Karlsruhe Institute of Technology

Topics in Water Chemistry and Water Technology

Annual Report of the Chair of Water Chemistry and Water Technology and the DVGW Research Center at the Engler-Bunte-Institut **2021**

Dear colleagues and friends,

as you can see, the editorial is written this year by two persons of our group. We thereby hope to widen the view on the research conducted in 2021. Despite hopes of many of us and the statement in the editorial 2020, the world in 2021 still struggled with the COVID-19 pandemic. Fortunately, the vaccination campaign brought some relief and life became little by little normal. As in 2020, we continued almost in an undisturbed manner our research activities. Either by being at the institute under contact restrictions or in home-office.

This year we welcomed two new Humboldt scholars in our group – Prof. Marta Gmurek (Lodz University of Technology), working on photocatalytic degradation of antibiotics and antibiotic resistance genes, and Dr. Rui Du (Beijing University of Technology), who works on a combination of denitrification and anammox. Within the German Academic Exchange Service (DAAD), we also host a visiting PhD student, Hessam Addin Nadernia from Sahand University of Technology (Iran), to work on removal of antibiotics from water during the solar photocatalysis.

One of our PhD students – Stephan Zimmermann – received a Travel Grant of Karlsruhe House of Young Scientists (KHYS) that allowed him to perform part of his research in the Institut Polytechnique UniLaSalle in Rennes-Bruz (France).

Despite decades of intensive investigations, the contamination with micropollutants is still an important pillar of water research in 2021. This fact was highlighted during the Water Online Conference on Micropollutants organized together with the 40th anniversary of the European Water Association. Guest speakers, both from academia and practice, summarized the state-of-the-art of the micropollutants domain and discussed the European approaches to mitigate the problem. You can read about our contributions in the field of micropollutants research on page 8.

With respect to new projects we have been able to join one of the large BMBF funded projects (Leitprojekte) for Green Hydrogen based technologies. *H_2Mare* is supposed to elucidate the option for offshore hydrogen production with electrical energy from wind power (page 3). We will be responsible for the water management; especially for the application of membrane technologies for sea water desalination and waste water treatment.

The water/energy nexus is also addressed in another project related to the Federal Horticultural Show "Bundesgartenschau 2023" in Mannheim. Together with the group of Johannes Gescher we will install a public toilet and set up a bioelectrical rotating disc biofilm contactor system, which will treat the collected urine and produce hydrogen. This approach demonstrates to the public the capabilities of biochemical systems for the treatment of waste/yellow water in combination with the production of valuable precursor chemicals. Within this context, Harald Horn deeply regrets that the KIT was not able to keep Johannes Gescher. Congratulations to Johannes and his new colleagues at Hamburg University of Technology (TUHH), the latter won an outstanding researcher and colleague.

We send our best wishes for 2022 to all of you.

Ewa Borowska Harald Horn

DVGW

Water Research Network Baden-Württemberg

Ulrike Scherer

Funding:
Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg (MWK)

Partners:
Universities in Baden-Württemberg
www.wassernetzwerk-bw.de

2021 was the last year of funding for the Water Research Programme of the Land Baden-Württemberg. The three interdisciplinary projects "CHARM: Challenges of Reservoir Management" (Universities Stuttgart, Konstanz and Freiburg), "DRIeR: Drought Impacts, Processes and Resilience" (Universities Freiburg, Heidelberg and Tübingen) and "Effect-Net: Effect-Network in Water Research" (Universities Heidelberg, Tübingen and KIT) were successfully completed. The results of the projects were presented and discussed at the Final Conference that was held online on 20 and 21 May 2021.

In addition, this years`s Water Research Horizon Conference (WRHC) was jointly organized by the Water Research Network Baden-Württemberg and the Water Science Alliance e. V. on the topic of "Droughts, Floods & and their Emerging Challenges". This international online conference on 15 and 16 June 2021 was attended by about 300 participants. Discussions focused on the dynamic interactions between extreme events, anthropogenic influences and ecosystems, and the development of strategies for risk management and adaptation measures.

The Water Research Network Baden-Württemberg gained huge attention in Germany and beyond as it could show that the highly diverse water research community can be won over for successful interdisciplinary cooperation. KIT will therefore continue the coordination office of the Water Research Network after the funding from the Ministry of Science, Research and the Arts has expired.

