttgarter Berichte zur Siedlungswasserwirtschaft 225), 2015, 07.-08.10.2015, 123-130
- Huber, M., Horstmeyer, N., Drewes, J.E., Helmreich, B.: Bewachsener Oberboden nach DWA-A 138 und DWA-M 153 im Kontext des Entwurfs der Mantel-Verordnung und der Aktualisierung der Geringfügigkeitsschwellenwerte. Tagung Straßenbauwerk - Umweltschutz - Kreislaufwirtschaft (StrUK), 2015, 22.-23.06.2015, 114-123
- Huber, M., Welker, A., Drewes, J.E., Helmreich, B.: Anforderungen an dezentrale Anlagen zur Behandlung von Verkehrsflächenabflüssen. Tagung Straßenbauwerk - Umweltschutz - Kreislaufwirtschaft (StrUK), 2015, 22.-23.06.2015, 101-113
- Koch, K., Plabst, M., Schmidt, A., Helmreich, B., Drewes, J.E.: Co-Vergärung von Speiseresten auf kommunalen Kläranlagen: Vergleich von Laborergebnissen und Erfahrungen aus der Praxis. 10. Fachtagung „Anaerobe biologische Abfallbehandlung“ der TU Dresden, 2015, 29.-30.09.2015, 105-115
- Lindenblatt, C., Drewes, J.E.: Vergleich der Deammonifikation in ein- und zweistufigen SBR-Anlagen. Industrietage Wassertechnik 2015, 2015, 10.-11.11.2015
- Vesting, A., Huber, M., Giga, A., Helmreich, B., Wichern, M.: Erfahrungen aus Praxisuntersuchungen eines dezentralen Behandlungssystems zur Reduktion von Kohlenwasserstoffen und organischen Spurenstoffen aus Verkehrsflächenabflüssen. Aqua Urbanica 2015 (Stuttgarter Berichte zur Siedlungswasserwirtschaft 225), 2015, 07.-08.10.2015, 131-141
- Walters, E., Rutschmann, P., Schwarzwälder, K., Müller, E., Horn, H.: Verbleib von fäkalen Indikatorkeimen aus Mischwasserentlastungen nach der Einleitung in Fließgewässer. Aqua Urbanica 2015 (Stuttgarter Berichte zur Siedlungswasserwirtschaft 225), 2015, 07.-08.10.2015, 63-71
- Weißbach, M., Koch, K., Drewes, J.E.: Lachgas in der biologischen Abwasserbehandlung - eine potenzielle Quelle zur nachhaltigen Energierückgewinnung. 43. Abwassertechnisches Seminar: Energieeffiziente Verfahren zur Stickstoffelimination - Innovationen aus der Forschung und Erfahrungen aus der Praxis, 2015, 16.07.2015, 61-80
- Welker, A., Huber, M., Dierschke, M., Drewes, J.E., Helmreich, B.: Weitergehende Anforderungen an dezentrale Behandlungsanlagen für Verkehrsflächenabflüsse: organische Schadstoffe und Phosphor. Aqua Urbanica 2015 (Stuttgarter Berichte zur Siedlungswasserwirtschaft 225), 2015, 07.-08.10.2015, 91-107

Thesis

Doctoral Dissertation

- Rajab, M. (2015): Electrochemical oxidation using a boron doped diamond electrode as a water treatment process- removal of residual micropollutants and inactivation of microorganisms

