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 2023

Dear colleagues and friends,

the past weeks and months have given rise to increased concern in many different areas.
In addition to severe political conflicts around the world, the consequences of climate change are becoming significantly noticeable in our daily life. The EU Climate Change Service Copernicus in Reading, UK, announced that the summer of 2023 was record-breaking with its high temperatures - and is now actually by far the hottest since records began in 1940. The extreme weather events have huge impact on the aqueous environment: floods and heavy rain events, water scarcity and droughts, glacier melting, lowering of the groundwater level, just to name a few aspects.
By this, water and energy topics play a major role in this context. In the following report we would like to give you a small insight into the teaching and research activities of the Chair of Water Chemistry and Water Technology and the DVGW Research Center at the Engler-Bunte-Institut.

Although we would like to see even more students interested in Chemical and Process Engineering and Bioengineering, the number of new students has not increased in the previous years. A stagnation and also a decline in the engineering and natural science subjects is observed at other universities and is a cause for concern. After the very limited possibilities in the pandemic years, the lectures and practical courses could again take place completely in attendance from the winter semester 22/23 onwards.

Two young researchers completed their PhD work successfully: Fabian Brunner (December 2022) in a topic related to aerobic granules in municipal wastewater treatment; Giorgio Pratofiorito (June 2023) in a topic related to low-pressure reverse osmosis in a two-stage biogas production.
Congratulation to Jonas Ullmann, his master thesis "Treatment of Groundwater with Activated Carbon Filtration Using the Example of the Rauschen and Schlierbach Waterworks" was awarded by the Gesellschaft der Freunde des Engler-Bunte-Instituts in June. And in addition, the thesis was awarded with the German Studienpreis Wasser by the German Technical and Scientific Association for Gas and Water (DVGW).
Moreover, guest students, researchers and new PhD students have joined our group, others have left again: a warm welcome to Süheyla Duran, Turkey; Nurul Faiqotul Himma, Indonesia; Israel Larralde Pina, Mexico; Willow Neske, USA. A farewell to Na Li, and Dr. Rui Du, Humboldt scholar, both have returned to their home universities in China; Prof. Isam Sabbah, Israel, continued his research stay in Italy; Dr. Anwar Dawas, Israel, joined us during August 2023.

We have been actively involved in several joint research programs. On the next pages you will find a more detailed report on some further projects and a list of other running and completed research activities. New research projects with the topics "Biologically Treated Wastewater for Hydrogen Electrolysis", and "Biofilm Formation in Reverse Osmosis Membranes" started at the DVGW Research Center.
One highlight of a challenging project has been the pilot plant reactor producing microbially catalyzed hydrogen from urine at the Federal Garden Show (BUGA 2023). The reactor was operating under real conditions for almost 6 months (further details on page 5). A status meeting was held within the project *KoalAplan* in July 2023. At the meeting, the different pilot plant reactors, installed at the Wastewater Treatment Plant for Education and Research at the University of Stuttgart, were presented also to the funding representatives of the Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg (further details on page 6).

Enjoy reading, best regards and wishing you all the best for 2024,

Gudrun Abbt-Braun Harald Horn

An Automated OCT-Based System for Biofouling Monitoring in Reverse Osmosis Desalination Plants

Szilárd Bucs

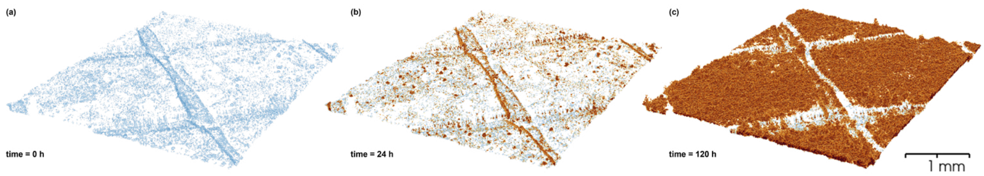
Florencia Saravia

Michael Wagner

The H_2*Mare PtX-Wind* project focuses on using offshore wind energy to produce green hydrogen through water electrolysis and PtX products. Offshore locations provide access to seawater, but it requires desalination to produce ultrapure water. Reverse osmosis membrane desalination has high potential but faces fouling issues, especially biological fouling. Therefore, one of the aims of the project is to develop an automated system to detect biological fouling in an early stage.

The system includes a three-axis robotic platform, optical coherence tomography (OCT), and high-pressure flow cells with side windows. The platform ensures precise OCT scans at set intervals, with data processing by a dedicated computer pipeline. Key conditions for accurate fouling detection are: i) maintain positioning accuracy within 5 μm on each axis; ii) match image processing precision to OCT lens resolution; iii) fully automated image processing and integration into plant operations.

