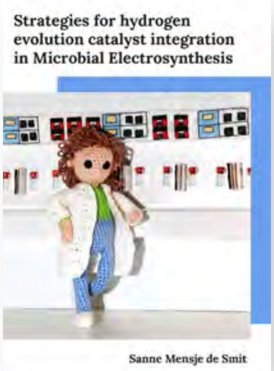
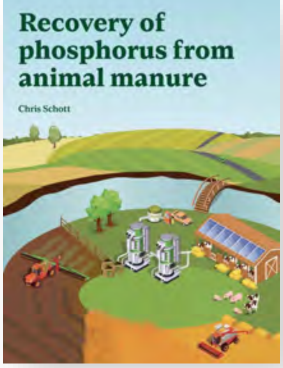
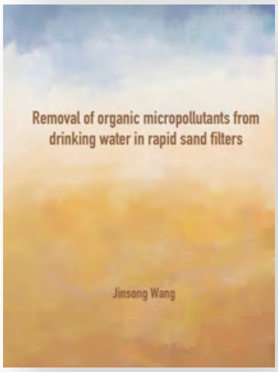
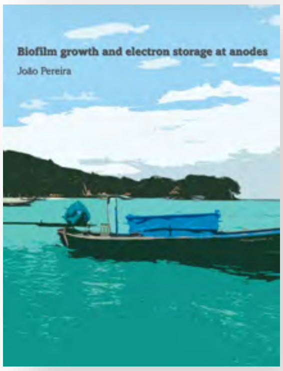
Environmental Technology









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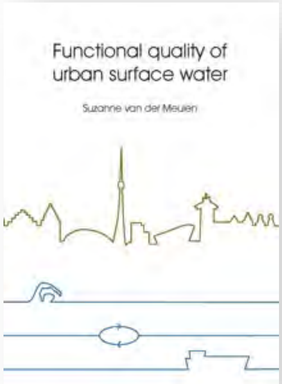
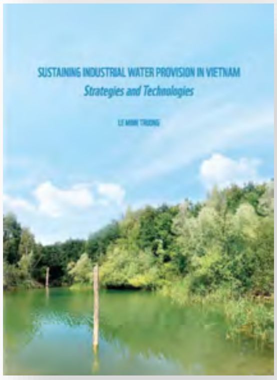
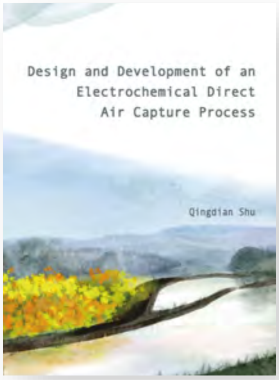
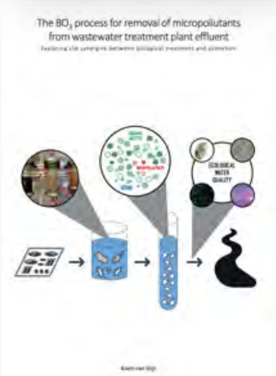
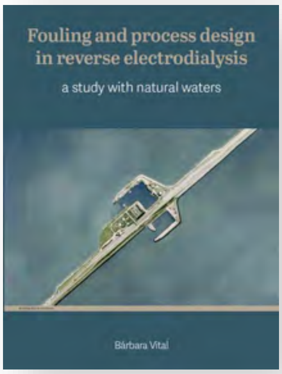
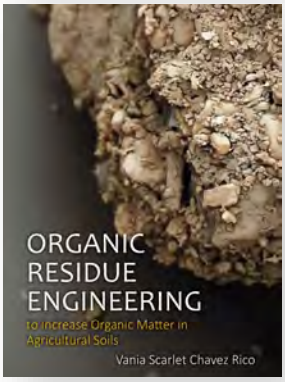












WAGENINGEN UNIVERSITY & RESEARCH

Introduction

This brochure aims at informing you on the activities of the Environmental Technology (ETE) Group of Wageningen University over the year 2023. Our current activities in education and research are presented in terms of a brief overview of the courses and educational programmes ETE participates in, concise information on each of our running research projects, and our list of 2023 publications. We also present you some output numbers.

The Environmental Technology Group

New Leadership

The ETE group is chaired by two people: Annemiek ter Heijne, Professor in (Bio)Recovery Technology for Circular Economy (since July 2023), and Huub Rijnaarts, Professor in Environment and Water Technology (since September 2009). One new professor will be appointed to take over Huub's position in the course of 2024, since Huub will become emeritus professor in May. Dr. Nora Sutton will take the role as interim chair, from April 2024 on, until Huub's successor starts. Annemiek and Nora form together the strategic leadership of the group.

We are very proud that in 2023, 55 MSc and 32 BSc thesis students, graduated under supervision of our ETE staff, and 70 PhD students conducted their research in ETE of which 14 graduated.

We perform this education and research with 20 members of scientific staff (of which 5 lecturers), 10 Laboratory and technology supporting co-workers, and 2 postdocs. Our staff is from diverse backgrounds and well connected to the national and international network. Annemiek ter Heijne is active in the scientific network of the International Society for Microbial Electrochemistry & Technology. Nora Sutton is leading in the field of micropollutant and pathogen treatment for a safe circular economy. Prof. Cees Buisman, former chair holder BRC, is now 0.2 fte Personal Professor Biocrystallization, and scientific director of WETSUS. Huub Rijnaarts continues to coordinate research programs such as AquaConnect and the RIET-Tsinghua-Suzhou-WIMEK (20 PhDs) collaboration, and is scientific director of the institute for Circular Society of the EWUU alliance challenging future generations. We have part time special professors from diverse industrial/institutional backgrounds such as Prof. Dr. Ir. Bert van der Wal (Electrochemical Water Treatment/Evides), Prof. Dr. Ir. Bert Hamelers (Electrochemical Resource Recovery/WETSUS), Prof. Dr. Ir. Tania Fernandes (Ecotechnologies for Water and Resource Recovery/IHE), a candidate professor Circular Water and Resources (Delta Climate Centre/Vlissingen), and Dr. Ir. Hans Cappon Lector Water Technology (HZ university of applied sciences/Vlissingen). Few industrial principal investigators complete our team with part time associations, namely Dr. Ir Adriaan Mels from Vitens-Evides-International (VEI), Dr. Ir. Roberta Hofman (KWR), Dr. Ir Arjen van Nieuwenhuijzen and Dr. Willie van den Broek from the Amsterdam Institute of Advanced Metropolitan Solutions-AMS.

Mission

The mission of the ETE group is to create unique breakthrough technologies for establishing new systems for recovery and reuse for both water and resources. A strong nature based and biotechnological component is combined with physics, chemistry and also social sciences. Concepts such as bio-crystallization, micropollutant biodegradation, bio-retention and bio-electrochemistry, combined with redox-chemistry, fluid mechanics and mass transfer processes, generate technologies for producing products such as recyclable organic matters, reusable water and renewable fertilizers. In addition to technology development and engineering, our urban system engineering working group designs urban, industrial and agricultural systems based on circular economy principles, in which we integrate sustainable energy production and use. Here advanced modelling and processing big data becomes an increasingly important component of our work.

Industrial and municipal waste streams are considered as resource streams, from which energy, water and minerals can be recovered, breaking the chain between the increased use of non-renewable sources and growing production and consumption. Thus these technologies and their integration in urban, industrial and agricultural systems help to reduce Human Footprints and safeguard a sustained supply of water, energy, nutrients and other resources for the growing world population. Circular agriculture, as promoted in NL and EU policies is becoming a new and important research line in our program. Furthermore, we believe that water, nutrients and carbon need to be recycled between urban, industrial and agricultural systems, on local and global scales. Technology development and system engineering combined, as done in the Environmental technology group allows us to generate scientific breakthroughs as well as societal innovations, thus creating science with impact. In addition to NL and EU societies, we collaborate with leading global economies (North America, China, India, Middle East) and selected countries in the global south (Ethiopia, Tanzania, Kenia, Vietnam, Bangladesh, Indonesia, Brazil, and Chili).

In our vision, we believe that new technologies and new system designs come into society through entrepreneurial companies, and therefore we have strong cooperation with industrial technology companies and stimulate technology spin offs, that bring our research outcomes to upscaled implementation in society. The Lettinga Associates Foundation - LeAF - carrying the name of the world wide known icon prof. Lettinga on development and global application of anaerobic water technology, is an important partner for ETE and hosted in our lab. LeAF is recognized by many industrial partners as a powerful independent platform in bringing sustainable technologies for treatment and valorisation of organic residues to global application. The ETE group supports various other spin-off and start-up enterprises such as ChainCraft (producing long chain fatty acids from organic waste) and works with many other companies, consultants, and knowledge institutes like Deltares, Wageningen Research, KWR, to bring science to practice.

Awards/Grants

During the EU-ISMET 2023, organized in Wageningen:

- Xiaofang Yan received two prizes for her work on ammonium oxidation. First, she won the best oral presentation award for her talk on how “ammonium oxidation should be as easy as cycling in the Netherlands.” Secondly, she was awarded with the 2023 ISMET innovation award for her work on N_2O free ammonium oxidation. In her work (https://pubs.acs.org/doi/full/10.1021/acs.est.3c02227) she describes how, by introducing the anode as electron acceptor instead of oxygen, which is normally used in wastewater treatment plants, ammonium oxidation can be steered more selectively towards N_2 gas, thereby avoiding emissions of the greenhouse gas N_2O.
- Rikke Linssen received the Best Poster Award for her creative poster
- Sanne de Smit received the Discovery Award for Best Scientific Paper for her research on the role of metals in the bacterial conversion of CO2 into fatty acids. (https://doi.org/10.1016/j.electacta.2023.142722)

Research

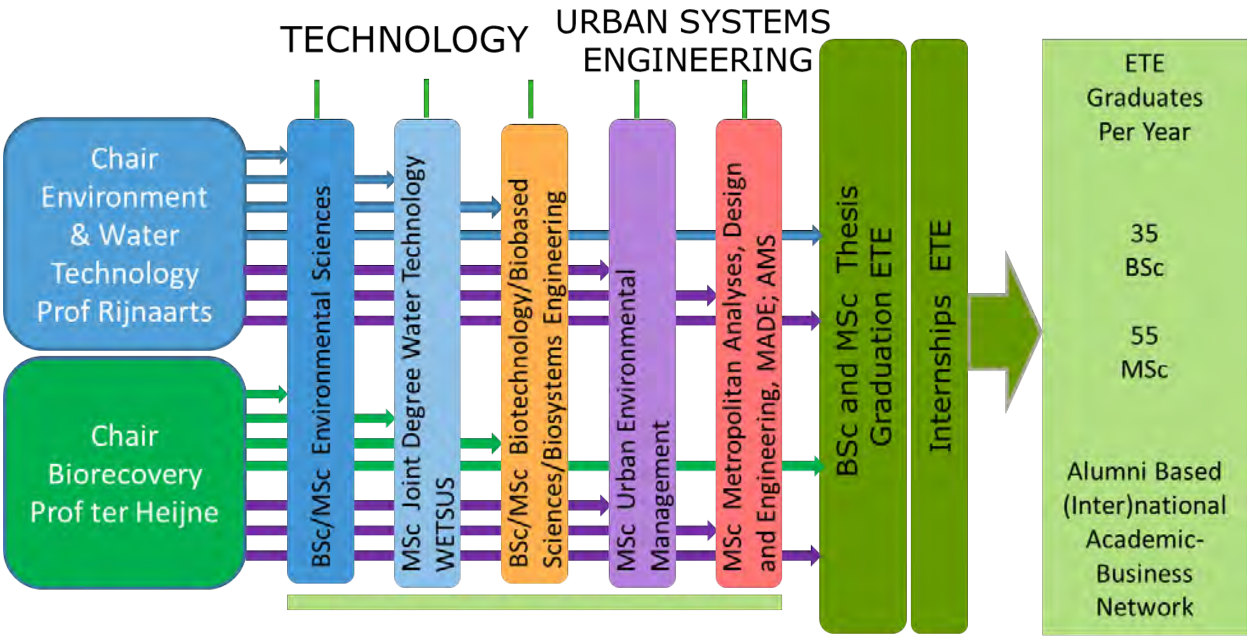
Our research program is characterized as follows:

⇒ **Biorecovery:** The biorecovery group focuses on optimal recovery of minerals and metals from wastewaters and gases and on recovery of renewable energy from waste and wastewater. Attention is being paid to the process bio-crystallisation and of bio-electrochemistry. And focusses also on the recovery of organic waste, including bio plastics, using new fermentation technologies.

⇒ **Reusable Water**: Technology focus is on bio-removal of micro pollutants and pathogens and improve the qualities of water resources for re-use. Our novel electrochemical desalinization techniques focus on reduced energy utilisation, in order to sustainably remove salt from water cycles, and to transform brackish water in delta’s into a sustainable fresh water resource.

⇒ **Urban Systems Engineering**: Cities currently hold half of the world’s population and it is estimated that three out of every five people will live in an urban environment by 2030. The world’s future sustainable development must therefore be largely accomplished by new approaches in urban sanitation, resource management and eco-innovative design of urban and associated agro and industrial systems. Balancing Urban Rural systems is a central theme for research and education.