Master’s Thesis

- Badenberg, Sophia C.: Bestimmung des Einflusses von Auftausalzen auf die Remobilisierung von auf Filtermaterialien zurückgehaltenen Schwermetallen
- Böhm, Stefan: Untersuchungen zum Einfluss von Streusalz auf den Sedimentationsprozess in Regenbecken an Autobahnen
- Brandl, Johannes: Untersuchungen zum Einfluss von Abwässern aus Autobahn-Rastplätzen auf kleinen kommunalen Kläranlagen - am Beispiel der Gemeinde A
- Buchner, Josef: Optimierung eines automatisierten Bestimmungsverfahrens für coliforme Keime auf Basis einer enzymatischen Reaktion
- Doblinger, Tobias: Feasibility of decentralized wastewater treatment and non-potable reuse in the town of Leh, Ladakh, India
- Fassnacht, Julius: Durchführung von Laborversuchen zum Schwermetallrückhalt unter Auftausalzbedingungen und Modellierung der Ergebnisse
- Fuchsreiter, Daniel: Development of a sustainable water and biogas concept at Ritaliza School in Holili, Tanzania
- Gauckler, Johannes: Determination of microbial degradation potential of Pendimethalin for agriculturally used areas by means of in situ microsoms
- Holfelder, Kathrin: Erarbeitung eines Abfallkennzahlsystems bei der MAN Truck & Bus AG am Standort München
- Hu, Sijie: Defluorination efficiency of nano magnesia in a chromium contaminated groundwater system
- Kaiser, Lisa Maria: Reduktion von Kalkscaling in einem thermophil betriebenen Membran-Bioreaktor (TMBR) zum Einsatz in der Industrieabwasserreinigung
- Kinshofer, Johanna: Ein systematischer Ansatz zur Sanierung von vertikal durchströmten Pflanzenbeeten am Beispiel einer Kläranlage

- Kirner, Simon: Determination of enzymatic activity in environmental samples
- Kolpakova, Irina: Establishment of photometric and mass spectrometric assays to detect enzymatic reactions of fungal laccases and to estimate their capabilities to degrade diclofenac and caffeine
- Lippert, Thomas: Hydrodynamics and Transport Phenomena within Osmotic Membrane Modules - A Modeling Approach by Use of COMSOL Multiphysics TM
- Liu, Yang: Untersuchung zur Synthese von anionischen Ton-Sand- Mischungen zur Grundwasserentfluorung
- Majer, Theresa: Ableitung einer Kostenschätzformel auf Grundlage einer Zustandsbewertung und Sanierungskonzeption von Grundwasserentwässerungsanlagen
- Ozegowski; Jan: Planung und Betrieb einer Klärschlammbehandlung am Beispiel der Kläranlage Gersthofen
- Röver, Marie: Potential of Typha latifolia for the phytoremediation of sulfamethoxazole
- Schiefer, Christoph: Soil column studies on metabolic mechanisms for the removal of trace organic chemicals in managed aquifer recharge systems
- Schima, Antonia Zoe: Optimierung der Reinigungsleistung von kleinen Kläranlagen durch Kombination verschiedener Verfahren
- Schlämmer, Julia: Ertüchtigung der Abwasserbeseitigung einer Gemeinde - Vergleichende Betrachtung von Alternativen
- Schledorn, Alexander: Klassifizierung von Schmutzwasserschächten im Hinblick auf eintretendes Niederschlagswasser über Schachtdeckelöffnungen im Zusammenhang einer Fremdwasserstudie am Fallbeispiel Rosenheim-Nord
- Seifert, Marie Luise: Evaluation of Natural Organic Matter Interference in Groundwater Defluoridation using Nano Magnesia
- Shuang, Chen: Metal ion incorporated sand for fluoride removal from aqueous solution
- Sihorsch, Stefan: Setup and monitoring of a bioreactor system producing nitrous oxide from digester centrate
- Silva, Rodolfo: Feasibility assessment of anaerobic digestion technologies for household wastes in Vietnam; with the case of Nam Binh Duong waste treatment complex in Binh Duong province
- Stahlschmidt, Max: 3D-Fluorescence spectroscopy coupled with parallel factor analysis for characterization of natural organic matter during managed aquifer recharge operation
- Storms, Janine: Massenspektrometrie basierte Untersuchung zur enzymatischen Transformation von Pharmazeutika - Etablierung von Single- und Multiplex-Methoden
- Villamayor, Lucia: A Sequential Biofiltration Concept for Enhanced Removal of Trace Organic Compounds during Wastewater Treatment
- Wagner, Stefan: Influence of the CO2 concentration in the flushing gas on the methane production in BMP tests
- Weingartner, Carolina: Techno-economic analysis of an off-grid power system with hydrokinetic power generation and electro-chemical storage
- Wulff, Moritz: Durchführung und Vergleich von Schnellbestimmungsmethoden und Säulenversuchen zur Ermittlung des Schwermetallrückhalts an Filtermaterialien
- Wunderle, Max: Design, Construction and Commissioning of an Automated Fluidized Bed Ultrafiltration Membrane Reactor for Wastewater Treatment
- Wycisk, Konstantin: Evaluation of the trace organic chemical (TOrC) removal in sequential managed aquifer recharge systems as a function of different dissolved organic carbon (DOC) compositions
- Yurchak, Nicole: Comparison of Different Physical Cleaning Methods - Backshock and Backwash - in Dead-End Ultrafiltration of Tertiary Wastewater