For this purpose, a lab-scale setup was developed, and positioning system accuracy was validated by capturing multiple OCT images, showing lateral accuracy within 5 μm and slight axial deviations. However, image processing corrects for axial deviations, making the system suitable for the project objectives. Fouling quantification is performed by automated image processing as follows: an initial image taken when no fouling is present serves as the base image for subsequent scans. This base image acts as a mask for all consecutive images, excluding the membrane and feed spacer, retaining only accumulated material for evaluation (figure). After image segmentation, parameters like fouling thickness, volume, and surface coverage are calculated. These fouling characteristics will be correlated with membrane system performance metrics, such as permeability, rejection, and pressure drop. The system also enables real-time assessment of membrane cleaning efficiency, minimizing downtime and optimizing performance recovery.



OCT scans illustrating the membrane's (blue color) initial clean state (a), appearance of early biofilm (brown color) formation on the membrane surface after 24 h of operation (b), and complete biofouling (brown color) of the membrane after 120 h (c).

Funding:

Gesellschaft der Freunde des Engler-Bunte-Instituts

Federal Ministry of Education and Research (BMBF)

H_2Mare PtX-Wind: CO_2 Extraction from Water by Bipolar Membrane Electrodialysis

Florencia Saravia

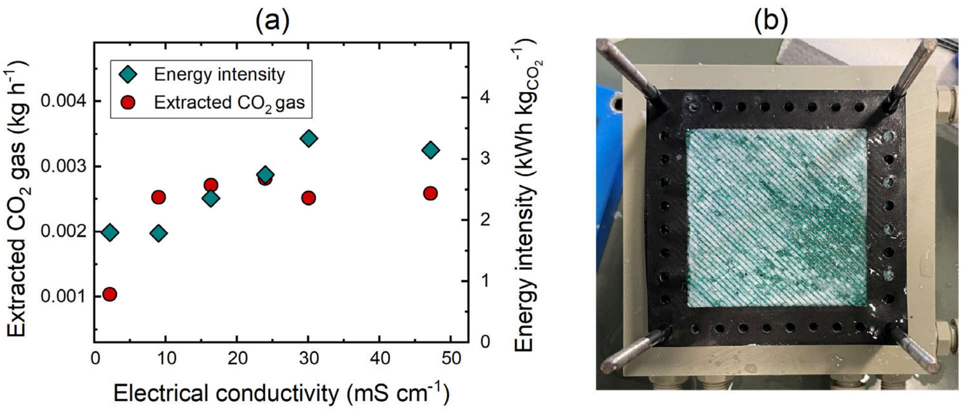
Mehran Aliaskari

CO_2 capture (from air, water or large emission sources) plays an important role in achieving carbon neutrality. The product CO_2 can be used in power-to-x processes for the production of fuels and hydrocarbons to close the carbon cycle. By using a bipolar membrane electrodialysis system coupled with a membrane contactor, it is possible to extract the dissolved CO_2 from different water sources.

In order to elucidate the working mechanisms of CO_2 extraction from water, experiments with different water qualities and operating conditions were designed and performed. A laboratory setup was used with 5 acidic and 5 basic cells (10 x 10 cm^2). The CO_2 was extracted from the acidic solution using a commercial membrane contactor and a vacuum pump. The extracted gas was measured (milligas counter) and analyzed (gas chromatography) while investigating the effect of salinity, flow rate, applied voltage and a new redox system.

Mass of extracted CO_2 gas and the energy intensity are presented in figure (a). With 2 mS cm^{-1} feed an average acidic pH of 6.3 was observed in which the bicarbonate is still not changed to dissolved CO_2. With increasing salinity (> 9 mS cm^{-1}) of the feed water, the mass flow of extracted CO_2 becomes slightly stable, however the electrochemical energy consumption increases. This increase is due to the increasing concentration of ions and co/counter ions passage through the membrane and other ohmic losses resulting from operations at higher current densities.

Due to severe scaling in the initial experiments (visible in figure (b)), an extensive cleaning method was developed and used after each experiment. In the next part of the project, the scaling on the bipolar membrane will be investigated online through an in-house developed flow cell and by optical coherence tomography (OCT).



(a) Increasing feedwater salinity impact on mass flow of CO_2 and the energy intensity (electrolyte: 10 g L^{-1} Na_2SO_4, flow rate: 50 L h^{-1}, electric potential: 15 V); (b) severe scaling in the membrane stack after the initial experiments without post experiment cleaning.