Education of ETE: Three environmental technology and two urban systems engineering programs delivering around 90 graduates



We hope you will enjoy reading this brochure. Please feel free to contact us in case you want to know more about our education or research or check our website www.wur.nl/ete

Prof.dr.ir. Annemiek ter Heijne

Dr.ir. Nora Sutton

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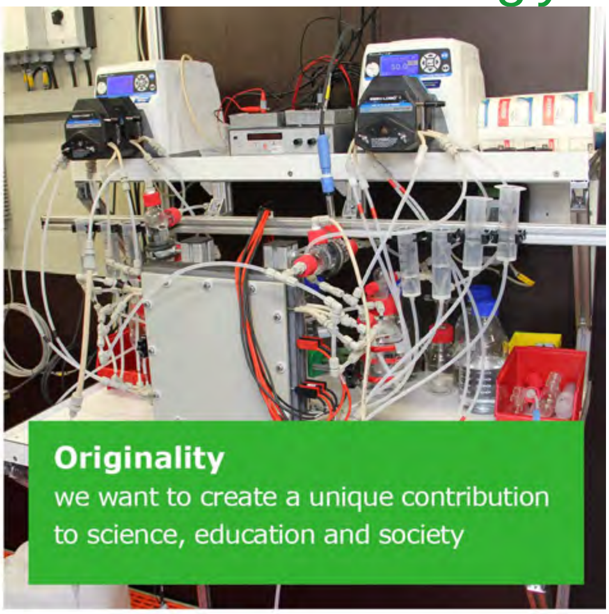
Our contribution to the sustainable development goals

Mission and Vision

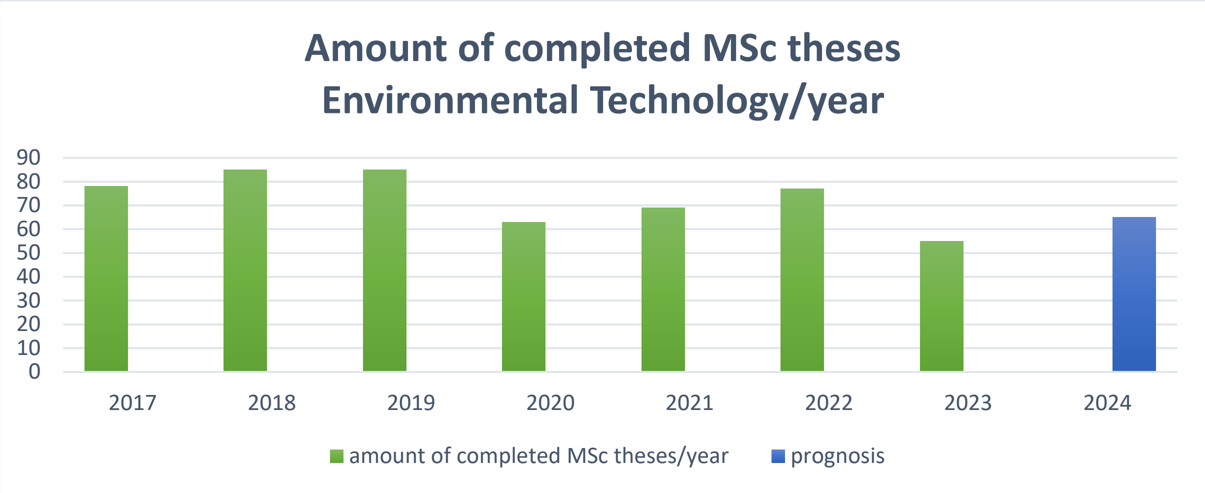
We develop and evaluate innovative environmental technologies and concepts based on processes from nature, to recover and reuse essential components and maintain and recreate a viable environment.
Our education inspires students to develop their talents. We impact society by innovation through top science and focus on applicability.

Values of Environmental Technology



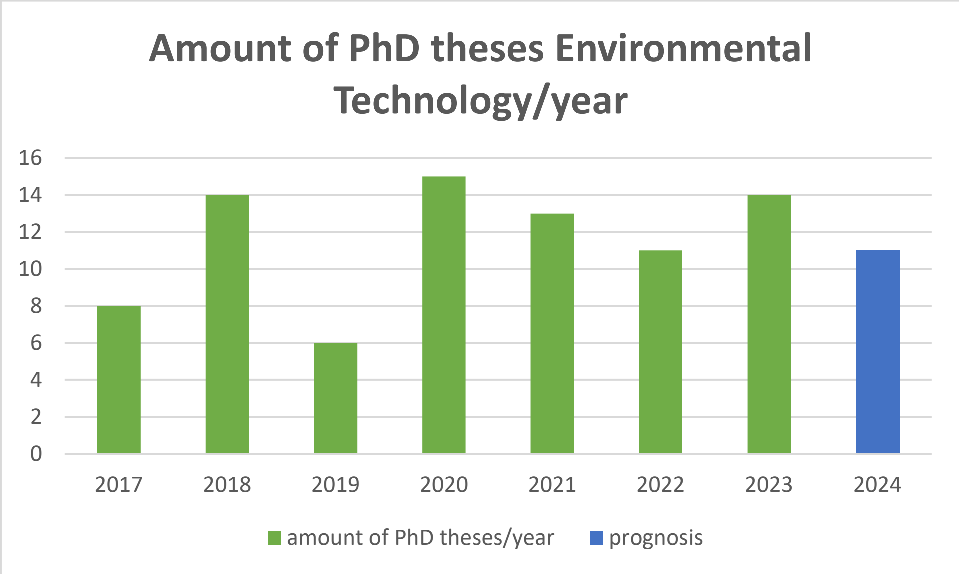
Output ETE 2023

In 2023, 55 MSc student completed a thesis in Environmental Technology, which is a considerable decrease compared to 2022. However, the number of BSc students is increasing (28 in 2022, 32 in 2023) In the coming years we expect again a small increase in MSc theses, based on the expected total number of thesis students in Environmental Technology at Wageningen University (50-60) as well as in the masters Water Technology in Leeuwarden (5-10), and Metropolitan Analysis, Design & Engineering in Amsterdam (5-10).

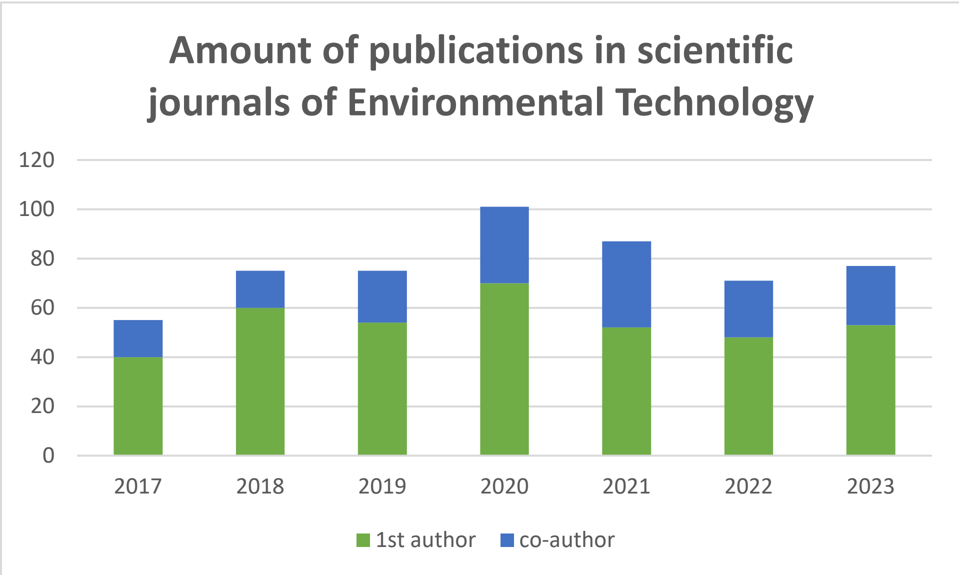


In 2023 we had 14 PhD defences. At the beginning of 2024 70 PhD students were working on their PhD research and did not yet graduate.

PhD Theses Environmental Technology 2023		
Name	**Promotor(s)**	**Title**
Koen van Gijn	Rijnaarts	The BO_3 process for removal of micropollutants from wastewater treatment plant effluent
Suzanne van der Meulen	Rijnaarts	Functional quality of urban surface water
Jinsong Wang	Van der Wal	Removal of organic micropollutants from drinking water in rapid sand filters
Sanne de Smit	Buisman/Bitter	Strategies for hydrogen evolution catalyst integration in microbial electrosynthesis
Le Minh Truong	Rijnaarts	Sustaining Industrial water provision in Vietnam : Strategies and technologies
Margo Elzinga	Ter Heijne/ Buisman	Exploring the degradation of organosulfur compounds at biocathodes
Qingdian Shu	Hamelers	Design and development of an electrochemical direct air capture Process
Chris Schott	Buisman	Recovery of phosphorus from animal manure
Adrian Hidalgo	Buisman	Thermoacidophilic elemental sulfur reduction for the recovery of metals from hydrometallurgical streams
Elackiya Sithamparanathan	Rijnaarts	Improving vertical flow constructed wetlands with novel filter materials to treat wastewate
Joao Pereira	Ter Heijne/ Hamelers	Biofilm growth and electron storage at anodes
Barbara Vital	Hamelers	Fouling and process design in reverse electrodialysis: a study with natural waters
Vania Chavez Rico	Buisman	Organic residue engineering to increase organic matter in agricultural soils
Kaiyi Wu	Rijnaarts	Microalgae-based technology for wastewater treatment: exploring organic micropollutants removal



The complete Publication List of Environmental Technology 2023 can be found at the end of this brochure.



Education

Environmental Technology offers an education and research programme that is focused on sustainable technological solutions for the worldwide environmental problems. Our approach is to combine several disciplines (microbiology, environmental chemistry, physical chemistry, fluid dynamics, mathematical and computational system and grid theory, and system design) in order to achieve innovations for environmental solutions. We consider the socio-econimical aspects by co-operating with Environmental Policy and Economics, related groups of the university.

Environmental Technology participates with courses and other educational subjects in a number of study programmes of Wageningen University, both on BSc and MSc level:

1. Bachelor of Science (BSc) programme:
- Environmental Sciences (BES)

Environmental Technology is one of the three specialisations within this programme.

2. Master of Science (MSc) programmes:
- Environmental Sciences (MES)
- Urban Environmental Management (MUE)
- Biotechnology (MBT)
- Biosystems Engineering (MAB)
- Molecular Life Sciences (MML)

3. Master of Analyses, Design and Engineering of Metropolitan systems (MADE), at AMS in Amsterdam, including Living Lab, Professional Profile and Thesis completion

4. Master in Water Technology at WETSUS

In all these Master programmes, students can major in Environmental Technology.

The joint degree programme Water Technology of Wageningen University, Twente University and Groningen University, started in 2008, has been accredited. The courses are offered in Leeuwarden at the Wetsus academy (*www.wetsusacademy.nl*).

Overview Courses and Planned fieldtrips

Course Number	Course Name	Planned fieldtrips in 2024
ETE10806	Introduction Environmental Technology	• Excursion to soil remediation locations in Wageningen by bike • Excursion to wastewater treatment plant Bennekom by bike
ETE21306	Water Treatment	• Wastewater treatment plant Amersfoort
ETE22806	Principles of Urban Environmental Management	• NIOO Wageningen • AVR Duiven
ETE24804	Fundamentals of Environmental Technology	
ETE 25306	Basic Technologies for Urban Environmental Management	• Wastewater treatment plant • Solid Waste Management company
ETE25812	Environmental Project studies	
ETE26304	Renewable Energy Technologies	
ETE26806	Environmental Process Engineering	
ETE30306	Biological Processes for Resource recovery	
ETE30806	Processes for Water Treatment and Reuse	
ETE32806	Managing Urban Environmental Infrastructure	• Vitens drinking water production site
ETE33806	Planning and Design of Urban Space	• Culemborg – EVA Lanxmeer:
ETE34306	Urban Energy, Water and Nutrient Cycles	• Sneek – Desah
ETE34806	Resource Quality in the Circular Economy	• Circular greenhouse facilities at Glastuinbouw in Bleiswijk • Hengel0 – the Marke
ETE35306	Environmental Electrochemical Engineering	
ETE50401/ ETE50406	Capita Selecta Environmental Technology	
ETE50803/ ETE50806	Capita Selecta Urban Environmental Technology and Management	
ETE51302	Data driven Environmental Modelling and Optimization for resource management	
XWT20805	Water Technologies in Global Context	
XWT30305	Biological Water Treatment and Recovery Technology	
XWT32305	Colloid Chemistry	

Theses and Internships	
ETE80903 BSc Thesis Environmental Technology Part 1: Design Tools	ETE80909 BSc Thesis Environmental Technology Part 2
ETE70224 and 70424 Internship Environmental Technology	ETE70724 and 70824 Internship Urban Sytems Engineering
ETE78324 and 79324 MSc Research Practice Environmental Technology	ETE78424 and 79424 MSc Research Practice Urban Systems Engineering
ETE80424 and ETE80436 Thesis Environmental Technology	ETE81824 and ETE81836 Thesis Urban Sytems Engineering

PhD courses (WIMEK-SENSE)
Micropollutants in the water cycle

We participate in the following MOOCs

MOOC
Sustainable Urban Development: Discover Advanced Metropolitan Solutions
Circular Economy: An interdisciplinary Approach

Facilities

Modutech: a unique technology development facility

Modutech is a fully equipped, state of the art modular technology facility for bio-based and environmental sciences research. It offers a wide variety of support and services. Research institutes, other departments of Wageningen UR and companies have the opportunity to rent individual units to carry out their own research. Within this partnership, we can offer scientific and technical expertise as well as in house laboratory facilities for standard analyses.