Standard Methods for the Examination of Water, Waste Water and Sludge

Birgit C. Gordalla

Funding:
Water Chemistry Society (Division of the Gesellschaft Deutscher Chemiker e. V., GDCh)

The Umweltbundesamt (UBA)

In year 2 of SARS CoV-2, standardization activities in order to update the above-mentioned collection of analytical methods still have been performed only via online meetings or in writing. A new standardization project arose from the pandemic itself: The microbiology group within the technical committee DIN NA 119-01-03 AA "Water examination" is developing a RT-pPCR based method which allows for detection and surveillance of SARS-CoV-2 and its variants in waste water, as is requested in the recommendation (EU) 2021/472 of the European commission. The procedure shall be suitable for trend monitoring of virus RNA load in sewers and at the inflow of waste water treatment plants as part of an early-warning system. Ten countries participate in this standardization project, which is accepted as a work item parallel in ISO/TC 147 "Water quality" and in CEN/TC 230 "Water analysis".

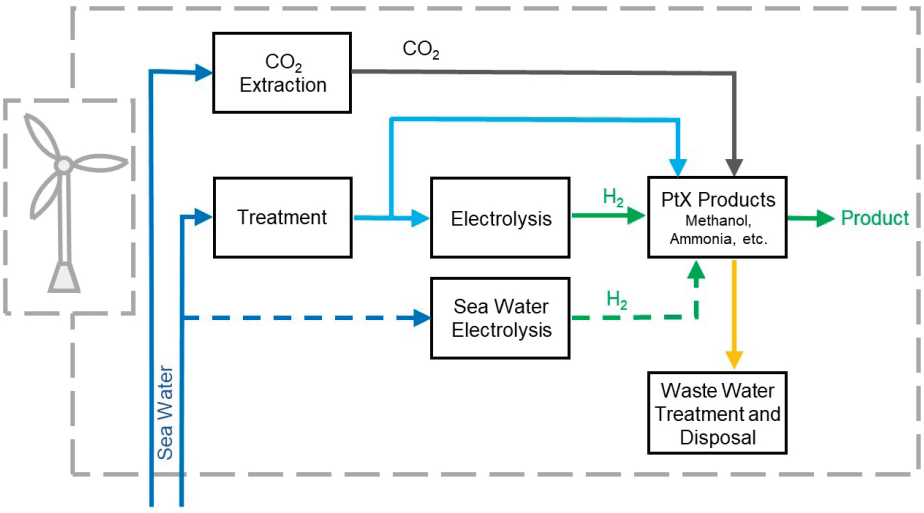
For drinking water analysis, a method is being standardized suitable to monitor a parametric value of 60 µg L^{-1} for the sum of monochloro-, dichloro- and trichloro-acetic acids, and mono- and dibromo-acetic acids, subsumed as parameter "HAA5" in the revised Drinking Water Directive (EU) 2020/2184. This parameter shall be measured if disinfection methods are used that can generate haloacetic acids. A limit of quantification of 30 % or less of the parametric value, and a measurement uncertainty of maximum 50 % are specified as performance characteristics for the method to be applied.

H_2Mare: Offshore Generation of Hydrogen and Power-to-X Products Using Wind Energy

As part of the national plan for the transition toward a sustainable and carbon-neutral energy supply, the Federal Ministry of Education and Research runs a funding initiative to enter into a green hydrogen economy. *H_2Mare*, one of these leading projects, focuses on the offshore generation of green hydrogen along with downstream Power-to-X (PtX) products powered with off-the-grid wind energy (e.g. methanol, road fuel alternatives). The project seeks to take advantage of the favorable conditions for wind power generation and water availability on the sea and thus low costs compared to onshore production of hydrogen and PtX products.

H_2Mare is divided into sub-projects dealing with different aspects of operating such a technology offshore. The DVGW Research Center at the Engler-Bunte-Institut at KIT, Water Chemistry and Water Technology, is a key player in the collaborative sub-project PtX-Wind, which examines each of the PtX processes and leads the water management aspect within it.

Our team investigates the treatment, monitoring and supply of water needed for the electrolysis and related PtX processes by applying innovative as well as established technologies. Treatment and disposal measures for the waste waters originating from the different processes are of relevance and are thus being investigated in detail (see figure). In addition, CO_2 production directly from sea water is evaluated, as it is an essential input for PtX processes. Ongoing investigations focus on the application and optimization of sea water electrolysis including the monitoring and control of fouling. Within the upcoming four years, the evaluation and optimization of the previously mentioned processes will be performed, based on an offshore operation perspective with the goal of providing a basis for future implementation of offshore plants of this kind.



Schematic showing of the PtX-Wind processes under investigation.