Study Projects

- AlRiyami, Shamma: Demonstration of Confocal Laser Scanning Microscopy in membrane biofilm analysis
- Badenberg, Sophia C.: Implementation and evaluation of three rapid scale test methods for the determination of heavy metal removal by filter materials
- Brandl, Johannes: Performance evaluation of the groundwater treatment facility at the Chair of Aquatic System Biology, Weihenstephan
- Chahli, Yasmin: Determination of ozone concentration and OH radical exposure produced by a BDD-Electrode depending on applied current density
- Crocs, Vivien: Operation manual of the PANOWA research reactor system at the chair of urban water systems engineering
- Ederer, Jürgen: Abbau von Bisphenol-A mit der bordotierten Diamantelektrode
- Egeler, Maria: Study about the mechanical sewage sludge dewatering of the sewage plant Obere Iller
- Emmer, Ludwig: Projektarbeit im Kernbereich K1 Abfallbehandlung: Plastic inputs into the environment: Ecological impacts and solution approaches
- Fassnacht, Julius: Dezentrale Beseitigung von Niederschlagswasser in den Bundesländern: Rechtliche Vorgaben
- Finder, Sarah Grace: Legislative, Energy and Cost Considerations for Different Treatment Trains for Potable Water Reuse

- Friesen, Margarethe: Analyse der Eignung eines Begin-of-pipe-Ansatzes bei der Entsorgung von Antibiotika in der Mikrobiologie
- Han, Youl: Optimization of staining method using flow cytometry for virus quantification
- Hauck Sabadini, Natalia: Carbon and nitrogen content of prokariots from groundwater of varying trophic status
- Högel, Lukas: Potential and Profitability Analysis of Pumps and Turbines in Conjunction with Smart Pressure Management for Energy Generation and Recuperation in Water Distribution Networks
- Hölzwimmer, Sebastian: Unterschiede in Konstruktion und Betrieb von zentralen Sedimentations- und Abscheideanlagen zur Regenwasserbehandlung an Straßen
- Hu, Sijie: Projektarbeit: Simulation der biogenen Schwefelsäurekorrosion im Labor
- Lindholm, Katharina: Micropollutant removal from secondary effluents by advanced oxidation process with boron-doped diamond electrodes
- Lippert, Thomas: Hydrodynamic modelling of pure water flow within a flatsheet membrane module by use of the software Siemens NX 8.0
- Rosenwirth, Bianca: Optimization of sour water sedimentation during residue incineration and improvement of filter and press properties in the disposal center
- Röver, Marie: Status and fate of the anti-inflammatory drug diclofenac and the steroid hormones 17ß-estradiol and 17a-ethinylestradiol in wastewater effluents and in the aquatic environment - a literature research
- Santos, Esther Natalie: Evaluation of Nitrous Oxide Extraction Methods
- Strasser, Andreas: Sorption of Trace Organic Chemicals to Clay
- Tackaert, Rodrigo: Investigation and Review of Surrogate Parameters to Evaluate Oxidation of Trace Organic Contaminants during Ozonation of Wastewater Effluents
- Usman, Muhammad: Optimization of Soil Aquifer Treatment by chemical oxidation with hydrogen peroxide addition
- Vatankhah, Hooman: Evaluation of Alternative Treatment Design in Wastewater Treatment by Implementing a Toolbox
- Vikainen, Jussi: Bacterial community fingerprinting in heavy metal contaminated soils
- Wagner, Stefan: Influence of headspace flushing on methane production in Biochemical Methane Potential (BMP) tests
- Wojak, Nadja: Investigation of Nitrous Oxide Concentration Profiles in an Experimental Water Column
- Wycisk, Konstantin: Aufbau und Inbetriebnahme eines Säulensystems zum Vergleich des Spurenstoffabbaus bei verschiedenen Zuläufen
- Zeynep Inan, Ayse: Deactivation and reactivation of Pseudomonas Putida strain F1 under growth and starvation conditions