Customized to specific research needs

Modutech covers a total of 300 m^2 including 24 units of 2 m^2 and 4 units of 6 m^2. The units can be fully customized and adapted to specific research needs. Each unit has basic supplies, such as electricity (standard 220 V as well as power current 380 V), water and water drain, nitrogen and compressed air and ventilation. Some units are also temperature controlled between 15-35 ^{0}C . Extra connections are available for CO_2 and O_2. Additional special safety storage for dangerous gasses is also available for each unit. A Draeger safety system, equipped with gas sensors, can detect different toxic and explosive gasses, for example CH_4, H_2, H_2S and NO_2. In 2021, Modutech expanded with 6 extra 2 m^2 units. In 3 of these units temperature and humidity can be regulated. Also lighting can be regulated by means of LED lamps. This is to simulate sunlight for research on wetlands. In the future, Modutech will have the unique possibility to work under fully anoxic conditions in 2 units, offering a spacious area to conduct experiments.

Scientific and technical expertise

Modutech not only offers fully customizable, state of the art units, but also offers full technical and scientific support, including 3D-printing. There is substantial in-house expertise on bio-based science, experimental design and laboratory support. Students can be commissioned to carry out either long-term or short-term experiments.

Combination of research facilities

For wastewater treatment and sanitation research, Modutech offers special facilities that go well beyond standard research accommodations. Pipelines from the Bennekom WTP directs raw wastewater (1 m^3/hour) and 2 types of effluent to Modutech for research. Water can also be stored in one of the two cooled 3.5 m^3 tanks. Sanitation studies are also possible with 2 Roediger vacuum toilets, 2 Gustavsberg no-mix toilets, 2 Urimat water free urinals and a separate grey water collection facility. September 2013 we installed eight 4x3 m^2 constructed wetlands (helophyte filtering) for additional wastewater cleaning steps. These offer the possibility to conduct even salt-water experiments. In 2017, three of the wetlands were split into six smaller wetlands consisting of 3 horizontal wetlands, 3 vertical wetlands and 3 water ponds. The diversity and quantity of equipment support almost any experimental setup and allow clients to run several experiments simultaneously.

The NWO Unlock project

The Modular Bioreactor Platform from the Unlock project is housed at ETE adjacent to Modutech. The Modular Bioreactor Platform consists of different types of bioreactors with many on/in-line sensors and analytical equipment. Some possibilities include: sampling the bioreactors with or without biomass, measuring living biomass content, monitoring online gas composition with MS, and performing real-time NMR scans. https://m-unlock.nl/

Laboratory facilities @ ETE

Modutech is supported by a well-equipped analytical research environment with an analytical staff of 6 persons and 1 support staff member . The analytical team has a broad practical knowledge in research and take care of the lab organisation, equipment maintenance and method development. During the education period, part of the analytical team also provide support in teaching and guiding the students during practical courses. . The lab provides the researchers with basic laboratory equipment and a set of routine analysis methods (e.g. biogas analysis, VFA analysis, micro-pollutants analysis, ICP metal analysis). In addition to the routine setups, they can offer some flexibility to switch and set up analytical methods on a number of different GC and LC systems according to the specific analytical research question in a project.

Environmental Technology makes use of concepts and processes from different scientific disciplines. To support this, ETE has a variety of microbiological research facilities, including an anaerobic hood, laminar flow cabinet and microscopes. In 2022 ETE attain their own facilities for molecular research purposes. This laboratory has the required equipment to do DNA extraction procedures from environmental samples. Added to this facilities, at the ETE department it is also possible to do qPCR analysis for bacteria and archaea. Additional to the above mentioned facilities, the department also has collaborations with other groups within the university which gives us access to more specialised molecular techniques, like Next Generation Sequencing .

Overview of available analytical techniques in the ETE analytical labs.

Principle	Equipment	Detections method	To analyze
Chromatography	GC	FID	VFA & MCFA
			SC Alcohols
			TPH
		ECD	Chlorinated compounds
		FDP	Mercaptans, H_2S
		HWD	O_2, N_2, CH_4, CO_2, CO, H_2
	LC	RI	sugars
		UV-Fluorescence	PAHs
		DAD	Micro-pollutants (medicines, pesticides, hormones)
		Conductivity	NH_4^+
		QQQ-MS	Micro-pollutants. PFAS
	IC	Conductivity Electrochemical	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, H_2S
Spectroscopy	Plate reader	UV-VIS	Sugar screening
		Fluorescence	Toxicity screening
		Luminescence	
	Cuvette double beam	UV-VIS	NH_4^+, NO_3^-, PO_4^{3-}, Fe^{2+}/Fe^{3+}, Starch, COD, TOC
	ICP	Optical emission	Metal ions, phosphorus & sulphur
	Laser	Raman 785 laser	Methanol, ethanol
X-ray analysis	XRD	X-ray diffraction	Minerals, polymers, nanoparticles
	XRF	X-ray fluorescence	Elemental composition

Environmental Technology

Bio*recovery*

Our research focuses on *bio-based technologies for recovery of valuable components from* residual streams *in the form of fuels,electricity,sulphur, copper, and phosphate.*

Re*usable* Water

Water shortage threatens billions of people. Reuse and protection of our water sources are essential. Our research focuses on *removal of nutrients, pathogens nutrients, pathogens from water.*

Urban *System Engineering*

Scale and speed of urbanization leads to new challenges for our urban services. Closed resource cycles are necessary. We focus on *new sustainable biorecovery and cleaning concepts for management of urban and industrial water, sanitation, waste,nutrient and energy. Feedbacks from cities to agriculture are also studied.*

Environmental Technology focuses on resource efficiency and resource recovery to prevent depletion and on quality of water, soil and recycled resources to prevent pollution

Urban Systems Engineering focusses on systematic integration of concepts, techniques and models to improve the Metropolitan Environment.

Scientific Staff Environmental Technology

Biorecovery and Urban Systems Engineering	Reusable Water and Urban Systems Engineering
 dr.ir. David Strik E-mail: David.Strik@wur.nl Tel: 0317-483447	 dr. ir. Katarzyna Kujawa-Roeleveld E-mail: Katarzyna.Kujawa@wur.nl Tel: 0316-485404
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 dr.ir. Sanne de Smit E-mail: Sanne.de Smit@wur.nl Tel: 0317-483339	 dr. Shahab Shariat Torbaghan E-mail: Shahab.Torbaghan@wur.nl Tel: 0317-483339

Biorecovery and Urban Systems Engineering	Reusable Water and Urban Systems Engineering
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	 dr. Lixia Chu E-mail: Lixia.Chu@wur.nl Tel: 0317-483339
	 dr. Thomas Wagner E-mail: Thomas.Wagner@wur.nl Tel: 0317-483339

Special Professors, (Industrial) Principal Investigators, and others at Environmental Technology

Biorecovery and Urban Systems Engineering	**Reusable Water and Urban Systems Engineering**
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	 dr.ir. Roberta Hofman E-mail: Roberta.Hofman@wur.nl Tel: 0317-483339 From: KWR

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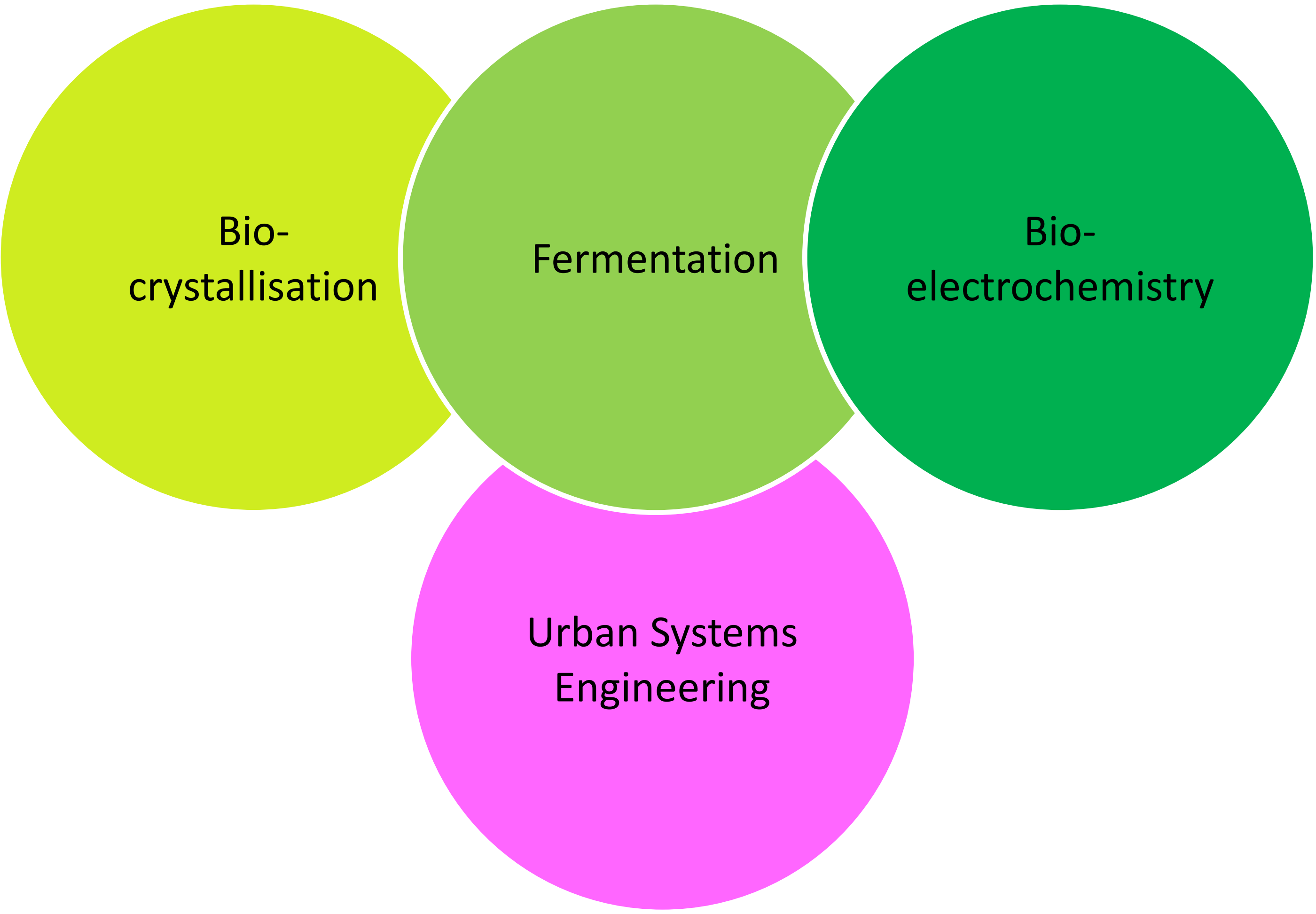
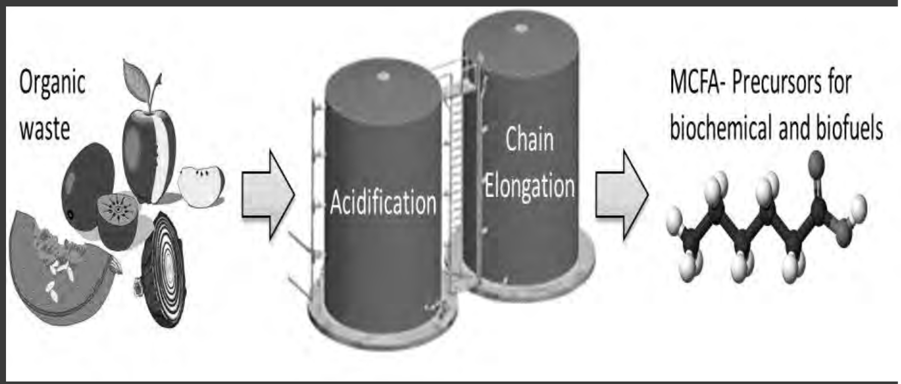
Biorecovery

Environmental Technology

Biorecovery



Biorecovery



Environmental problems

Societies are highly dependent on access to mineral and energy resources. At this moment the world depends on fossil reserves of both minerals and energy. For the transition to a more sustainable world it is necessary to change from fossil sources to renewable sources. For minerals, recovery from many residual streams of industry and cities can be a new source. Energy can be recovered from residual streams from cities and agriculture. Finally, new energy conversion technologies based on the sun (biomass, direct sun conversion, fresh water flows) can be developed.