Florencia Saravia

Michael Wagner

Yair Morales

Partners:
Institute for Micro Processing Engineering (IMVT), KIT;
Institute of Chemistry, Catalysis and Materials Engineering Group, TU Berlin;
DVGW Research Center, Gas Technology at the Engler-Bunte-Institut, KIT;
DECHEMA e. V., Frankfurt am Main; Helmholtz-Zentrum, Geesthacht;
EnBW Energie Baden-Württemberg AG; EnviroChemie GmbH, Rossdorf;
INERATEC GmbH, Karlsruhe; Siemens Gamesa Renewable Energy
GmbH & Co. KG, Denmark, and other partners from universities, research
institutions and companies in Germany

Funding:
Federal Ministry of
Education and Research (BMBF)

Development of Novel, Scalable Reactor Concepts for Bioelectrochemical Application

Andrea Hille-Reichel

Max Hackbarth

Maximilian Miehle

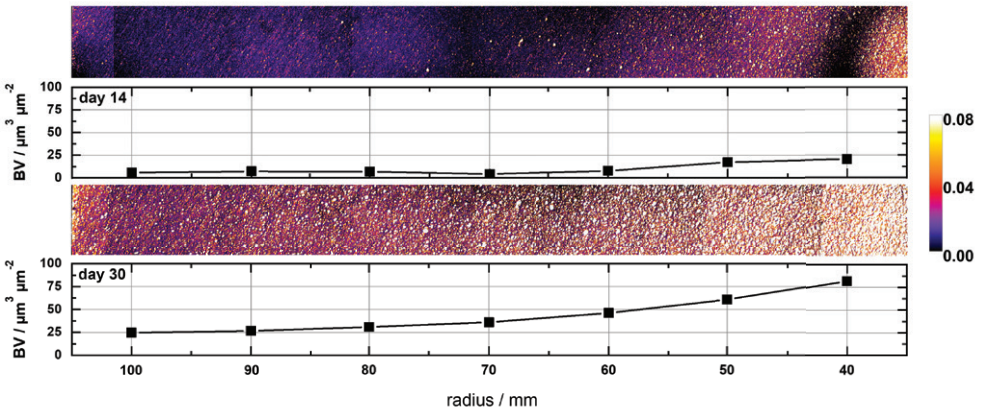
Johannes Reiner

Primary microbial electrochemical technologies (METs) are applications based on the direct interaction of microorganisms with an electrode. Depending on the choice of biocatalyst and electrode potential, there are different possible applications such as waste water treatment or the production of value-added chemicals. Although METs may have several advantages over conventional biotechnological processes, turnover rates have so far been too low for a commercially viable process. The literature mainly claims two limiting factors: the microbe-electrode-interaction itself and the lack of specialized and scalable reactor systems. The institute's growing expertise in the development of novel, scalable reactor concepts for bioelectrochemical applications is evident in the following three projects:

1. The BMBF project *BioElectroPlast*, focusing on the production of polyhydroxybutyrate (PHB) from CO_2 and electric current, was completed this spring. A biological contactor with rotating electrodes was developed and successfully operated for the culturing of the PHB-producing biocatalyst (see figure).

2. A similar reactor system was designed for the current project *BROWSE* (Biopolymers from Waste), that aims to establish a continuously operated reaction cascade in order to convert food waste into 2,3-butanediol. The 10-liter biological contactor is operated as a so-called microbial electrolysis cell to degrade unwanted organic acids in the production stream, coupled to a cathodic hydrogen production.

3. In *ContiBio-Elect*, a reactor for continuous, anaerobic oxidation processes is designed, where a conducting monospecies bacterial biofilm is cultivated on a packed bed of anodic polymer granules. Model process is the conversion of glucose to the value-added platform chemical acetoin. We intend to achieve space-time-yields comparable to existing (and often oxic) batch systems with the advantages of high carbon yield and low generation of biomass and by-products typical of anoxic cultivations.



Height maps derived from OCT (Optical Coherence Tomography)-datasets of radial sections of the rotating graphite cathode in the novel biological contactor after 14 and 30 days of cultivation of the thermoacidophilic, electroautotrophic bacterium Kyrpidia spormannii. The corresponding biovolumes as a function of radius are given below.

Funding:
Federal Ministry of Education and Research (BMBF)

Partners:
[1,2,3] Institute of Applied Biology (IAB), KIT, since 07/21: Institute of Technical Microbiology, Hamburg University of Technology;
[1,2] Environmental Process Engineering, University of Bremen;
[1] EnBW Energie Baden-Württemberg AG;
[2] Laboratory of Applied Chemistry, Institute of Organic Chemistry (IOC), KIT;
[2] Fraunhofer Institute for Solar Energy Systems (ISE), Freiburg;
[3] Eisenhuth GmbH & Co. KG, Osterode am Harz