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)

DEMOBioBZ: Reactor Integration of Energy-Efficient Denitrification into Bioelectrochemical Wastewater Treatment

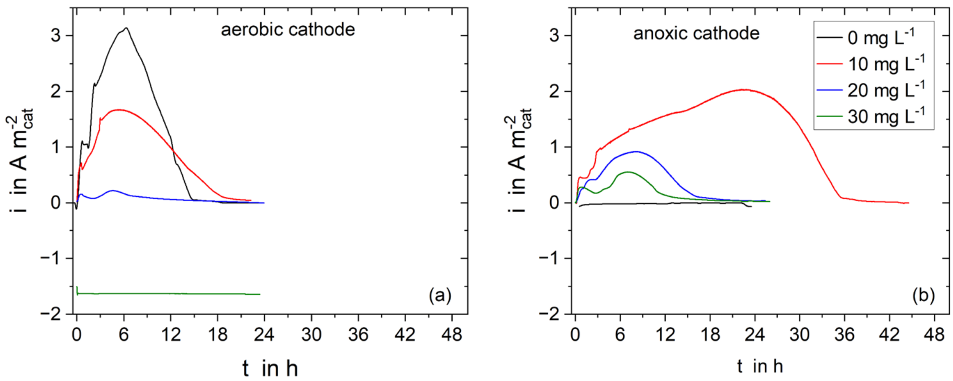
Michael Wagner

Andreas Netsch

The joint research project *DEMOBioBZ* aims to develop the globally first integration of a microbial fuel cell (MFC) into a municipal wastewater treatment plant on a technical scale (up to 500 people equivalents). MFCs enable the conversion of chemically bound energy (e.g. organic waste components) to electrical energy by means of electroactive biofilms developing on the anodes. Predominantly, oxygen has been implemented as electron acceptor at the cathode through the oxygen reduction reaction (ORR). Though, under anoxic conditions nitrate and nitrite can be used as alternative cathodic electron acceptors in wastewater MFCs.

One goal of the *DEMOBioBZ* project is the integration of the denitrification in a single chamber MFC for simultaneous carbon and nitrogen removal by guiding the nitrate-rich wastewater after the nitrification stage into the MFC. The nitrate acts as a competitive electron acceptor to the anode as well as to the oxygen at the cathode possibly diminishing the power production of the MFC. Thus, two single chamber MFCs with air-breathing cathodes were operated to investigate the effect of different nitrate concentrations on the power production. Furthermore, the current production of a cathodic nitrate reduction reaction under anoxic conditions was compared with the ORR.

In fed-batch experiments (see figure), a decrease of the current density from max. 3.14 A m^{-2} to 1.67 A m^{-2} by the addition of 10 mg L^{-1} NO_3^--N at constant COD = 250 mg L^{-1} was observed. A further increase of the NO_3^--N concentration to 20 mg L^{-1} diminished the current density to ≤ 0.22 A m^{-2}. Under anoxic conditions it was shown that the addition of nitrate was necessary to produce current, where a max. current density of 2.03 A m^{-2} could be achieved with a NO_3^--N concentration of 10 mg L^{-1}. Interestingly, higher nitrate concentrations led to a decrease of the produced current, indicating an optimal range for the nitrate concentration in order to maximize the power production.



Current development of MFC after nutrient addition with different nitrate (NO_3^--N) concentrations for aerobic cathode (a) and nitrate-reducing anoxic cathode (b).

Funding:

Federal Ministry of Education and Research (BMBF)

Partners:

CUTEC Forschungszentrum and Institute of Chemical and Electrochemical Process Engineering, both TU Clausthal;
Institute of Biochemistry, Chair of Electrobiochemistry, University of Greifswald;
Eisenhuth GmbH & Co. KG, Osterode am Harz;
Common-Link AG, Karlsruhe;
Eurawasser Betriebsführungsgesellschaft mbH, Goslar;
Umwelttechnik und Anlagebau GmbH, Plauen