By developing new technologies to recover energy and minerals from waste, also new methods can be found to clean up the waste streams from existing processes for energy and mineral extraction from fossil sources. These new technologies enable removal of sulphur, metals and nitrogen, or preventing their emissions from water and gas streams. These technologies will have a positive influence on many environmental problems, like acid rain, climate change, and cadmium pollution of soils.

Our solutions

The biorecovery group seeks to solve these environmental problems by using biobased technologies to recover energy and inorganic compounds from residual streams. Innovative research is on-going in the following areas:

1) Production of electrical energy, fuels and sustainable heat from residual biomass. This type of biomass is left over after extraction of valuable (food) ingredients from agricultural products. The use of residual biomass enhances the economic and social potential of our processes. We use natural biotechnology i.e. we employ the processes as they occur in nature.

2) Application of the biological sulphur-cycle in water and gas treatment.

3) Biocrystallisation: biological recovery and removal of metals and minerals from industrial wastewater and/or groundwater.

4) Biological modification of (waste) materials to reduce the environmental impact or improve the efficiency of industrial processing.

Our approach

- Central in our approach is the development and operation of bioreactors that enable the selection of the right organism for the desired conversion. The research is based on lab-scale systems where the selection of natural micro-organisms takes place and can be studied and steered. Next to this practical research models are needed to describe and further develop these processes
- The research has a multidisciplinary character, including microbiology, analytical and colloid chemistry, geology, biophysics, process technology, electrochemistry, and automation.
- Development of innovative processes for the recovery of inorganic minerals, organic fules/chemicals and the production of renewable energy.
- Development of more sustainable industrial production processes, in co-operation with end-users and technology providers.

Development of new biological desulfurization processing schemes

Nov 2020 - 2024

Researcher	Supervisor	Promotor
Kestral Johnston	Dr. ir. Johannes B.M. Klok Dr. Pawel Roman	Prof. dr. ir. Cees Buisman Prof. dr. ir. Karel Keesman

Motivation

Currently, most of the world's sulfur is produced as a by-product of the treatment of gas streams that come from the mining of fossil fuels. These gas streams contain dihydrogen sulfide (H_2S), which is recovered and transformed into sulfur using both energy and chemically intensive processes. As the world transitions to using more sustainable forms of energy, sulfur production will decrease and may no longer be available for use in industries such as agriculture. With this decrease comes the need to enhance current sulfur recovery technologies. The biodesulfurization technology utilizes sulfide oxidizing bacteria (SOB) that convert H_2S gas to elemental sulfur under ambient conditions making it more sustainable than physiochemical processes. However, the current process produces thiosulfate and sulfate as by-products, both of which are unwanted due to their consumption of caustic, bleed stream formation, and reduction in the recovery yield of elemental sulfur.

The main goal of this research is to understand and explore the mechanisms behind the shuttling capacity of the SOB. By understanding these mechanisms, new biological desulfurization schemes will be developed to produce more robust microbial communities and limit unwanted by-product formation. The following research questions will be addressed:

1. Understand underlying redox processes the SOB use to produce sulfur
2. Develop methods to quantify the shuttling capacity using a continuous-batch flow reactor
3. Develop methods to stimulate the shuttling capacity
4. Propose and test new process schemes

[1] ter Heijne, A., *et. al.*, Environmental science & technology letters, 5(8), (2018). 495-499.
[2] de Rink, R. *et. al.*, Environmental science & technology, 53(8), (2019). 4519-4527.

Technological challenge

Recently, it was discovered that the SOB are able to remove sulfide (HS^-) in anaerobic conditions and reduce oxygen in sulfide-free condition [1]. This ability, known as the shuttling capacity, can be further enhanced when the SOB are grown in alternating "anaerobic-sulfide rich" and "aerobic-sulfide-free" conditions [2]. The underlying mechanisms for the shuttling capacity are not understood; therefore, a multi-scale approach is needed to understand this ability (Fig. 1). The technological challenge is to determine if and how the shuttling capacity can be quantified, stimulated, and optimized for the recovery of sulfur.

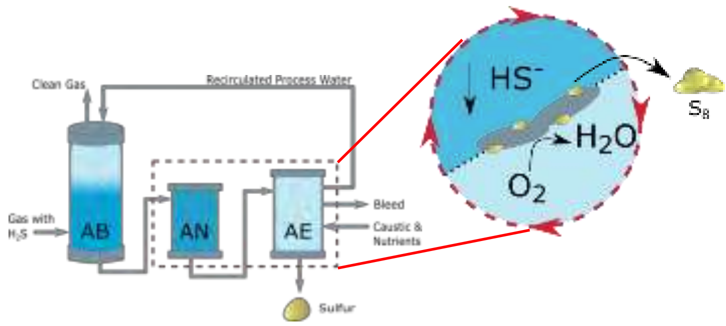


Fig. 1 - Schematic of the current biodesulfurization process and the shuttling capacity the occurs between the anaerobic (AN) and the aerobic (AE) reactors.

CV

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Understanding the kinetics, transfers and reactions in the biological gas desulfurization process.

Nov 2022 - 2026

Researcher	Supervisor	Promotor
Joris Bergman	Dr. ir. Annemerel Mol Ir. Margo Elzinga	Prof. dr. ir. Karel Keesman Prof. dr. ir. Cees Buisman

Motivation

H_2S is a toxic and environmentally harmful gas that requires removing from (bio-) gas streams. The biological gas desulfurization process is an environmentally friendly process that converts H_2S into elemental sulfur (S^0) using sulfur-oxidizing bacteria (SOB) under haloalkaline conditions (pH 8-9.5 and ionic strength 1-1.5 M) [1]. Within the process, biological, chemical and mass-transfer reactions take place simultaneously. The process consists of three steps: 1) absorption of H_2S into a (bi) carbonate solution to form dissolved HS^-, 2) anaerobic uptake of HS- by SOB and 3) aerobic conversion of stored HS- into S^0. Aside from S^0 , SO_4^{2-} (sulfate) and $S_2O_3^{2-}$ (thiosulfate) can also be formed through biological or chemical oxidation. Theoretically, 98% of incoming S atoms can end up in S^0, but in practice lower percentages are achieved [2]. Modelling can help understand the interplay between the different processes in order to improve the process design and control. The aim of this research is to model the biological gas desulfurization process using both past data and by generating new experimental data.

Technological challenge

Three challenges must be overcome in the modelling of the biological gas desulfurization process:

- Aspects of the SOB biology, e.g. their ability to take up and store HS- under anaerobic conditions. This most likely requires the development of advanced kinetic models.
- Both sulfur crystals and bacteria are known to enhance mass transfer in the absorber column [3,4]. To date no quantitative information exists on the relative contributions of both forms of enhancement and no model exists in literature that combines both biological and chemical mass transfer enhancement.
- Investigating the hypothesis that most of the chemical conversions in the micro-aerophilic reactor take place within a gradient around the reactor O2 and HS^- injection points. This necessitates the use of computational fluid dynamics (CFD).

The project has the following research goals:

1. Determine the dominant physical, chemical and biological processes and quantify their kinetics;
2. Develop a novel model for the SOB biological rates;
3. Model simultaneous chemical and biological mass transfer enhancement in the absorber column;
4. Model the processes that take place around the HS- and O2 injection points and determine how the mixing pattern around these points affects the process performance;

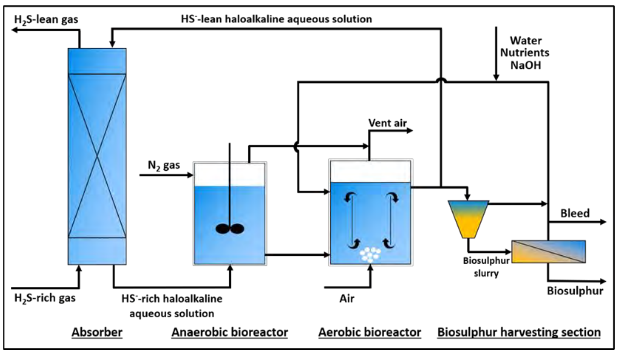

Fig 1. Current process line-up

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Iron recovery and arsenic isolation from drinking water treatment sludge

Environmental Technology

May 2022 - 2026

Researcher
Milan Adriaenssens

Supervisors
Dr. ir. Annemerel Mol
Ir. Leon Korving
Dr. Renata van der Weijden

Promotor
Prof. dr. ir. Cees Buisman

Motivation

During the production of drinking water, carcinogenic arsenic is removed from the raw water into an iron sludge. While the iron in the sludge still has value, a high concentration of arsenic in the sludge challenges its reuse. Consequently, drinking water treatment sludge is regularly landfilled, risking arsenic leaching into soil and groundwater and inhibiting circularity in drinking water production. With the development of an iron-sludge treatment technology, both iron recovery and stable arsenic storage are aimed for, eliminating iron landfilling.

Technological challenge

Clean drinking water can be obtained, due to the high affinity of arsenic to iron adsorbents. However, this results in a challenge to separate/mobilize arsenic from the iron compounds, an essential first step in the isolation of arsenic and recovery of iron. By altering reaction conditions, affecting both chemical and biological processes, a separation between iron and arsenic is hypothesized (Fig 1).

Secondly, the obtained arsenic should be immobilized into a stable mineral to avoid environmental contaminations when disposed of. For example as scorodite, which has a low Fe/As molar ratio.

Finally, the recovered iron needs to be obtained in a quality/purity suitable for other application. Potential end-users could be WWTPs for phosphate removal or bio fermenters for sulfide elimination. If reuse in drinking production is possible, lower operational costs can be obtained, making save drinking water more available.

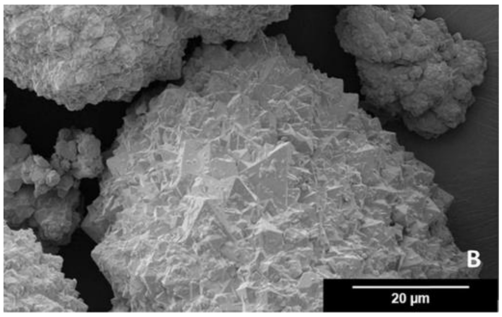

Figure 2. SEM picture of bioscorodite (by Vega-Hernandez et al., 2021)

Research goals

- Understand the mobility of iron and arsenic under different reaction conditions.
- Identify reactions to form a stable As-mineral at low arsenic concentrations.
- Comprehend how different conditions affect the value of the obtained iron product.

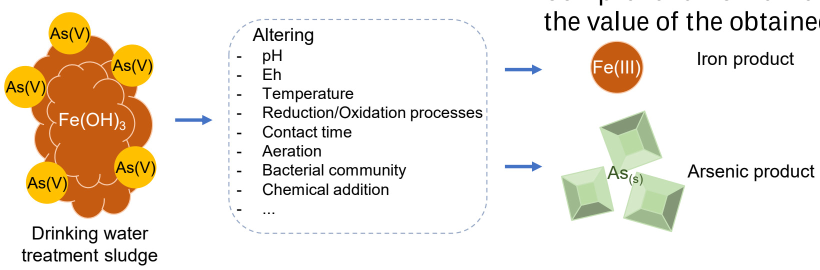

Figure 1. Proposed scheme for iron recovery and arsenic isolation

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WAGENINGEN UNIVERSITY & RESEARCH

Experiments in Wageningen

EPS-based solutions to increase soil structure and resilience to drought

Jan 2023 - 2027

Researcher	Supervisor	Promotor
Mithat Can Kuscu	Dr. ir. Annemiek ter Heijne Dr. Valentina Sechi Dr. Yujia Luo	Prof. dr. ir. Cees Buisman

Motivation

It has been estimated that almost 40% of the total agricultural land in Europe is prone to soil degradation at a moderate or higher level of severity [3]. Microorganisms and their metabolic products affect soil structure by binding loose soil particles into water-stable aggregates [2]. In particular, extracellular polymeric substances (EPS), produced by soil microorganisms, are known to have numerous, positive effects on soils, including improved water retention and aggregate stability [1]. This research project aims to develop engineering strategies to enhance EPS production and increase soil structure and resilience to drought.

Technological challenge

- The use of EPS in agriculture is still very limited
- Our knowledge of EPS composition, structures, and functions is far from complete.
- Our understanding of the mechanisms involved in the biosynthesis and degradation of EPS in soil and their role in determining soil properties is still unclear.

Research Goals

The project's ultimate goals are to develop nature-based management strategies to increase soil structure and resilience to drought via EPS stimulation (Figure 1).
The research will be targeting the following research questions:
1: What is the role of OAs and C/N ratio in soil EPS production?
2: What is the role of EPS in soil aggregation?
3: What is the relationship between EPS and drought resistance of the soil?
4: What are the effects of OA-induced EPS on different types of soils?