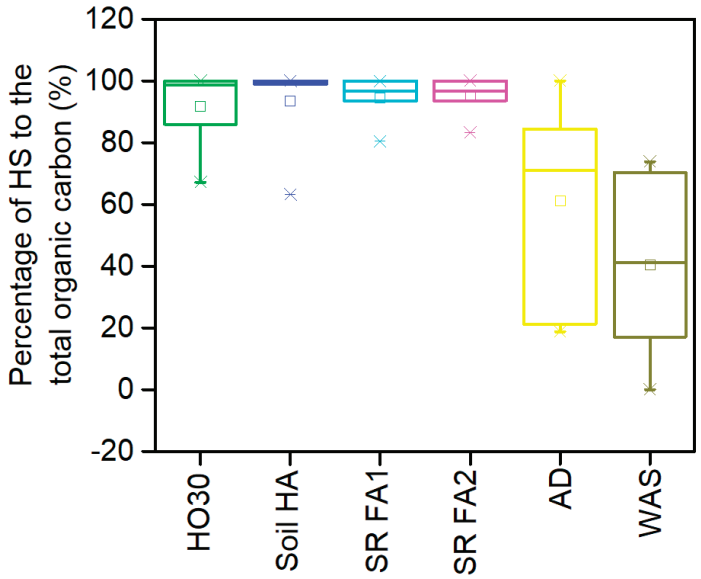
"Humic Substances" Measurement in Sludge Dissolved Organic Matter: A Critical Assessment

Keke Xiao

Gudrun Abbt-Braun

The current used methods for humic substances (HS) quantification in dissolved organic matter (DOM) of sludge had been tested for several sludge DOM samples (anaerobic digested raw sludge (AD) and waste activated raw sludge (WAS)). For the calibration of several methods, different samples from natural organic matter have been used (brown water taken from Lake Hohloh (HO30), and isolated fulvic and humic acid samples (Soil HA, SR FA1, SR FA2)).

The results indicated that the current methods showed overestimated and contradictory results for HS quantification in sludge DOM. Using the modified Lowry method, different values were obtained depending on the humic acids used for calibration, and false negative results were observed for some sludge samples. By using the relative amount of HS (based on dissolved organic carbon (DOC)) to total sludge DOM (based on DOC), variations among the results of different analysis methods for the same sample were high. The results obtained by three-dimensional excitation emission matrix (3D-EEM), either with spectra analysis methods by peak picking, fluorescence region integration (FRI, both region volume and area integration), or PARAllel FACtor analysis showed higher degrees of dissimilarity to those quantified by size exclusion liquid chromatography (LC-OCD) or the XAD-8 method (see figure). The selection of fluorescence regions for HS seemed to be the determining factor for overestimation obtained by the 3D-EEM technique. Strategies, like a consistent terminology of HS, the use of an internal standard sample and the related standardized operation for HS quantification in sludge DOM need to be established.



Box plots showing the variation in the proportion of HS to the total organic carbon of DOM in both calibration and sludge DOM samples measured by methods of LC-OCD, XAD-8, and FRI-region volume, FRI-region area, peak picking, and PARAFAC analysis of 3D-EEM (n = 6). Within the boxplot chart, the cross-pieces of each box plot represent (from top to bottom) maximum, upper-quartile, median, lower-quartile and minimum values. HO30: brown water taken from the Lake Hohloh; Soil HA: IHSS soil humic acid reference; SR FA1: IHSS Suwannee River fulvic acid; SR FA2: IHSS Suwannee River fulvic acid (IHSS: International Humic Substances Society).

Funding:
Alexander von Humboldt Foundation

Karlsruhe Institute of Technology (KIT)

Retained Suspended Solids within a Granulated Activated Carbon Filter by Means of Magnetic Resonance Imaging

Florian Ranzinger

Gisela Guthausen

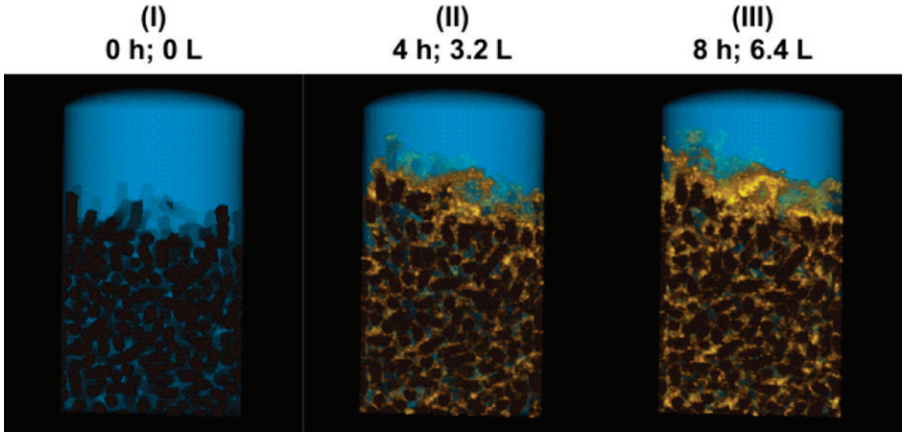
Michael Wagner

Potential threats to the aquatic environment are seen in the discharge of micropollutants and phosphorous sources. Among others, filtration of waste water through granulated activated carbon (GAC) filters is a treatment to remove micropollutants. Dependent on the process integration GAC may additionally serve as filter medium to remove suspended solids (SusS) after precipitation and flocculation of residual phosphorous. Questions arise whether the retention of SusS has disadvantages regarding the process performance of GAC filters.