PeePower™: Scale-Up and Field Test of a Novel Microbial Electrolysis Reactor

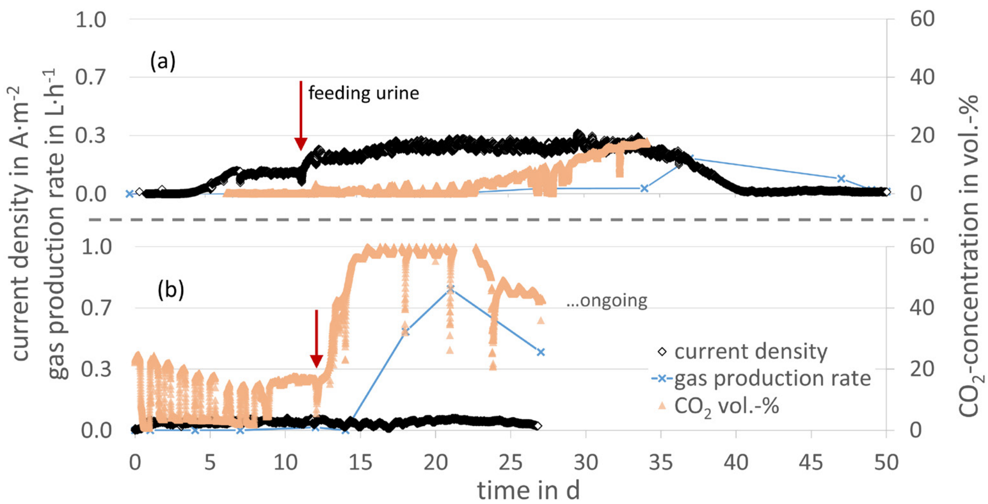
A large-scale microbial electrolysis cell is investigated within the project *PeePower*™ for a bioelectrochemical hydrogen production from urine. It was installed in a separating toilet facility at the Federal Garden Show (BUGA) in Mannheim. It was operated with the obtained raw urine between April and October 2023. The 100 L reactor contains rotating graphite discs (anode) with a surface area of 10 m² on which microorganisms can grow as a biofilm. The cultivated exoelectrogenic bacteria (*Geobacter sulfurreducens* and *Shewanella oneidensis*) are able to oxidize organic substrates from urine and transfer the generated electrons to the anode surface. At the cathode (stainless steel screen, 2 m²), electrons and protons are recombined to form hydrogen. The project aims to provide insights into a possible scale-up scenario of laboratory bioelectrochemical systems with exoelectrogenic bacteria. The field test can also reveal shortcomings of the reactor design for future improvements, as the rotating disc reactor could serve as a platform system for multiple waste-to-product processes in efforts towards a sustainable bioeconomy.

Jonas Ullmann

Max Hackbarth

Jochen Wezstein

The initial startup of the reactor was successful, the introduction of urine on day 12 (figure (a)) increased the current density twofold to 0.2 A m^{-2}. Gas production started 10 days after urine was introduced and reached a peak of 0.2 L h^{-1} at day 37 of operation, with a H_2 content of > 80 %. Since the coulombic efficiency of the electron-to-hydrogen turnover was 14 %, molybdate was used to suppress potentially disruptive sulfate reducing bacteria that consume hydrogen. However, the productive biofilm was harmed which resulted in the sudden drop in current density and gas production rate. The new startup (figure (b)) was operated continuously with urine until the end of BUGA in October 2023.



Continuously observed parameters during operation of the urine-fed rotating disc bioelectrochemical reactor at initial startup (a) and restart in September (b).

Partners:

Institute of Technical Microbiology, Hamburg University of Technology

Funding:

Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg;

Karlsruhe Institute of Technology (KIT)

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KoalAplan: Valorization of Organic Carbon in the Sludge Treatment Step of a Wastewater Biorefinery via Dark Fermentation