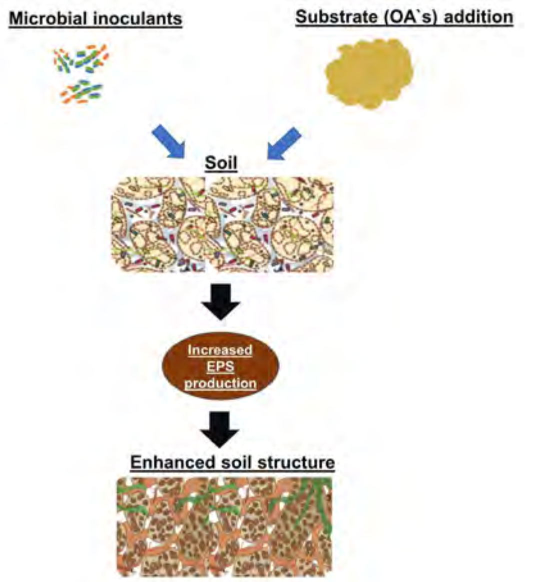

Figure 1. Modified conceptual framework of the research approach [3].

References

[1] O. Y. A. Costa, J. M. Raaijmakers, E. E. Kuramae, 2018, *Frontiers in Microbiology* 9, 1636
[2] R. J. Swaby, 1949, *Journal of General Microbiology* 3(2), 236–254
[3] R. Lal, 2008, *Nutrient Cycling in Agroecosystems* 81(2), 113-127

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Optimization of manure processing: Towards more sustainable manure-based fertilizers

Nov 2022-2026

Researcher	Supervisor	Promotor
Lourens van Langeveld	Dr. Ir. Miriam van Eekert, Dr. Paul Bodelier, Dr. Valentina Sechi	Prof. dr. ir. Cees Buisman

Motivation

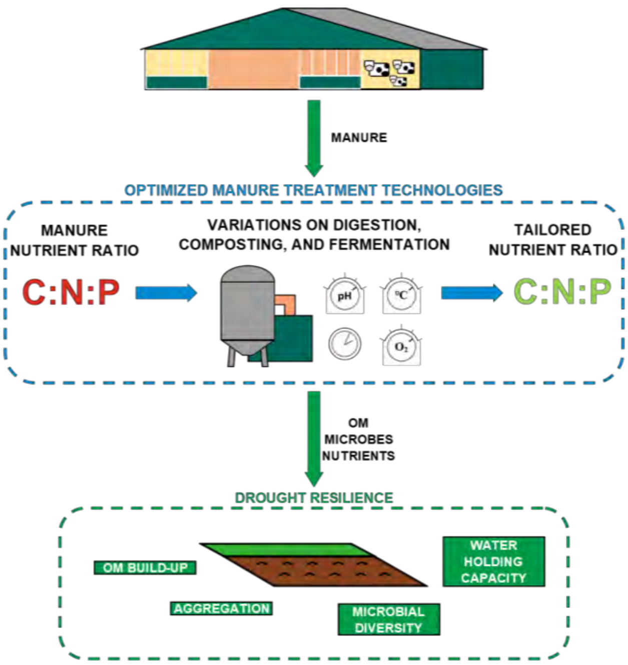
Organic matter supports many ecosystem functions vital for crop production and plays a central regulatory role in GHG-emission control and soil carbon sequestration. Globally, soil organic matter, and thus carbon stores are increasingly depleted as a result of intensive farming practices, affecting both soil functionality and productivity. As a result, many ecosystem services are negatively impacted, such as water holding capacity, GHG sequestration, and crop growth. Reintroduction of carbon into the soil system is often achieved by amendment with (treated) manure. However, current methods can lead to increased GHG-emissions and eutrophication, as treatment methods and application strategies are far from optimized. In addition, the effect of the treated manures on the microbial, physical, and chemical characteristics of the soil are poorly understood. Steps are made to move from intensive agricultural practices to more regenerative agricultural practices, with the intention to maintain crop output whilst ameliorating soil health and improving drought resilience.

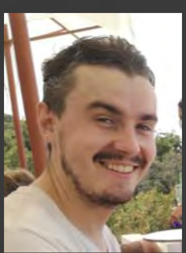
This research project aims to improve current manure treatment technologies by combining knowledge and integrating the frontier between bioprocess technology and soil science.

Technological challenge

Manure digestion, and other (post- or pre-) treatments, can improve the sustainability of agricultural practices by allowing increased reintroduction of carbon and nutrients into the food chain. However, measuring microbial traits like carbon and nitrogen use efficiency or contribution of microbial carbon to soil organic matter are still highly challenging. In order to achieve more effective use of amendments in agriculture, the impact of processed manure on soil needs to be investigated in relation to the following parameters:

- Carbon uptake
- GHG emissions
- Nutrient leaching
- Organic inputs and associated microorganisms
- Water holding capacity





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The effect of different organic fertilizers on the soil microbiome

Biorecovery
Environmental Technology

Mar 2024 - 2028

Researcher	Supervisor	Promotor
Brenda Speek	Eline Keuning Dr. Valentina Sechi	Prof. dr. ir. Cees Buisman Prof. dr. ir. Martijn Bezemer

Motivation

Grasslands cover approximately 70% of agricultural soils worldwide and account for 53% of agricultural grounds in the Netherlands. Fertilization is an essential component of grassland management, used for increasing forage production and yield.

In the Netherlands, grasslands are often fertilized with animal manure, which serves as a vital source of nutrients crucial for plant growth and development. Manure is rich in nitrogen; excessive application contributes to emission of greenhouse gases, loss of nutrient through leaching and soil acidification. To make agricultural practice more sustainable, nitrogen emissions need to be reduced.

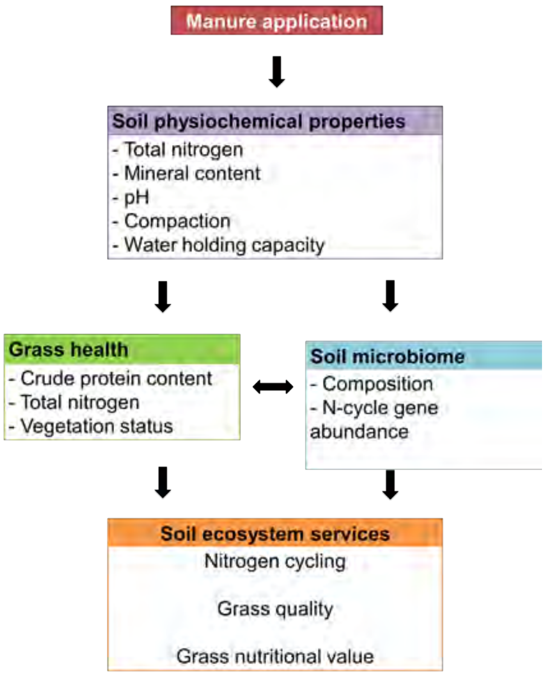
Technological challenge

Microorganisms play important roles in soil nitrogen cycling, yet the impact of organic fertilization on grassland microbiomes remains understudied. Especially in Northern-Europe, research on this topic is still lacking. Therefore, insight is needed to unravel the influence of manure application on soil microbiomes, particularly the effect on microorganisms involved in the nitrogen cycle and their influence on plant nitrogen uptake and unwanted emissions to the environment.
By elucidating the effect of manure fertilization on the soil microbiome, this study aims to contribute to the establishment of efficient fertilization strategies and reducing nitrogen emission.

Research goals

The goals of this research is to investigate the effect of different forms of manure fertilization (slurry, digestate and composted) and two different application methods (injection and above ground spreading) on the grassland soil microbiome, with a particular focus on the nitrogen cycle.
This research aims to answer the following questions:

1. What is the impact of different organic fertilizers on composition and diversity of the soil microbial community in grasslands?
2. How does fertilizer injection influence the soil microbial composition and diversity compared to above ground application?
3. Can soil and grass nitrogen content be linked to nitrogen-cycle related gene abundance?



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WAGENINGEN UNIVERSITY & RESEARCH

N_2O, NO and N_2 emissions from anaerobically stored manure

Jan 2023 – 2027

Researcher	Supervisor	Promotor
Rik Maasdam	Dr. ir. Miriam van Eekert Dr. ir. Karin Groenestein	Prof. dr. ir. Huub Rijnaarts

Motivation

In the livestock sector two major air polluting problems relating to manure management are: the release of nitrogen in the form of NH_3 and the release of greenhouse gases (GHG) such as CH_4 and N_2O. While we generally know how much and under which conditions NH_3 and CH_4 are emitted, this is not the case for the other nitrogen gasses in the nitrogen cycle: N_2O, NO and N_2. To try to minimize the emission of the environmental detrimental gasses N_2O and NO this project aims to get a better understanding on the biological conversions of nitrogen in manure.

Technological challenge

From studies on soil and wastewater treatment plants four different microbial conversion pathways are known in which N_2O, NO and N_2 might be formed and emitted: nitrification, denitrification, nitrifier denitrification and anammox.

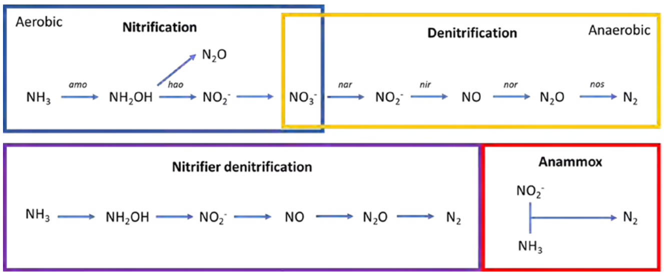


Figure 1. microbial nitrogen pathways: the coupled nitrification and denitrification, nitrifier denitrification and anammox.

While manure is stored primarily anaerobically, conventional storage tanks are partially open and therefor the surface area is under influence of the outside conditions. This can cause drying of the surface layer forming a crust, thus creating a porous aerobic environment. Hypothetically, all four of the nitrogen pathways can take place in stored manure. The technical challenge of this project will be determining and quantifying which pathway takes place under which conditions (figure 2).

This project will use multiple batch reactors with manure where the emitted gasses are continuously measured to get a better understanding on the nitrogen conversions.

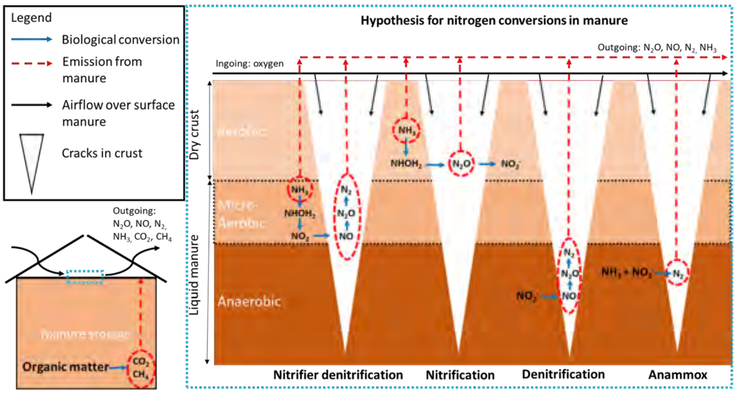
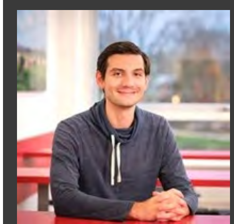


Figure 2. hypothesis of the nitrogen conversion pathways taking place in anaerobically stored manure as well as in the crust layer during storage.

Research objectives:

- Determine the main microbial nitrogen pathways responsible for the emission of N_2O, NO and N_2 and the effect of storage conditions and environmental parameters on these emissions.
- Propose and test mitigating strategies to minimize N_2O and NO emissions from stored manure.



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Optimization of (hyper)thermophilic blackwater treatment for recovery of biofertilizers and energy

Oct 2023 - 2027

Researcher	Supervisor	Promotor
Melissa Mwikali Mativo	Dr. ir. M.H.A. van Eekert Dr. L. Hernandez-Leal	Prof. dr. ir. Cees Buisman

Motivation

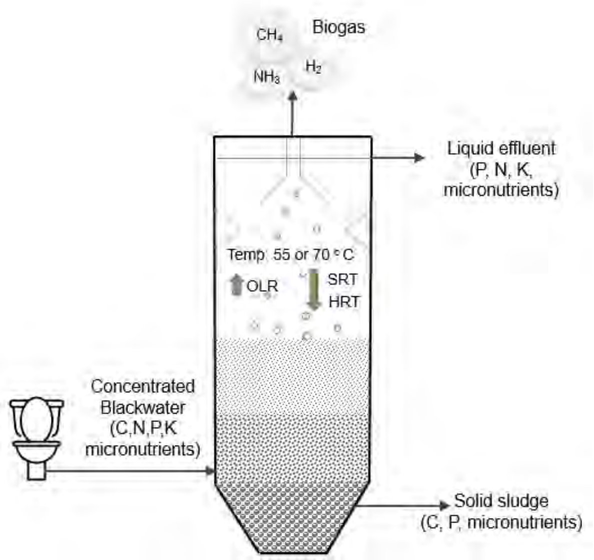
Efforts to address soil deficiencies and improve global food production have resulted in a heavy reliance on mineral fertilizers. Human feces and urine contain essential nutrients such as carbon, nitrogen, phosphorus and potassium which are crucial for plant growth. Fortunately, anaerobic treatment of concentrated source-separated blackwater under thermophilic conditions is already shows promise for effective COD removal and biogas production, along with pathogen elimination for enhanced safety of nutrients and biosolids during reuse.