By magnetic resonance imaging (MRI) the filtration of SusS after precipitation/flocculation was dynamically measured by loading pre-treated waste water in steps of 0.2 L onto a GAC model filter. The total SusS concentration amounted to approximately 8.4 g L^{-1}. Overall 6.4 L of pre-treated waste water were launched, corresponding to a typical technical operation time of 8 h.

Results indicate that SusS are retained within as well as on top of the GAC filter (see figure). With progressing operation time, a deposit above the GAC bed developed. However, the deposit did not completely cover the surface, leading to flow paths in the GAC bed. Flow velocities were larger within the GAC filter due to the channeling within the GAC bed. The initial equivalent velocity of 28.8 m h^{-1} increased to a maximum of 100.8 m h^{-1} at the end of the experiment.

The early blockage of the GAC filter aligned with channeling seem unfavorable for the filtration process and could demand for frequent backwashing in real scale processes. A separate removal step of SusS is recommended before a GAC treatment.



3D rendered representation of MRI datasets shows the retention of SusS (yellow) onto a granulated activated carbon (GAC) filter (darkvolumes). With operation time progressing, SusS accumulated within as well as on top of the GAC filter.

Funding:
Karlsruhe Institute of Technology (KIT)

Removal of Diverse and Abundant Antibiotic Resistance Genes by Microfiltration-Nanofiltration Process from Pig Manure and Digestate

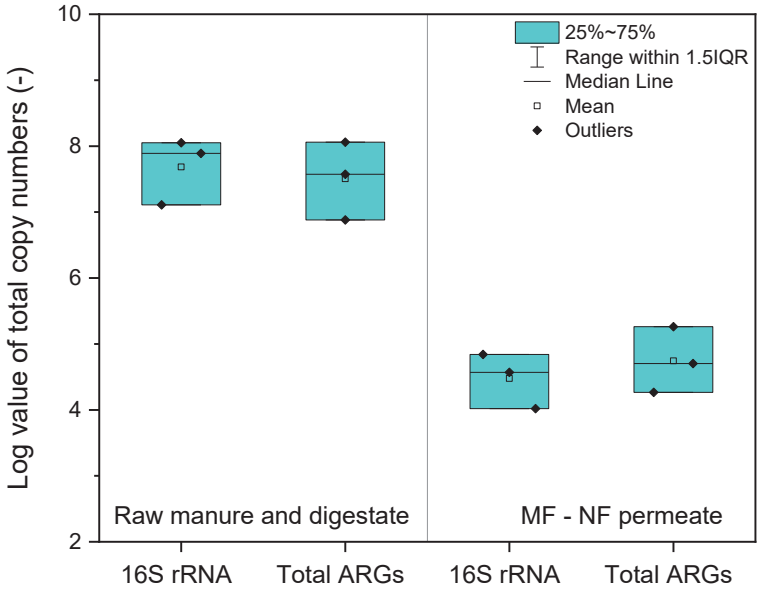
Prantik Samanta

Florencia Saravia

Antibiotic resistance genes (ARGs) are emerging as one main threat to worldwide human health and are expected to kill 10 million people by 2050. Intensive livestock husbandry, along with biogas digestate are considered as one of the biggest ARGs reservoirs.

Despite major concerns, little information is available on the diversity and abundance of various ARGs in small to large scale pig farms and biogas digestate slurry in Germany and their removal using a microfiltration-nanofiltration (MF-NF) process.

In the framework of our project "KompaGG-N", funded by the Federal Ministry of Education and Research (BMBF), it was possible to identify and quantify in total 189 ARGs in raw manure and digestate samples, out of which 66 ARGs were shared among manures and 53 ARGs were shared among both manure and digestate samples. The highest reported total ARGs and 16S rRNA copy numbers in a single manure sampling site was 1.15 × 108 and 1.13 ×108 copies respectively. In addition, we found the absolute concentrations of 37 ARGs were above 105 copies per 100 µL. MF-NF process showed, that the highly concentrated ARGs (except aminoglycoside resistance ARGs) in feed presented high log retention value (LRV) from 3 to as high as 5. Additionally, LRV below 2 was noticed where the initial absolute ARG concentrations were ≤ 10^3 copies / 100 µL. ARG removal was found to be directly proportional to its initial concentration in the raw manure and in digestate samples. Thus, some ARGs can still be found within the permeate of NF with up to 104 copies / 100 µL.