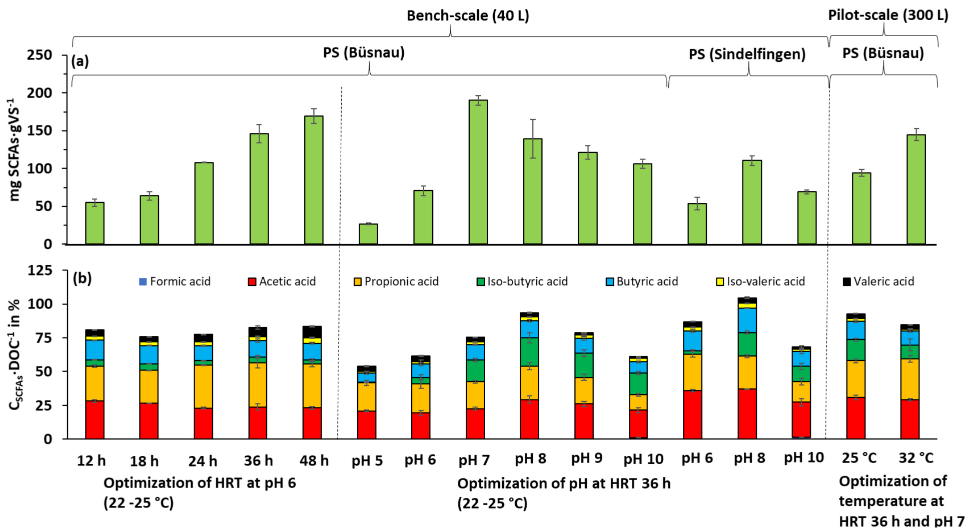
Andrea Hille-Reichel

Nikhil Shylaja Prakash

Organic carbon collected as sludge in a typical wastewater treatment plant (WWTP) is converted to biogas in the sludge treatment step via anaerobic digestion (AD). Primary sludge (PS) contributes to around 70 % of the sludge produced in a WWTP. Valorization of organic carbon in PS can lead to the recovery of value-added products like hydrogen and bioplastics and can substantiate the idea of a wastewater biorefinery.

PS is rich in organic content and serves as a potential pathway to extract short-chained fatty acids (SCFAs) through dark fermentation (DF). DF, similar to AD, involves the breakdown of complex macromolecules such as proteins, carbohydrates and fats into simpler molecules, which can then be utilized by microorganisms to produce metabolic intermediates (SCFAs). However, in AD, biogas production is prioritized, but DF aims to achieve hyper acidification by optimizing parameters in such a way that acidogenic bacteria are favoured over methanogenic archaea.

Results showed that a very low hydraulic retention time or solids retention time between 12 h to 48 h was adequate, and acidogenesis reached a plateau at 36 h. pH plays a very important role in DF, either through biological or physicochemically aided biological effects. However, in this study it was noted that longer residence times are needed to capitalize the physicochemical effect at alkaline pH values, and that higher yields can be achieved under optimal redox conditions (i.e. around neutral to slightly alkaline pH). Though temperature is known to increase the reaction rates, in this study it was noted that at mesophilic temperatures, there was an exclusive increase in acetic and propionic acid productivities, presumably due to shift in microbial communities.



(a) Yield of SCFAs in milligrams with respect to the volatile solids (VS) fed in grams; (b) ratio of SCFAs as carbon equivalents to dissolved organic carbon (DOC) expressed as percentage. All experiments were performed in semi-continuous mode. For optimization of hydraulic retention time (HRT) and pH, a 40 L bench-scale reactor was used. pH optimization was carried out with PS obtained from WWTPs Büsnau and Sindelfingen. Temperature optimization was done using a 300 L pilot-scale reactor.

Co-funded by the European Union

Baden-Württemberg

Funding:

European Regional Development Fund (ERDF): Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg, co-financed by the European Union

Partners:

CUTEC Clausthal Research Center for Environmental Technologies, TU Clausthal;
Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), Stuttgart;
Institute of Technical Microbiology, Hamburg University of Technology;
Umwelttechnik BW GmbH, Stuttgart;
Treatment Plant for Education and Research at the University of Stuttgart

ContiBio-Elect: Upflow Anaerobic Fixed Bed Reactor for Bioelectrochemical Applications

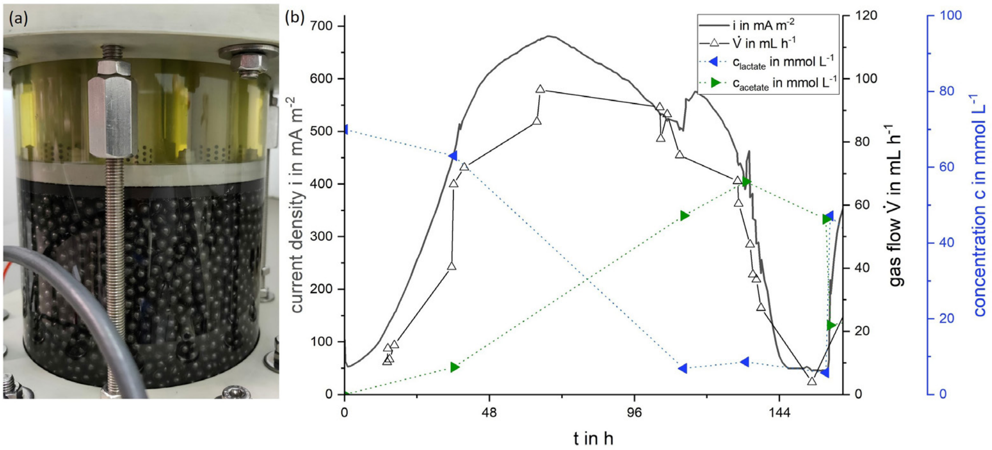
Andrea Hille-Reichel

Maximilian Miehle

A reactor concept for application of different microbial electrochemical technologies (METs), among them the direct production of value-added chemicals and/or hydrogen, was developed. As an example, the model process tested is the anaerobic oxidation of lactate to acetate by a *Shewanella oneidensis* strain.