Technological challenge

Thermophilic treatment of blackwater, at 55°C, is a stable process that has been previously pilot tested under the H2020 Run4Life project. Already, COD removal (~70%) and methanization conversions (~60%) comparable to those reported during mesophilic treatment have been achieved while operating at higher organic loading rates (OLRs) and shorter sludge and hydraulic retention times (SRTs and HRTs). Now, we will optimize operating conditions for (hyper)thermophilic anaerobic treatment, as enhanced hydrolysis should allow for long-term operation at even higher loading rates and shorter retention times, without compromising on effluent quality.

Hyper-thermophilic treatment of blackwater at 70°C, could result in hygienically safe products as well, but at even shorter SRTs. However, methane production was impeded by unfavorable environmental conditions, i.e., high ammonia levels and volatile fatty acid accumulation. Thus, there is need to investigate alternative products, preferably separate CNPK nutrient recovery streams as single nutrient agricultural inputs are more beneficial.

Phosphorous was largely retained in the sludge, while nitrogen and potassium was present in the effluent. Nevertheless, this study will address the fate of micronutrients in blackwater, which was not evaluated previously. Overall, even though the recovered products may not be risk-free, they need to be risk-mitigated as much as is feasible. Therefore, the removal efficiency for micropollutants in blackwater through thermophilic anaerobic treatment will be determined.



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Think Green, Burn Clean: Unleashing the power of microbes in transforming wood into sustainable bioenergy

Sep 2021 - 2025

Researcher	Supervisor	Promotor
Anran Li	Dr. ir. Wei-Shan Chen	Prof. dr. ir. Cees Buisman

Motivation

Woody biomass has been a primary source of heat and fuel for centuries. Today, energy-dedicated bioconversion of wood is considered more sustainable and efficient than conventional wood combustion, gaining increasing research interest. In nature, some microorganisms (primarily fungi) can break down woody lignocellulose into simpler compounds or CO_2, depending on the species and conditions. At around 40°C, a compost-derived thermophilic microbial consortium could efficiently decompose woody lignocellulose and produce heat that can be used for sustainable heat production (termed as biological wood oxidation, BWO). Another promising process is selective fungal delignification, where certain fungi extensively remove lignin while leaving the cellulose intact. Cellulose can then be used to produce bio-based fuels like methane, ethanol, or hydrogen.

Technological Challenge

Biological wood oxidation

The slow reaction rate is a major hurdle to the commercial viability of BWO. For improvement, we have identified and are working on four aspects:

(1) Optimization of environmental factors to enhance the reaction rate.

(2) Design of enlarged bioreactors to improve mass transfer, nutrients recycling, and product removal.

(3) Learning from operational data of large-scale (wood) compost heat recovery systems.

(4) Exploring the resource valorization potential of BWO on other (non-woody) agro-industrial waste streams.

Batch-mode BWO reactor & woody substrate colonized by fungi.

Selective fungal delignification

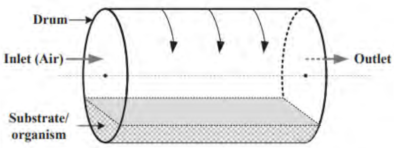
More challenging than BWO, selective fungal delignification has dual requirements for reaction rate and degradation selectivity. Major challenges associated with it include:

(1) Identification and selection of strains.

(2) Regulation of fungal growth and improvement of their degradative selectivity.

(3) Optimization of reactor set-up.

(4) Control of microbial contamination, as most of these processes are sterile.



A proof-of-concept rotary drum reactor (batch mode).

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Microbial chain elongation from bioplastics to carboxylates: polylactic acids (PLA) fermentation

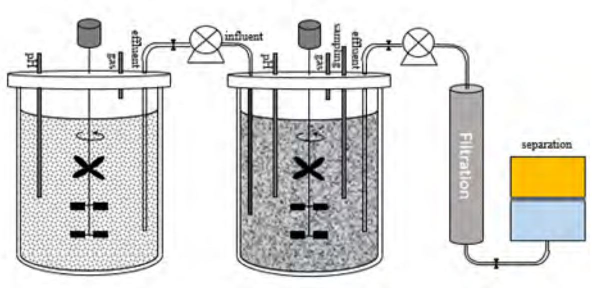
Nov 2021 - 2025

Researcher	(Co-)Supervisors
MSc, Yong Jin (John).	Dr. ir. David Strik Dr. ir. Kasper Leeuw

Motivation

Current fossil-based plastic production, poor plastic recyclability, and invalid waste management greatly threaten the environment and our health. About 50% of biobased plastics are made of biodegradable polymers like starch or polylactic acid. Biodegradable (bio)plastics end up in various waste streams and represent a potential feedstock for new biomaterials production. There is a need to develop a sustainable method to recover the emerging amounts of biodegradable bioplastic wastes.

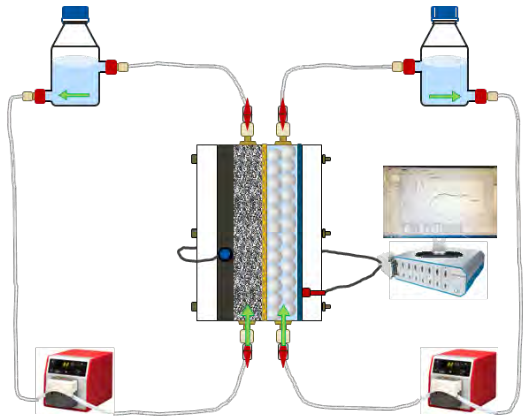
Biodegradable plastic waste is handled in various ways. We want to develop microbial chain elongation processes to produce medium-chain fatty acids (MCFAs) and prevent methane formation. These MCFAs can be used for various technical applications (like lubricants) but also serve as herbicides or feed additives.



Two-stage fermentation recovery process.

Microbial chain elongation from organic waste to valuable chemicals has been frequently explored in the last decades. The first commercial demonstration factory was launched by ChainCraft B.V. in Amsterdam. Besides the MCFAs, other valuable biochemicals, like alcohols, can be produced from organic and biodegradable plastic waste.

Hence, this project aims to identify the feasibility of MCFAs and other valuable biochemical production from biodegradable plastics (taking PLA as an example) by anaerobic fermentation under parameters promotion and system evaluation.



Recovery of carboxylates via electrodialysis.

Research challenge

The challenge is to develop a stable and cost-effective fermentation & recovery process via the next steps:

- Study the feasibility of chain elongation from PLA by comparison of single-temperature fermentation and temperature-phased conversion.
- Study the effect of pH and pretreatments on bioplastic degradation and production of fatty acids and/or alcohols.
- Study effective separation for MCFAs under comparison of different methods

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Medium chain fatty acids and alcohols production from biomass waste by granular sludge based chain elongation bioprocess

Sub-department of Environmental Technology

2020 - onwards

Researcher
Dr ir. Kasper de Leeuw

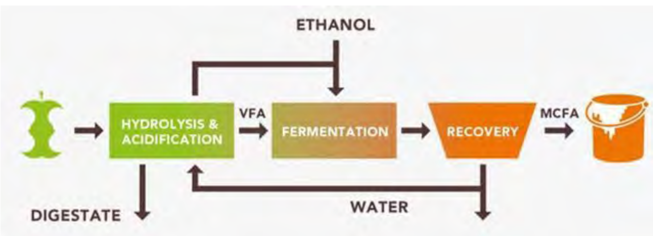
Supervisor
Dr. ir. Dr. ir. David Strik

Motivation

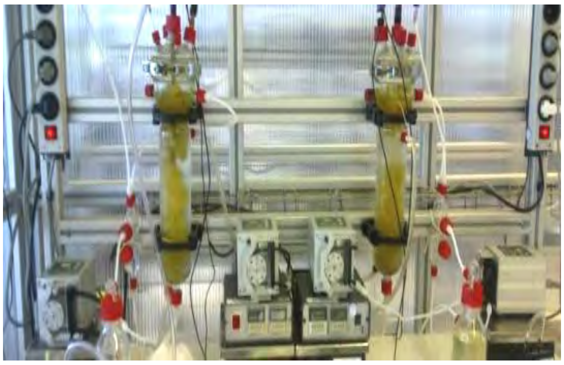
There is an increasing demand for sustainable solutions to quench our thirst for oil-derived carbon compounds. Anaerobic treatment provides the means to efficiently produce renewable chemicals from organic residues. The recent discovery of controllable microbial chain elongation processes to produce medium chain fatty acids (MCFAs) opens the possibility to develop new biorecovery technologies. MCFAs and their corresponding alcohols are platform chemicals which can be used for a wide range of products, including: flavors, fragrances, animal feed additives, emulsifiers and organic solvents.

Technological principle

Anaerobic treatment is a widespread method to produce biogas from biomass residues. With the developed chain elongation processes anaerobic digesters can be turned into biochemicals producing bioreactor. In the anaerobic microbial conversion processes the energy and carbon is largely maintained in the product, allowing for high yields and low costs during production of biochemicals. The most important factor that defines the anaerobic process is the applied selective pressure. To stimulate chain elongation ethanol or other extra electron donors are supplied.



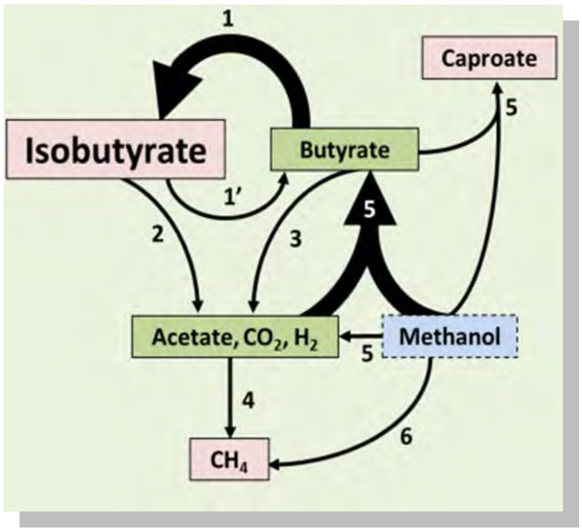
Biowaste to MCFA biorefinery



Lab-scale bioreactors

Research challenges

- Pinpoint control mechanisms of selection pressure on microbiomes which lead to effective bioreactor operation and microbial granulation
- Identify the key microbes and use their characteristics to optimize the process



Overview of potential conversion routes in mixed-culture chain elongation microbiome

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Mixed bioplastic waste fermentation into carboxylic acids to foster the circular economy

Mar 2023 - 2027

Researcher
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Supervisors
Dr.ir. David Strik
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Motivation

The phenomenon of plastic pollution is becoming increasingly prominent. Also implementation of recycling of plastic waste is a huge challenge faced by many countries. To reduce the present environmental impact of plastics there is a trend to create products based on biodegradable plastic polymers. These biodegradable plastic are often made from biomass which reduces the need of fossil resources. Conventional biodegradable plastic waste disposal methods have typical a down-cycle model, such as landfill and incineration.

In fact, recovering chemicals from biodegradable plastic is a potential to a promising way to foster the circular economy. Carboxylic acids like acetate, butyrate and caproate, represent key-chemicals which likely can be produced via fermentation of various types of bioplastics. These carboxylates or also groups as volatile fatty acids (VFAs) are emerging platform chemical and can for example be used for microorganism to accumulate polyhydroxyalkanoates (PHA) to re-make bioplastics (Fig.1). Recently organic waste fermentation processes to produce VFA were developed; a similar approach is proposed here.

Fig.1 Biodegradable plastics closed loop recycling

Technological challenge

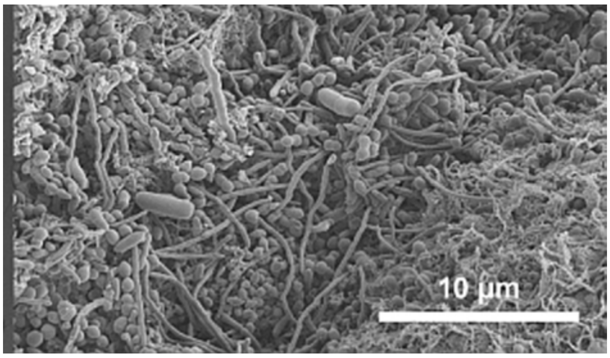

Fig. 2 Mixed microbial community producing carboxylic acids in bioreactor (Roghair et al. 2016).