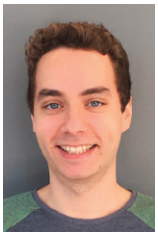
Comparison between log value of total copy numbers of 16S rRNA and ARGs in raw manure and digestate samples and MF-NF permeate samples of all sampling sites together.

Funding:
Federal Ministry of
Education and Research (BMBF)

Partners:
BIORESTEC UG, Laatzen;
Institute for Sanitary Engineering and Waste Managements (ISAH), Leibniz University Hannover;
E&P Anlagenbau GmbH, Berlin

Occurrence and Environmental Impact of Micropollutants on the Aquatic Environment

Amélie Chabilan



Stephan Zimmermann

Hessam Addin Nadernia

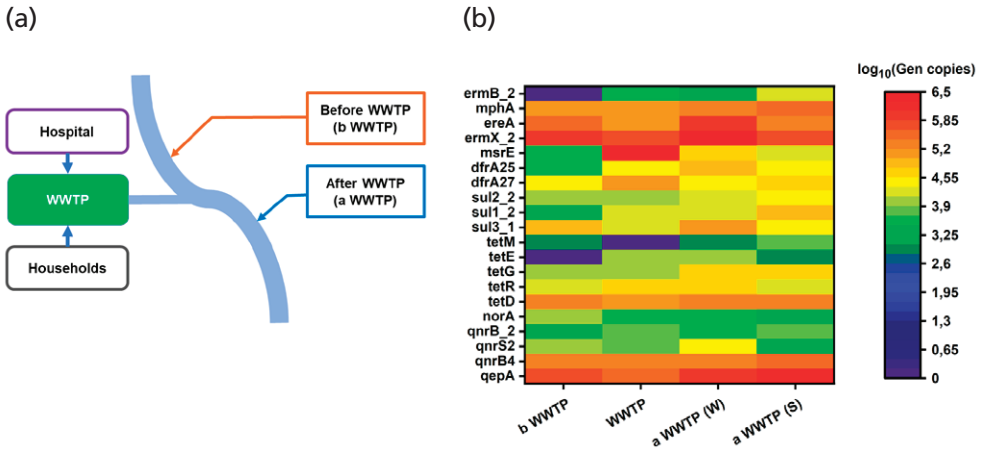
Ewa Borowska

The problem of micropollutants in the aquatic environment has been recognized already 40 years ago, and despite intensive research in this field, there are still many unknowns. In our group we focus on quantification of the environmental contamination with micropollutants, as well as oxidative methods that can support their removal during water treatment processes.

To assess the scale of river contamination with antibiotics (ABs), we chose the local river Alb that receives the discharge of a waste water treatment plant (WWTP). We quantify 19 antibiotics (3 macrolides, 4 tetracyclines, 4 fluoroquinolones, 6 sulfonamides, clindamycin and trimethoprim) in water and sediment phase in 3 locations before the discharge of WWTP, and in 10 locations along the river after the discharge. To assess if there is any relation between the ABs concentration and abundances of antibiotic resistance genes (ARGs) at the same sampling spots we determined the abundances of 20 ARGs (see figure).

Another aspect of our work concerns degradation of selected cytostatic drugs in water by oxidation processes, namely UV-irradiation, ozone and the combination of both. Our results have shown that capecitabine and irinotecan are susceptible for degradation with UV and ozone, and the combination UV/O_3 results in a complete removal within minutes of the process. On the other hand, bicalutamide is resistant to ozonation and can be removed by UV and UV/O_3 process. In the next step we evaluate the impact of the formed transformation products on the aquatic organisms using toxicity tests with *Daphnia magna* and comet assay, in collaboration with Institut Polytechnique UniLaSalle in Rennes (France).

Together with Sahand University of Technology (Iran) we test the applicability of $MgSn(OH)_6$ based catalysts for the removal of fluoroquinolones from aqueous media in the process initiated by solar light. The first results indicate that the catalysts are indeed active in the solar spectrum, however their efficiency in degrading selected antibiotics is still under investigation.



(a) Scheme of the sampling site on river Alb, (b) absolute abundances of selected ARGs measured in the river Alb before (b WWTP) and after discharge of the waste water treatment plant (a WWTP) in the aqueous phase (W) and in sediment (S).