Bachelor's Thesis

- Andrianjafidago, Stephanie: Neue Auswertestrategien von Transformationsprodukten in der Umwelt (Pflanzenschutzmittel)
- Batzdorf, Lotte: Darstellung von Trends und Möglichkeiten zukunftsorientierter Oberflächenentwässerung
- Baumgartner, Thomas: Grabenlose Renovierungsverfahren im Vergleich: Gegenüberstellung von Auskleidungsverfahren mit vorgefertigten Rohren gegenüber örtlich hergestellten und erhärtenden Rohren - konkret am Beispiel Schlauchlining und Close-Fit-Lining
- Bickert, Nadine: Konzepterstellung zur mechanischen Luftfiltration in Trinkwasserbehältern
- Charnoske, Cody: Vergleich deutscher und ausländischer Bemessungsansätze zur Behandlung und Rückhaltung von Straßenoberflächenwasser - Recherche, Analyse und Weiterentwicklung
- Gawlick, Julia: Analyse der Faulgaszusammensetzung verschiedener Kläranlagen
- Groß, Thomas: Fremdwasseranalyse in der Gemeinde Westerheim: Ermittlung von Anfallschwerpunkten und Ursachen samt Konzeption zur Reduzierung des Fremdwasseranteils
- Heider, Martina: Untersuchungen zum Einfluss von Streusalz auf den Sedimentationsprozess in Regenbecken
- Hettmann, Andreas: Auslegung und Implementierung einer LABVIEW-Steuerung zur Automatisierung einer Ultrafiltrationsmembranreaktorversuchsanlage in der Abwasserbehandlung
- Höhener, Miriam: Einsatz von Pflanzen als schwimmende Inseln auf Regenbecken für Straßenoberflächenwasser
- Jell, Johannes: Machbarkeitsstudie zur Abkopplung vom Regenwasser aus dem Mischwassernetz im Einzugsgebiet vor dem Regenüberlaufbauwerk Adenauerallee, Leipzig
- Kirchner, Marlen: Neue Auswertestrategien von Transformationsprodukten in der Umwelt (Pharmaka)
- Kronschnabl, Sebastian: Trinkwasserdesinfektion in Deutschland - Stand der Technik
- Lammers, Martin: Lachgasextraktionsmöglichkeiten in der zweiten Stufe des CANDO-Prozesses
- Moeller, Andreas Bruno: Untersuchungen zum Verlust von Stickstofffrachten und der Ammoniumoxidationsraten abhängig vom pH-Wert in einem Bioreaktor zur Nitritation
- Musch, Alexandra Isabella: Vergleich verschiedener Verfahren zu Phosphorrückgewinnung aus Klärschlamm und Abwasser

- Neumaier, Marina: Erstellung eines Abwasserkatasters am Beispiel der Überprüfung eines bestehenden Abwasserkatasters der Kläranlage eines Industrieparks
- Pfluger, Samuel: Vergleich verschiedener Infiltrationstechniken zur Grundwasseranreicherung
- Rager, Florian: Durchführung eines Expositionsversuchs mit Muscheln und Entwicklung einer Probenaufbereitungsmethode für die Analyse von Mikroplastik mittels Raman-Mikrospektroskopie
- Rempe, Lisa-Marie: Untersuchung der biogenen Schwefelsäurekorrosion im Labor
- Entwicklung und Kalibrierung eines Versuchsstands zur gasvolumetrischen Bestimmung von hohen (>50mg/L) Nitritstickstoffkonzentrationen zur Überwachung des Coupled Aerobic-anoxic Nitrous Decomposition Operation (CANDO) Prozess
- Schnick, Sandrine: Evaluation primärer Stressereignisse in der Phytoremediation
- Schweiger, Daniela: Entfernung organischer Spurenstoffe bei der naturnahen Abwasserreinigung
- Schweizer, Stefanie: Potenzial der Kläranlage Garching in Bezug auf ein neuartiges Verfahren zur Energiegewinnung aus Stickstoff
- Skiebe, Axel: Polare organische Spurenstoffe in der wässrigen Umwelt (log P -0,4 - 0)
- Streit, Verena: Investigation of a chemical enhanced forward flush as new method in the regeneration of ultrafiltration membranes
- Weihofer, Björn: Analyse von Faulgas auf verschiedenen Kläranlagen zur Untersuchung der biogenen Schwefelsäurekorrosion im Faulbehälter
- Wolf, Alexander: Extrem polare organische Spurenstoffe in der wässrigen Umwelt (logP -1 bis -0,4)