The reactor is designed as an upflow anaerobic fixed bed reactor with a packing (1.6 L) of graphite-polymer granules of approx. 6 mm diameter as anodic carrier material (figure (a)), resulting in an effective anode surface area of approx. 0.567 m^2. The electroactive bacteria attaching to and growing on these carriers transfer the electrons gained from lactate oxidation to the anodic packed bed. The protons generated are reduced to hydrogen at the stainless steel rods of the counter electrode (cathode). These rods are arranged in bundles surrounded by perforated plastic tubes for electrical insulation and immersed in the fixed bed.

Figure (b) shows the first batch of a repeated batch cultivation, inoculated with an optical density of S. *oneidensis* (OD_{600}) of 0.5. The anode was poised with a potential of 300 mV against the standard hydrogen electrode (SHE), and the initial lactate concentration was chosen to be 70 mM. The liquid phase was recirculated at 17 mL min^{-1}, which equals an average flow velocity of 0.034 mm s^{-1} through the packed bed. The current density reached a maximum of almost 700 mA m^{-2} of anode surface. The produced gas consisted of 80 % H_2 and 20 % CO_2.



(a) Photograph of the reactor during operation (heating mat surrounding the glass body was removed) with the packed bed of conductive 6 mm spheres and the non-conductive tubes protruding from the bed with cathodic rod bundles inside; (b) development of current density i, substrate and product concentrations $c_{lactate}$ and $c_{acetate,}$ and gas flow rate V during the first batch.

Partners:

Institute of Technical Microbiology, Hamburg University of Technology;
Institute of Organic Chemistry, Material Science Center, KIT;
Eisenhuth GmbH & Co. KG, Osterode am Harz

Funding:

Federal Ministry of Education and Research (BMBF)

Partial Denitrification

Rui Du

Anwar Dawas

Partial denitrification (PD), the reduction of nitrate to nitrite, was recently demonstrated to be another pathway of nitrite production for anammox with strong robustness, high efficiency, and easy control.

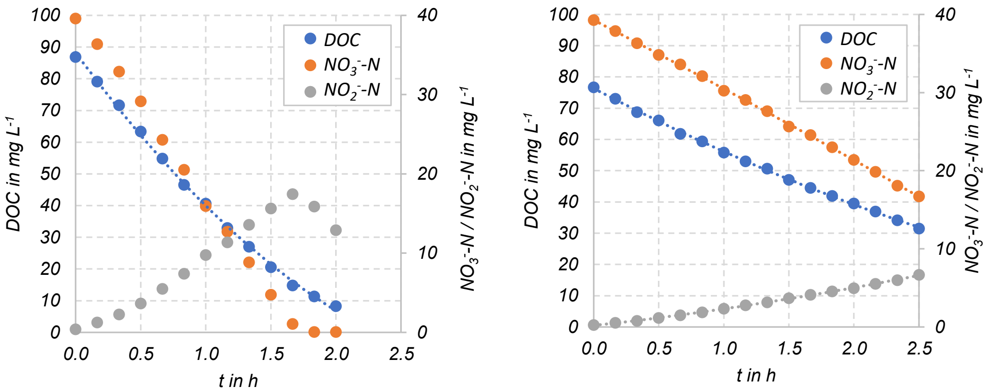
The Humboldt stipend Dr. Rui Du worked for 18 months on this topic at the Engler-Bunte-Institut. We know that a wide range of bacteria are involved in the anoxic growth of heterotrophs. Within the activated sludge model (ASM) they are lumped in one type of biomass, typically known as X_{het}. However, depending on the boundary conditions it could be shown that during anoxic sequencing batch processes the concentration of nitrite increased while nitrate was reduced.

There are two options:
- denitrifying bacteria which cover the full pathway from nitrate to nitrogen gas cannot reduce further the nitrite with the same rate as the nitrate is reduced, which then is leading to an accumulation of nitrite,
- there are also denitrifying bacteria, which can only reduce the nitrate to nitrite and then release it into the bulk phase.

To a certain extent, we do know the bacterial communities involved in PD, but we don't know the factors that lead to nitrite accumulation and how the activity of the different species of these communities are involved in this process.