Funding:
Baden-Württemberg Stiftung
Karlsruhe Institute of Technology (KIT)
Karlsruhe House of Young Scientists (KHYS) at KIT
German Academic Exchange Service (DAAD)

Partners:
Institut Polytechnique UniLaSalle, Rennes, France;
Sahand University of Technology, Tabriz, Iran

New and Ongoing Research Projects

WATER QUALITY		
Marta Gmurek	Application of Solar-Induced Recyclable Heterogeneous Photocatalysis Based Processes for the Removal of Antibiotic-Related Micropollutants, Antibiotic Resistant Bacteria and its Resistance Genes from Urban Waste Water	Alexander von Humboldt Foundation
WATER TECHNOLOGY		
Samuel Bunani	Hybrid Electromembrane Processes for Removal of Heavy Metals from Water	Alexander von Humboldt Foundation
Andreas Netsch Michael Wagner	*DEMO-BioBZ* – Development and Demonstration of an Energy-Efficient Bio-Electrochemical Waste Water Treatment	Federal Ministry of Education and Research (BMBF)
Giorgio Pratofiorito Florencia Saravia	*ProBioLNG* – Innovative Process Chain for the Resource-Efficient Production of Liquified Biogas	Federal Ministry of Education and Research (BMBF)
Ali Sayegh Florencia Saravia	*NextGenRoadFuels* – Processing of Hydrothermal Liquefaction Products with Membrane Technologies	European Commission – Horizon 2020 www.nextgenroadfuels.eu
Michael Sturm	Microplastic-Free Sea Salt Production - Development of a Methodological and Technological Process for the Reduction of Microplastic Pollution during Sea Salt Extraction	German Federal Environmental Foundation (DBU) German Federal Ministry for Economic Affairs and Energy (BMWi) through the provision of ZIM
BIOLOGICAL INTERFACES		
Rui Du	Energy Efficient Nitrogen Removal by Partial Denitrification and Anammox Process	Alexander von Humboldt Foundation
Lizheng Guo	Impact of Chlorine on Biofilms in Pipes	Chinese Academy of Sciences (CAS) German Academic Exchange Service (DAAD)
Max Hackbarth Andrea Hille-Reichel	*PeePower BUGA 2023* – Use of a Microbial Electrolysis Cell on the Basis of an Immersion Disk for Sustainable Hydrogen Production from Urine at BUGA 2023	BWPLUS – Baden-Württemberg, Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg

Awards

SPARKASSEN ENVIRONMENT AWARD 2020

Dr. Philip Brown, a former PhD-student in our group, was awarded the Sparkassen Environment Award 2020 for his dissertation "Impact of antibiotics and particulate matter from wastewater discharges on the abundance of antibiotic resistence gens in river sediments". On July 26, 2021, the prizes of 2020 and 2021 could be awarded in presence.

GESELLSCHAFT DER FREUNDE DES ENGLER-BUNTE-INSTITUTS AWARDED MASTER THESIS

On June 18, 2021, Leonie Rominger was awarded for her master thesis "Bioelectrochemical process optimization of a cathode driven microbial production of chemicals". The thesis was supervised by Prof. Johannes Gescher and Prof. Harald Horn.

The WATER CHEMISTRY AND WATER TECHNOLOGY GROUP

Head of Chair

Prof. Dr. Harald Horn
Dr. Gudrun Abbt-Braun
Prof. Dr. Fritz H. Frimmel (retired)

Supervising Functions and Postdoctoral Positions

Dr. Ewa Borowska	Organic micropollutants
Apl. Prof. Dr. Gisela Guthausen	NMR/MRI
Dr. Andrea Hille-Reichel	Biological interfaces
Dr. Johannes Reiner	Microbial electrosynthesis
Dr.-Ing. Ulrike Scherer	Water Research Network BW
Dr. Michael Wagner	Biofilm structure and function
Dipl.-Ing. (FH) Stephanie West	Head of the laboratory

DVGW Research Center

Dr. Birgit Gordalla	Standardization
Dr.-Ing. Florencia Saravia	Deputy head, membrane technology

PhD Students

M.Sc. Alondra Alvarado	Organic carbon in anaerobic and aerobic waste water treatment
M.Sc. Dámare Araya Valenzuela	Decision support tools for water technologies in arid areas
Dipl.-Ing. Fabian Brunner	Aerobic granules for waste water treatment
M.Sc. Amélie Chabilan	Antibiotics in aquatic environment
Dipl.-Ing. Laure Cuny	Productive biofilms
M.Sc. Lizheng Guo	Disinfection and biofilms in water distribution systems (Guest PhD Student)
M.Sc. Max Hackbarth	Microbial electrosynthesis
M.Sc. Stephanie Kaschewski	Using smart water data to minimize risk in residential water quality
M.Sc. Oliver Kehl	Modelling the treatment performance of activated sludge plants
M.Sc. Jinpeng Liu	Membrane filtration
M.Sc. Maximilian Miehle	Bioproduction using biocatalysts for electrode assisted fermentation
M.Sc. Hessam Addin Nadernia	Solar photocatalysis for water treatment (Guest PhD Student)
M.Sc. Andreas Netsch	Energy-efficient bio-electrochemical waste water treatment
M.Sc. Nikhil Prakash	Waste water treatment
M.Sc. Giorgio Pratofiorito	Membrane processes for organic acids concentration
M.Sc. Florian Ranzinger	Visualization of water and biofilms in porous media
M.Sc. Prantik Samanta	Treatment of manure by membrane processes
M.Sc. Ali Sayegh	Membrane treatment of industrial waste water
M.Sc. Tim Schwarzenberger	Mono- and polychromatic UV disinfection (TZW)
M.Sc. Lara Stelmaszyk	PCR- and cultivation methods for antibiotic resistant genes (TZW)
M.Sc. Michael Sturm	Removal of microplastics from sea water
M.Sc. Fadi Tantish	Design of water treatment processes
M.Sc. Stephan Zimmermann	Degradation of cytostatic drugs in water by oxidation processes