Dissertations and Awards

Mohamad Rajab, M.Sc., successfully defended his dissertation on 30th of June 2015 with the title „*Electrochemical oxidation using a boron doped diamond electrode as a water treatment process- removal of residual micropollutants and inactivation of microorganisms*“. His reviewers were: Prof. Brigitte Helmreich of the chair, Prof. Michael Schuster of the faculty chemistry of TUM and Prof. Martin Jekel of TU Berlin. The chairperson was Prof. Jörg Drewes.

Stefan Böhm, a graduate of the Master's degree program Environmental Planning and Engineering Ecology was award in October for his master's thesis *“Studies on the effect of road salt on the sedimentation in rainwater retention basins on motorways*" with the **Max-von-Pettenkofer Prize 2015** from DWA. He produced his thesis in collaboration with the University of the Federal Armed Forces München.

Our PhD student, **Therese Burkhardt**, M.Sc., was awarded the **Laura Bassi Prize TUM** for outstanding women in science. The price includes a one-year doctoral fellowship.

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 theses 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 2015, the following lectures have been offered:

Summer Term

- Advanced Water Treatment Engineering and Reuse: Drewes, Jörg
- Bewirtschaftung von Kanalnetzen und Regenwassermanagement: Helmreich, Brigitte; Horstmeyer, Nils
- Brauchwasser: Glas, Karl
- Ergänzungskurs Siedlungswasser- und Abfallwirtschaft: Drewes, Jörg; Horstmeyer, Nils; Hübner, Uwe; Weißbach, Maximilian
- Exkursion Kanalisation: Helmreich, Brigitte, Weißbach, Maximilian
- Hydrochemistry Laboratory: Helmreich, Brigitte
- Klärschlammbehandlung: Koch, Konrad
- Microbiology of Groundwater Ecosystems: Griebler, Christian; Lüders, Tilman
- Modelling of aquatic systems: Koch, Konrad; Stamou, Anastasios
- PhD Seminar SiWaWi: Drewes, Jörg, Koch, Konrad
- Projektkurs Siedlungswasserwirtschaft: Drewes, Jörg
- Thermodynamik und Energietechnik Übung: Hübner, Uwe
- Thermodynamik und Energietechnik: Hübner, Uwe
- Umweltanalytik: Letzel, Thomas
- Umweltrecht: Spieler, Martin
- Urban Climate - Anwendungen: Katzschner, Lutz
- Waste Water Treatment: Helmreich, Brigitte

Winter Term

- Fundamentals of Urban Climate: Katzschner Lutz; Helmreich, Brigitte
- Gewässerschutz: Gschlößl, Tanja
- Grundlagen Ökologie: Hellauer, Karin; Lemmer, Hilde; Bettina, Huber; Müller, Elisabeth
- Grundlagen Verfahrenstechnik: Böhm, Bernhard; Koch, Konrad
- Hydrochemistry: Helmreich, Brigitte
- Hydrochemistry Laboratory: Helmreich, Brigitte; Hübner, Uwe; Horstmeyer, Nils; Weißbach, Maximilian
- Mikrobiologie: Lemmer, Hilde
- PhD Seminar SiWaWi: Drewes, Jörg; Koch, Konrad
- Planung, Bau und Betrieb von Kläranlagen: Schreff, Dieter
- Siedlungswasser- und Abfallwirtschaft Grundmodul: Helmreich, Brigitte; Koch, Konrad
- Siedlungswasserwirtschaft Grundmodul: Helmreich, Brigitte; Koch, Konrad
- Technical Communication Skills in Water and Wastewater Treatment: Drewes, Jörg; Koch, Konrad
- Water and Wastewater Treatment Engineering: Drewes, Jörg