Together with Dr. Anwar Dawas from the Tel-Aviv University we started to measure denitrification rates for active sludge sampled in different wastewater treatment plants. The sludge was filtered and washed. The experiments were run with acetate as organic carbon source and nitrate as electron acceptor.

The figures below represent results from two experiments. The nitrite accumulation is very different. The sludge with an age below 5 days (figure left) is obviously more active and generates more nitrite within the same time.



Denitrification batch experiments using sludge with different ages, below 5 d (left) and above 5 d (right).

Funding:

Alexander von Humboldt Foundation

Rector Fellowship, Tel-Aviv University, Israel

Karlsruhe Institute of Technology (KIT)

Publication:

Du, R., Horn, H., Cao, S., 2023. Chemical Engineering Journal 468, 143696.

New and Ongoing Research Projects

WATER QUALITY		
Amélie Chabilan Ewa Borowska	Antibiotics in Aquatic Environment *	Baden-Württemberg Stiftung; KIT
Ulrike Scherer	*ESI-CorA* – Systematic Surveillance of SARS-CoV-2 in Wastewater *	Emergency Support Instrument (European Commission)
Stephan Zimmermann	Degradation of Cytostatic Drugs in Water by Oxidation Processes	Karlsruhe Institute of Technology (KIT)
WATER TECHNOLOGY		
Nurul Faiqotul Himma Florencia Saravia	Membrane Distillation - Fouling and Wetting of Membranes	Karlsruhe Institute of Technology (KIT)
Yair Morales Sophie Oeppling Florencia Saravia	*H_2Mare TransferWind* – Research, Transfer, Technology Platform	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)
Prantik Samanta Florencia Saravia	*KompaGG-N* – Complete Treatment of Manure and Digestate Process - Development by Taking into Account Regional Material Flow Concepts for Nutrients and Pollutants *	Federal Ministry of Education and Research (BMBF)
Florencia Saravia	Development of a Monitoring System for Detection of Biofilm Formation in Reverse Osmosis Membranes	Central Innovation Programme for Small and Medium-Sized Enterprises (ZIM); Federal Ministry for Economic Affairs and Climate Action (BMBK)
Jan Singer Yair Morales Florencia Saravia	Determination of General Conditions for the Use of Biologically Treated Wastewater for Hydrogen Electrolysis – Requirements for the Production of Ultra Pure Water and Treatment of Wastewater Streams	Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg
BIOLOGICAL WASTEWATER TREATMENT		
Israel Larralde Pina	Oxidation of Pharmaceuticals by Fenton Reactions	Fellowship of Universidad Autónoma de Nuevo Léon, México; KIT
Willow Neske Andrea Hille-Reichel	Wastewater Reprocessing and Renewable Energy in Germany	Fulbright Germany; KIT
Isam Sabbah	Nano- and Microplastics in Aquatic Systems; Processes in Engineered Biological Systems; Water and Wastewater Treatment	Sabbatical at EBI, KIT Home: BRAUDE College of Engineering, Karmiel, Israel
BIOLOGICAL INTERFACES		
Süheyla Duran Andrea Hille-Reichel	Application of Membrane Biofilm Reactors for Biotechnological Production of Platform Chemicals	The Republic of Türkiye, Ministry of National Education; KIT
Na Li	Process of Biofilm Development and Succession of Microbial Communities in Water Distribution Systems *	Chinese Scholarship Council (CSC); KIT
Johannes Reiner Zhizhao Xiao Max Hackbarth Andreas Netsch Andrea Hille-Reichel	*BROWSE* – Reaction Cascades Generating Biopolymers from Waste	Federal Ministry of Education and Research (BMBF)
Michael Wagner	Visualization of the Mesoscopic Biofilm Structure by Means of Optical Coherence Tomography	Helmholtz Association

*completed in 2023

THE WATER CHEMISTRY AND WATER TECHNOLOGY GROUP

Head of Chair

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

DVGW Research Center

Dr.-Ing. Florencia Saravia	Deputy head, team leader research and development

Supervising Functions and Postdoctoral Positions

Dr.-Ing. Szilárd Bucs	Visualization and image analysis of biofilms
Apl. Prof. Dr. Gisela Guthausen	NMR/MRI
Dr. Andrea Hille-Reichel	Biological interfaces
Dr. Johannes Reiner	Microbial electrosynthesis (until February 2023)
Dr.-Ing. Prantik Samanta	Treatment of Fischer-Tropsch wastewater
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