The aim of study is to upgrade various biodegradable plastics wastes into VFA via a mixed culture fermentation process (Fig 2). Bioplastics can already be fermented to methane whereby the soluble monomers, including acetate and gaseous H2, are often formed as intermediate. Once one can inhibit the methanogens it is hypothesized that various volatile fatty acids will start to accumulate. Relevant hereby is to study the process of plastic depolymerization and hydrolyzation as potential rate-limiting steps of the fermentation. There are several challenges to be further investigated:

(1) Develop bioplastic fermentation processes with fast hydrolysis and methane inhibition conditions
(2) Understand the carbon fluxes during fermentation and effect of mixed plastics
(3) Elucidate the role of key-microbial players in the bioprocess to optimize the fermentation

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Plant microbial fuel cell: Mechanistic characterization

March 2018-2022

Researcher	Supervisor	Promotor
Pim de Jager	Dr. ir. David Strik	Prof. dr. ir. Cees Buisman

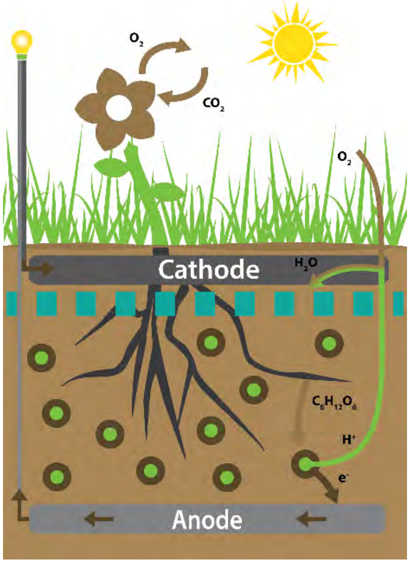
Motivation

The Plant Microbial Fuel Cell is a novel technology in which organic matter is converted into electricity using living plants and bacteria in the soil. Potential applications include desalination of saline and brackish waters, electricity production, methane reduction, and nature conservation. The technology therefore addresses different societal challenges such as the global energy transition, water scarcity, connecting remote communities and sustainable food production. The technology can be applied in all (constructed) wetlands or marine environments without harming the ecosystem or altering the aesthetics of the area. And since no external energy storage or input is necessary, the technology can be applied in remote areas without electrical infrastructure, keeping the costs low.

Plant microbial fuel cells applied in the field

Technological Principle

The plant microbial fuel cell is a fuel cell that utilizes organic matter that is available in wetland systems. This organic matter can become available in the form of exudation (directly excreted by plant-roots) or by other mechanisms such as bacterial conversion, hydrolysis or rhizodeposition in general. Some of this will react with oxygen, also released by plant roots. Micro-organisms in the anaerobic soil of marshes can convert the residual exudates from the roots of plants or dead plant material into CO2, protons and electrons. These electrons can be harvested by placing an anode in proximity of the micro-organisms which is connected through an external circuit to another electrode where a reduction reaction is taking place. By reducing oxygen and protons to water at the cathode, the electrons will flow through the circuit as a result of the potential difference.



Concept of a plant microbial fuel cell.

Research Challenge

In this research project we will aim at understanding some of the underlying mechanisms that are suspected to hinder or be of significant importance to the working of the plant microbial fuel cell. The results from this research can be brought directly into practice through different adjacent projects and companies that are involved

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Integration of direct air capture and biological processes for sustainable production of methane

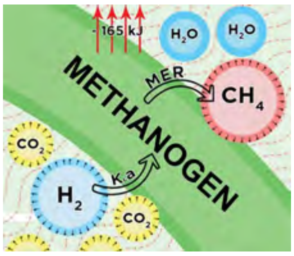
Sep 2021 - 2024

Researcher	Supervisor	Promotor
Shih-Hsuan Lin	dr. Michele Tedesco (Wetsus) dr. P (Philipp) Kuntke dr. Cristina Gagliano (Wetsus)	prof.dr.ir. HVM (Bert) Hamelers

Motivation

Carbon capture and utilization (CCU) is one of the strategies proposed for mitigating dependency on fossil resources. Direct air capture (DAC) technologies are able to capture CO2 directly from ambient air [1]. The captured CO2 can be used as commodity for multiple purposes or as a carbon feedstock for chemical production. A particularly interesting product is methane. With CO2 and H2 as feedstock, biomethanation reactors are able to produce grid-quality (>95%) methane [2].

Biological CO2 methanation take place in anaerobic, mild conditions [3], with pH range between 6.2-8.5 and temperature between 35-40°C (mesophilic) or 55-65°C (thermophilic), according to the following reaction,



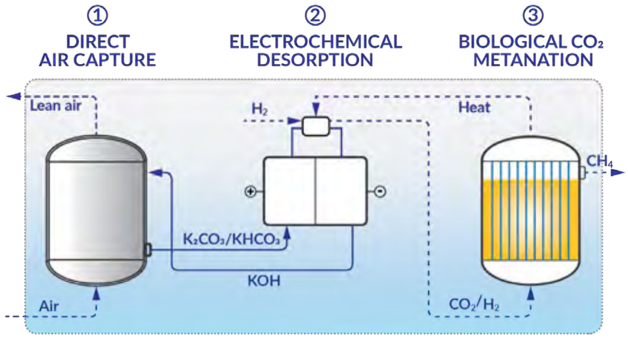
$$4H_2 + CO_2 \rightarrow CH_4 + H_2O$$
$$\Delta G^0 = -165 \text{ KJ/mol}$$

This research seeks to develop an energy-efficient process to produce renewable and biomass-free methane, by integrating a previously described electrochemically-assisted DAC [4] unit and biological CO2 methanation step.

Technological challenge

Typically the electrochemical system can be characterized as fast-responding with extreme conditions, whereas the bioreactor operates best at mild and stable conditions. To integrate the electrochemical unit with the bioreactor unit, the balance between these two systems is crucial.

Mass flows need be explicitly tuned to sustain a stable substrate/product balance for biomethanation. Heat and pH need to be managed to keep methanogens at optimal metabolic activity. Finally, to reach efficient methane production, individual mass and energy flow need to be optimized in terms of energy requirements (kJ/mol CO2), and product yield (mol CH4/m3 air).



Research goals

The research will be organized into three main objectives:

- Reach stable performance for integrated DAC with electrochemical desorption
- Optimize conditions for CO2 conversion to methane via biological CO2 methanation
- System integration and overall process optimization

[1] Sanz-Pérez, E.S., et al., Direct Capture of CO2 from Ambient Air. Chemical Reviews, 2016. 116(19): p. 11840-11876.
[2] Rusmanis, D., et al., Biological hydrogen methanation systems – an overview of design and efficiency. Bioengineered, 2019. 10(1): p. 604-634.
[3] Lecker, B., et al., Biological hydrogen methanation – A review. Bioresource Technology, 2017. 245: p. 1220-1228.
[4] Shu, Q., et al., Electrochemical Regeneration of Spent Alkaline Absorbent from Direct Air Capture. Environmental Science & Technology, 2020. 54(14): p. 8990-8998.

This research received funding from Dutch Research Council (NWO) in the framework of NWO Wetsus Partnership Programme on Sustainable Water Technology, under project number *ENWWS.2020.004.*

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In operando and non-invasive characterization of electroactive biofilms with magnetic resonance techniques

Dec 2022 - 2026

Researcher	Supervisor	Promotor
Paulien Sterken	Dr. Ir. Sanne de Smit	Dr. ir. Annemiek ter Heijne

Motivation

Electroactive biofilms and technologies which make use of them are promising in wastewater treatment and electricity generation. To non-invasively measure several parameters of the biofilm (such as its morphology), this project aims to develop an *in operando* Magnetic Resonance (MR) set-up with which to measure the biofilm, where the biofilm can be measured non-invasively while it is generation energy. This set-up can then be used to improve understanding of different parameters on e.g., biofilm growth and morphology.

Technological challenge

MR techniques have long been used in the medical field to visualize the inside of human bodies (e.g., MRI) without the need for surgery. While some studies exist which measure the biofilm, few have a set-up for measuring *in operando*, and therefore a set-up will be built during this project. The main technological challenge is creating this set-up for measurement in the MR spectrometer, as the reactor will have to be miniaturized and still be able to operate as it would in a regular set-up.

Some research goals are:

- Determining the electrode material to be used in the set-up
- Determining the effect of compound necessary for MR on the electroactive biofilm

To optimally perform this project, it is performed at both Environmental Technology and BioNanoTechnology.

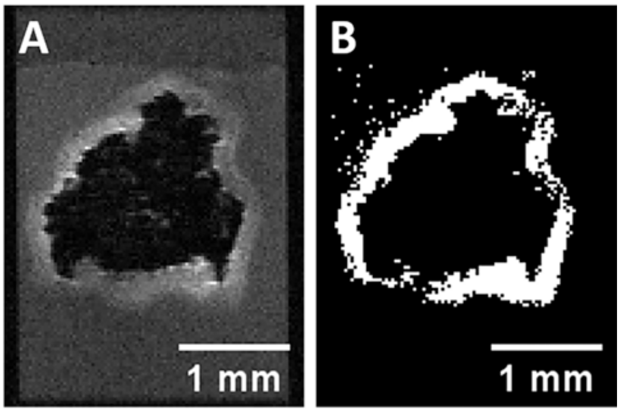


Figure 1. (Above) An example of biofilm on electrode material measured with MRI (A), and the image after threshold analysis (B). Taken from Caizán-Juanarena et al. (2019).

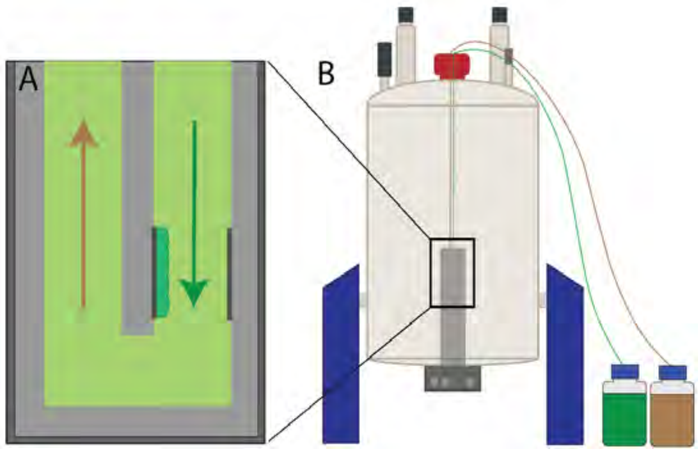
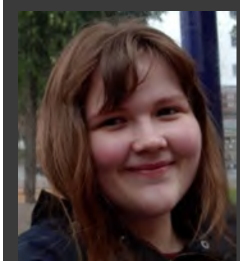


Figure 2. (Left) A schematic illustration of what the MR set-up might look like. (A) The biofilm reactor inside the MR sensor. (B) The MR scanner with the detector (gray), connected to influent (green) and effluent (brown) lines.



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Bioelectrochemical Systems for Ammonia Recovery from Wastewater

Sub-department of Environmental Technology

Sept 2017 - 2021

Researcher	Supervisors	Promotor
MSc. Steffen Georg	Dr. Philipp Kuntke Dr. ir. Annemiek ter Heijne	Prof. dr. ir. Cees Buisman

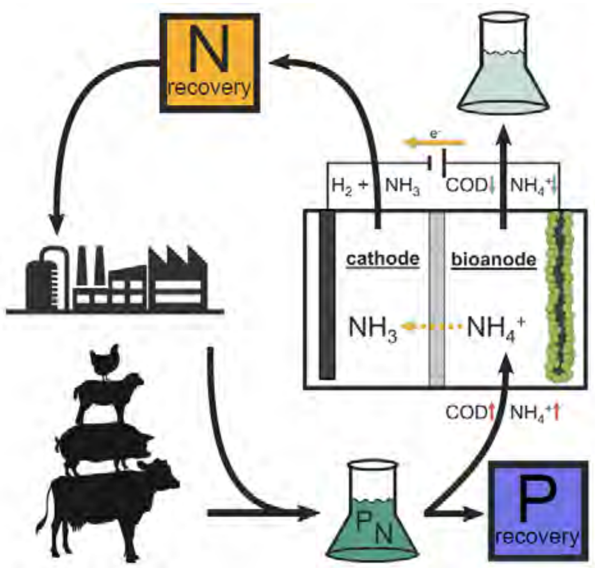

Figure 1: Nutrient removal and recovery cycle.

Motivation

- increasing fertilizer demand for NH_3
- increasing pollution water of NH_3 and organic compounds
- NH_3 and organics can be removed by bio-electrodialysis and subsequent recovery
- Bio-electrochemical Ammonium Recovery (BEAR): elegant combination of removing NH_3 and organics from wastewater and NH_3 recovery for fertilizer (Figure 1)

Technology

- Suitable wastewaters contain high concentrations of biodegradable organic compounds and Total Ammonia Nitrogen (TAN)
- Microbial Electrolysis Cell (MEC) oxidizes organics and removes TAN (Figure 2)
- TAN is recovered by TransMembrane Chemisorption as ammonium salt
- Ammonium salt can be used directly or as precursor of fertilizer

Research

- Investigate bio-degradability of concentrated wastewaters for BEAR
- Understand and improve MEC operational stability to improve process control
- Develop and test new reactor designs for more efficient and effective BEAR

Figure 2: Microbial electrolysis cell removing ammonium from wastewater.