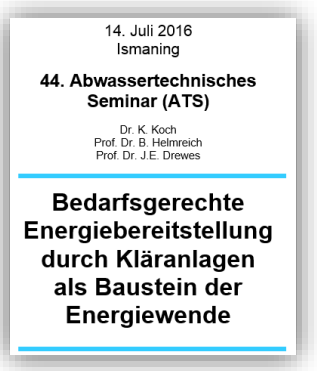
Upcoming dates

44. ABWASSER-TECHNISCHES SEMINAR (ATS)

DATE:
14. JULY 2016

LOCATION:
BÜRGERSAAL ISMANING,
ERICH-ZEITLER-STRAßE 2
85737 ISMANING

REGISTRATION:
WWW.SWW.BGU.TUM.DE/ATS



09:15 Uhr **Begrüßung und Einführung**
Prof. Dr. Jörg E. Drewes, TU München
09:30 Uhr **Strategien und Beiträge zur Energiewende aus bayerischer Sicht**
Dipl. Umweltwiss. Kerstin Ikenmeyer, Bayrisches Staatsministerium für Wirtschaft und Medien, Energie und Technologie, München
10:00 Uhr **Virtuelle Kraftwerke als Bausteine der Energiewende – wirtschaftliche und technische Herausforderungen**
Dipl.-Wi.-Ing. Barnabas Kittlaus, SWM Services GmbH, München
10:30 Uhr **Diskussion**
10:40 Uhr **Pause / Aussteller- und Posterforum**

Themenblock: Power to Gas (PtG)
Moderation: Prof. Dr. Jörg E. Drewes
11:10 Uhr **Kopplung Kläranlage mit PtG Anlage zur autonomen Strombedarfsdeckung**
Stephan Rieke, ETOGAS GmbH, Stuttgart
11:30 Uhr **Mikrobielle Methanisierung im Rahmen von Power-to-Gas-Konzepten: Stand und Perspektive**
Dr. Monika Reuter, MicrobEnergy GmbH, Schwandorf
11:50 Uhr **Biologische Methanisierung im Rieselbettverfahren**
Dipl.-Ing. Dietmar Strübing, Dr. Konrad Koch, Prof. Dr. Jörg E. Drewes, TU München
12:10 Uhr **Diskussion**
12:20 Uhr **Pause / Aussteller- und Posterforum**

Themenblock: KAs am Regelenergiemarkt
Moderation: Dr. Konrad Koch
13:30 Uhr **Biogasprognose zur Integration von Kläranlagen in virtuelle Kraftwerke**
Sebastian Hien, M.Sc., Prof. Joachim Hansen, Universität Luxemburg
13:50 Uhr **Aktuelle und perspektivische Vermarktungssituation für Strom aus Kläranlagen in der Praxis**
Thorsten Biela, Clean Energy Sourcing AG, Leipzig
14:10 Uhr **Kläranlagen als flexible Marktteilnehmer im Rahmen virtueller Kraftwerke**
Dipl.-Ing. Kurt Schwan, WVE GmbH, Kaiserslautern
14:30 Uhr **Diskussion**
14:40 Uhr **Pause / Aussteller- und Posterforum**
15:10 Uhr **Elektrische Lastverschiebung in der Abwasserreinigung - Kläranlagen als Bestandteil smarter Energiesysteme**
Univ.-Doz. Dipl.-Ing. Dr. Otto Nowak, Nowak Abwasser Beratung e.U., Eisenstadt, Österreich
15:30 Uhr **Kläranlagen als flexibler Baustein im Energienetz**
Dr. Volker Erbe, Wupperverband, Wuppertal
15:50 Uhr **Bedarfsgerechte Stromerzeugung mittels Fernzugriff: Erfahrungen eines Biogasanlagenbetreibers**
Josef Götz, Götz Agrardienst, Markt Indersdorf
16:10 Uhr **Diskussion**
16:20 Uhr **Schlusswort**
Prof. Dr. Jörg E. Drewes, TU München

Friends of the Chair

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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 are publishing once a year 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.

Donations can be transferred electronically to the following account at the Postbank München (IBAN: DE04 7001 0080 0034 9498 02, BIC: PBNKDEFF). All donations are tax deductible.

In 2015, the office of the Development Fund was led by Mr. Stefan Bieber.

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