M. Sc. Yair Morales	Water treatment

PhD Students

M. Sc. Mehran Aliaskari	Bipolar membrane electrodialysis
M. Sc. Simon Bär	In situ microscopy (Hochschule Mannheim)
M. Sc. Amélie Chabilan	Antibiotics in aquatic environment
M. Sc. Süheyla Duran	Biotechnological production of platform chemicals
M. Sc. Max Hackbarth	Microbial electrosynthesis
M. Sc. Steffen Hertle	Aerobic metabolic degradation processes (TZW)
M. Sc. Nurul Faiqotul Himma	Membrane distillation
M. Sc. Oliver Kehl	Modelling the treatment performance of activated sludge plants
M. Sc. Lukas Lesmeister	Treatment processes for removal of PFASs (TZW)
M. Sc. Na Li	Biofilms in water distribution systems (Guest PhD Student until April 2023)
M. Sc. Maximilian Miehle	Bioproduction using biocatalyst for electrode assisted fermentation
M. Sc. Andreas Netsch	Energy-efficient bioelectrochemical wastewater treatment
M. Sc. Nikhil Shylaja Prakash	Wastewater treatment
M. Sc. Giorgio Pratofiorito	Membrane processes for organic acids concentration (Dr.-Ing. since June 2023)
M. Sc. Tim Schwarzenberger	Mono- and polychromatic UV disinfection (TZW)
M. Sc. Vasco Welter	Electrolytic production of green hydrogen from sea water (until March 2023)
M. Sc. Stephan Zimmermann	Degradation of cytostatic drugs in water by oxidation processes

Project Engineers

M. Sc. Jochen Wezstein	Operation and maintenance of bioreactors
M. Sc. Zhizhao Xiao	Operation and maintenance of bioreactors

DVGW Research Center (Project Engineers)

M. Sc. Sophie Oeppling	Water management in PtX processes
M. Sc. Jan Singer	Hydrogen production in municipal water treatment plants
M. Sc. Jonas Ullmann	Microbially catalyzed hydrogen production from urine

Guest Researchers

Dr. Anwar Dawas	Anammox process (August 2023)
Dr. Rui Du	Denitrification/anammox process in biofilms (until August 2023)
M. Sc. Israel Larralde Pina	Fenton oxidation reactions (from August to November 2023)
B. Sc. Willow Neske	Wastewater processing (since September 2023)
Prof. Assoc. Dr. Isam Sabbah	Processes in natural and engineered aquatic systems (until May 2023)

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	ICP-MS, AAS, ICP-OES, IC

Secretarial Office

Ursula Schäfer

DVGW Research Center

Sylvia Heck

Apprentices

Maya Frey
David Gerlinger
Julia Gretschmann

RECENT PUBLICATIONS

Peer-Reviewed Journal Publications

Chabilan, A., Ledesma, D.G.B., Horn, H., Borowska, E., 2023. Mesocosm experiment to determine the contribution of adsorption, biodegradation, hydrolysis and photodegradation in the attenuation of antibiotics at the water sediment interface. Science of The Total Environment 866, 161385.

Du, R., Horn, H., Cao, S., 2023. Maximizing anammox in mainstream wastewater treatment: An integrated nitrite producing approach. Chemical Engineering Journal 468, 143696.

Gierl, L., Horn, H., Wagner, M., 2022. Impact of Fe^{2+} and shear stress on the development and mesoscopic structure of biofilms—a *bacillus subtilis* case study. Microorganisms 10 (11), 2234.

Gmurek, M., Alexander, J., Mazierski, P., Miodyńska, M., Fronczak, M., Klimczuk, T., Zaleska-Medynska, A., Horn, H., Schwartz, T., 2023. Enhancement of photocatalytic-based processes by mono- and bimetallic (CuPd) rutile loaded nanoparticles for antibiotic resistance genes and facultative pathogenic bacteria removal. Chemical Engineering Journal 462, 142243.

Guo, L., Ye, C., Yu, X., Horn, H., 2023. Induction of bacteria in biofilm into a VBNC state by chlorine and monitoring of biofilm structure changes by means of OCT. Science of The Total Environment 891, 164294.

Haas, S., Schmieg, B., Wendlich, P., Guthausen, G., Hubbuch, J., 2022. Magnetic resonance imaging: Time-dependent wetting and swelling behavior of an auxetic hydrogel based on natural polymers. Polymers 14 (22), 5023.

Hackbarth, M., Gescher, J., Horn, H., Reiner, J.E., 2023. A scalable, rotating disc bioelectrochemical reactor (RDBER) suitable for the cultivation of both cathodic and anodic biofilms. Bioresource Technology Reports 21, 101357.

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