DVGW Research Center

M.Sc. Yair Morales (project engineer)	Electrolysis of sea water for hydrogen production

Guest Researchers

Dr. Samuel Bunani	Hybrid self-regenerating electromembrane processes
Dr. Rui Du	Denitrification/anammox process in biofilms
Prof. Assoc. Dr. Marta Gmurek	Advanced oxidation processes for water treatment
Dr. Keke Xiao	Sewage sludge treatment processes

Technical Staff

Axel Heidt	GC/ECD, GC/MS, IC, AOX
Rafael Peschke	HPLC, LC/MS, IC
Matthias Weber	LC/OCD, DOC/TOC

DVGW Research Center

Ulrich Reichert	Operation of lab reactors
Reinhard Sembritzki	AAS, ICP-OES, IC

Secretarial Office

Ursula Schäfer

DVGW Research Center

Sylvia Heck

Apprentices

Maya Frey
Tobias Grundwald
Enrico Horst

RECENT PUBLICATIONS

Peer-Reviewed Journal Publications

Balbierer, R., Seegert, P., Herberger, S., Wetzel, T., Nirschl, H., Guthausen, G., 2021. Investigation of transverse relaxation rate distribution via magnetic resonance imaging: impact of electrode formation. Energy Technology 9 (6), 2000579.

Bauer, A., Wagner, M., Horn, H., Saravia, F., 2021. Operation conditions affecting scale formation in membrane distillation - An in situ scale study based on optical coherence tomography. Journal of Membrane Science 623, 118989.

Edel, M., Sturm, G., Sturm-Richter, K., Wagner, M., Ducassou, J. N., Couté, Y., Horn, H., Gescher, J., 2021. Extracellular riboflavin induces anaerobic biofilm formation in *Shewanella oneidensis*. Biotechnology for Biofuels 14 (1), 130.

Fraezna, C.C., Förster, E., Guthausen, G., Nirschl, H., Anoardo, E., 2021. Use of 1H-NMR spectroscopy, diffusometry and relaxometry for the characterization of thermally-induced degradation of motor oils. Tribology International 153, 106620.

Fundneider, T., Acevedo Alonso, V., Abbt-Braun, G., Wick, A., Albrecht, D., Lackner, S., 2021. Empty bed contact time: The key for micropollutant removal in activated carbon filters. Water Research 191, 116765.

Grießmeier, V., Wienhöfer, J., Horn, H., Gescher, J., 2021. Assessing and modeling biocatalysis in field denitrification beds reveals key influencing factors for future constructions. Water Research 188, 116467.

Jung, T., Hackbarth, M., Horn, H., Gescher, J., 2021. Improving the cathodic biofilm growth capabilities of *Kyrpidia spormannii* EA-1 by undirected mutagenesis. Microorganisms 9 (1), 77.

Miehle, M., Hackbarth, M., Gescher, J., Horn, H., Hille-Reichel, A., 2021. Biological biogas upgrading in a membrane biofilm reactor with and without organic carbon source. Bioresource Technology 335, 125287.

Pino-Soto, L., Schwarz, A., Vargas, C., Saravia, F., Horn, H., Bórquez, R., 2021. Influence of multivalent-electrolyte metal solutions on the superficial properties and performance of a polyamide nanofiltration membrane. Separation and Purification Technology 272, 118846.

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Volume 82: Ali, R., 2021. Propionic acid production through anaerobic fermentation of food waste.

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From left to right:
(first row) Yair Morales, Reinhard Sembritzki, Samuel Bunani, Stephanie West, Maya Frey, Nikhil Prakash, Marta Gmurek, Axel Heidt, Birgit Gordalla, Michael Wagner, Gudrun Abbt-Braun, Dui Ru, Ulrike Scherer
(second row) Andrea Hille-Reichel, Giorgio Pratofiorito, Amélie Chabilan, Harald Horn, Andreas Netsch, Ulrich Reichert, Matthias Weber
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