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Optimising electrochemical phosphate recovery

Nov 2022 - 2026

Researcher	Supervisor	Promotor
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Motivation

Phosphorous (P) is a crucial and unreplaceable nutrient for human life. Nowadays, it is mainly extracted from phosphate rocks. Unfortunately, this source is a finite and non-renewable resource. Moreover, there are no substantial P reservoirs in the European Union (EU). For these reasons, the EU declared this element a critical raw material in 2014. In addition, P is also a major polluter, and its abundance in wastewater is relatively high. A solution that would solve both aspects is the circular use of phosphorus. However, newer and cheaper solutions are needed for P removal and recovery from industrial wastewater. Electrochemically induced calcium phosphate precipitation is a suitable way to achieve that. This technology is particularly appealing for wastewater where P is close to saturation and the salinity is high (i.e., cheese wastewater).

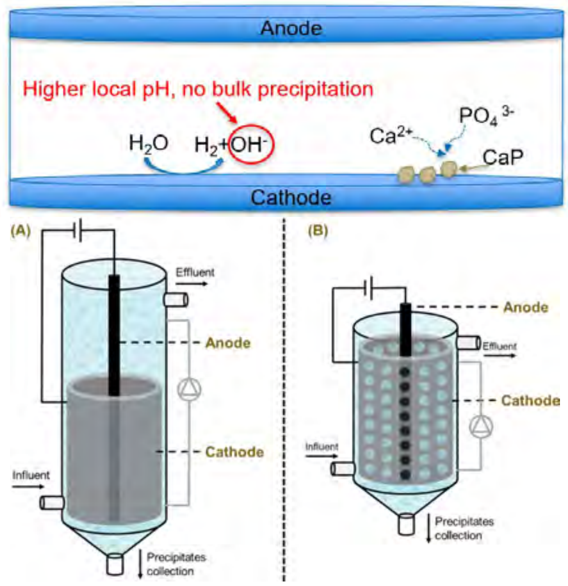
Technological challenge

This novel technology can induce calcium phosphate precipitation thanks to the higher local pH created at the cathode by the hydrogen evolution reaction without dosing any chemicals. The feasibility of electrochemical phosphate recovery has already been proven on a laboratory scale using real cheese wastewater and non-precious metal cathodes. However, the following issues need to be addressed to scale up the technology:

- Avoid chlorine evolution
- Reduce the energy consumption of the cell
- Reduce the cost of the cell
- Find a suitable way to collect the product in continuum.

To develop a pilot to treat cheese wastewater with our industrial partners and finally extend its usage to other wastewater streams, the following research questions are proposed:

- Are there ways to limit/avoid chlorine evolution and toxic product formation?
- What are the suitable electrode materials that reduce both capital and operation costs?
- What kind of cell design would allow for an effective and safe operation at the largest scale?
- Can this technology be expanded to other suitable industrial wastewater cases?



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Electrochemical nutrient recovery improvement and scaling prevention

June 2023 - 2027

Researcher	Supervisor	Promotor
Widya Iswarani	dr. Philipp Kuntke, dr. Tom Sleutels	Prof. dr. ir. Bert Hamelers

Motivation

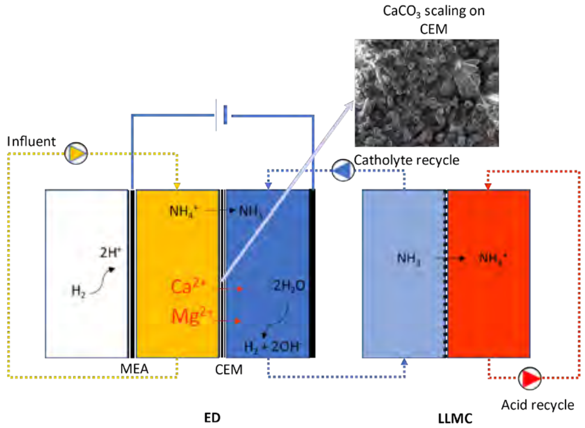
Agricultural productivity depends on the use of nitrogen (N), phosphorus (P) and potassium (K) fertilisers. However, the conventional production of these fertilisers is energy and resource-intensive and these fertilisers end up in waste streams. The production of fertiliser from (source-separated) wastewater, particularly through electrochemical systems (ES), offers significant benefits. ES can use renewable electricity and minimise the use of chemicals. Therefore, ES facilitate the recycling of nutrients to agriculture while minimising resource depletion and preventing environmental damage.

Technological challenge

The concept is proven, however inorganic scaling on the membrane still limits the application of ES on a larger scale. This project aims to mitigate unwanted inorganic scaling within the ES by investigating integrated chemical-free solutions. Improvements in cell design and operation are required to enhance circularity. Therefore, the use of fresh acids such as sulfuric acid or nitric acid in ES to separate ammonia from the concentrate stream will be limited in this project. In addition, the possibilities of ES for producing innovative sodium (Na^+) and chloride (Cl^-)-free pure fertilisers for agricultural use, such as NH_4NO_3 and K-rich streams, will be investigated.

In order to further improve electrochemical nutrient recovery to allow its integration into (source-separated) wastewater treatment, and at the same time, enhance its application in agriculture, the following research goals are proposed:

1. Apply chemical-free solutions to prevent inorganic scaling in ES.
2. Develop a model to predict scaling formation and optimise inorganic scaling prevention inside ES.
3. Reduce the chemicals (acid/base) required during ES ammonium recovery.
4. Design ES to effectively produce ammonium and potassium fertilisers (free of Na^+ and Cl^-).



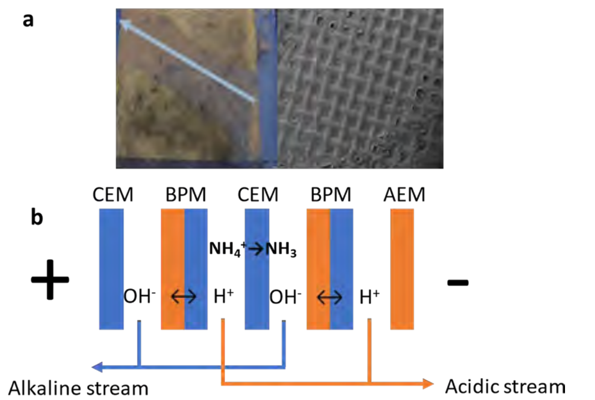


Figure 1. (left) Inorganic scaling of CEM in ES ammonia recovery. MEA: membrane electrode assembly, CEM: cation exchange membrane, ED: electrodialysis, LLMC: liquid-liquid membrane contactor. **Figure 2** (above) **a.** Inorganic scaling in CEM and spacers of ES. The arrow shows the direction of the flow. **b.** ES with possible production of acidic and alkaline streams. The possible use of these streams still needs investigation. AEM: anion exchange membrane, BPM: bipolar membrane.

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Anaerobic ammonium removal and electricity recovery with bioelectrochemical system

Oct 2020 - 2024

Researcher	Supervisor	Promotor
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Motivation

Removal of nitrogen compounds from wastewater is essential to prevent pollution of receiving water bodies. In wastewater, nitrogen is mostly present in the form of ammonium. Conventional ammonium removal technologies are biological processes, including nitrification and denitrification. They are energy-intensive due to aeration and carbon resource input. Besides the energy consumption, another downside is the production of NOx. NOx is a greenhouse gas, which emission should be minimized. For these reasons, novel and sustainable ammonium elimination processes should be developed. Bioelectrochemical systems (BESs) have gained attention as an alternative to ammonium treatment. They have been demonstrated to have efficient and energy-efficient ammonium removal performance.

Technological challenge

BESs utilize electrochemically active microorganism to catalyze the reaction in the electrode. Electrons driven by the oxidation of pollutants are transferred into the anode, resulting in pollutants removal. The electrons travel from anode to cathode offer the possibility of converting chemical energy into electrical energy.

In BESs, ammonium oxidation may occur under anaerobic conditions. In this project, we will explore how ammonium-oxidizing bacteria (AOB)/ nitrite-oxidizing bacteria (NOB) are able to directly transfer electrons to anode instead of oxygen and enable the recovery of electricity. Using bacteria to oxidize ammonium at the anode of a BES results in a reduced energy input for aeration, reduction in N2O emissions, and energy recovery from ammonium.

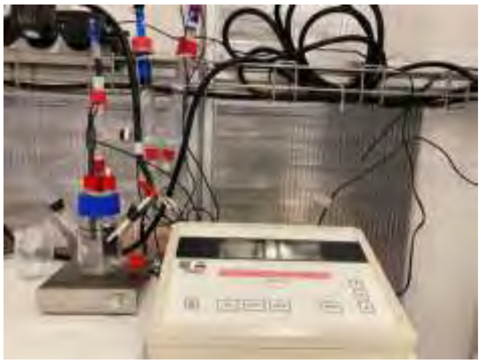

Figure 1 BESs system set-up

The technological challenge is to prove the concept of ammonium oxidation at the bio-anode and understanding the pathway of ammonium oxidation. Subsequently, we will explore the effect of operational conditions on the ammonium removal efficiency and electricity recovery. This study is expected to lay a fundamental basis for developing a more sustainable ammonium removal process using BESs.

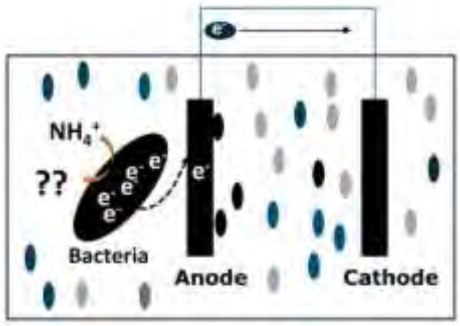

Figure 2 Concept of an anaerobic ammonium oxidation bioelectrochemical system integrating with electricity recovery.

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Electron shuttling and sulfide storage in sulfide oxidising bacteria

Sub-department of Environmental Technology

May 2020 - 2025

Researcher	Promotor	Co-Promotor
Rikke Linssen	Dr. ir. Annemiek ter Heijne	Prof. dr. ir. Cees Buisman Dr. ir. Jan Klok

Motivation

Hydrogen sulfide gas is a waste product often produced by mining, paper production and petroleum industries. The release of sulfur gas into the atmosphere causes the formation of sour rain, which has detrimental effects on the environment. The removal of H2S from waste streams can be done via biological desulfurisation such as employed in the Thiopaq process. This process uses haloalkaline (high salt – high pH) sulfur oxidising bacteria (SOB), which can convert dissolved hydrogen sulfide into elemental sulfur under microaerobic conditions. Gaining an in depth understanding of the mechanisms behind this process can help optimising the process by lowering caustic consumption and energy use, and thus help making the process more environmental friendly.

Technical Challenges

The addition of an anaerobic sulfide uptake chamber between absorber and reactor already decreases side product formation. However, the mechanism behind anaerobic sulfide removal by

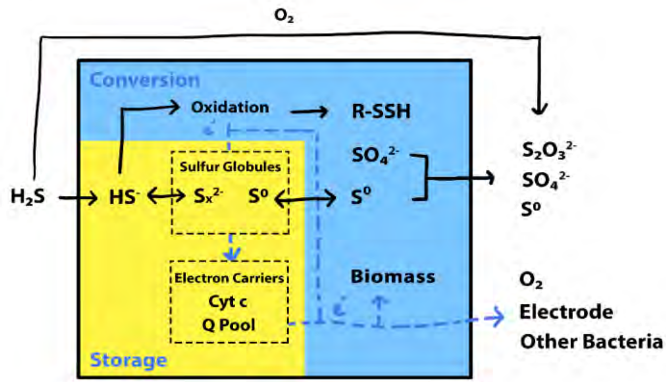
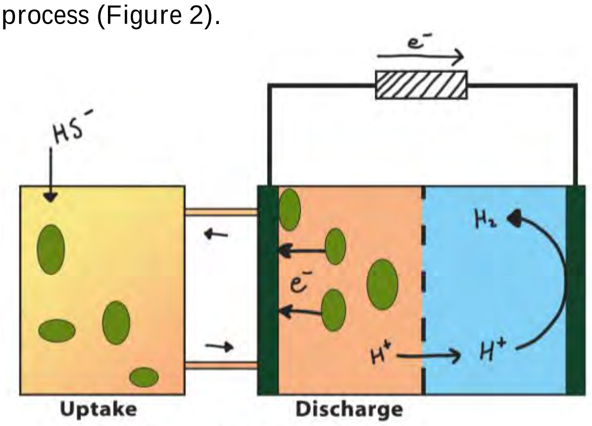


Figure 1 A simplified overview of the postulated mechanics of sulfide conversion and storage yellow field), and electron transfer (blue striped lines).

SOB is still unknown. It is hypothesized that two mechanisms are the main contributors: oxidation under anaerobic conditions and storage in the form of polysulfides in sulfur globules (Figure 1).

Additionally, it was found that SOB can use electrodes as electron acceptor instead of oxygen, which suggests the biological process can be performed fully anaerobically. This could reduce side product formation as sulfates and thiosulfates are produced via biological and chemical oxidation, and this opens the possibility of integrating hydrogen production into the desulfurisation process (Figure 2).



$HS^- \rightarrow S0 + H^+ + 2e^-$

Figure 2 A simplified sketch of a sulfide removal SOB fuel cell.

In this project, a measuring method will be developed to study the sulfide uptake and storage and cell discharge. After identifying the storage mechanisms and quantifying uptake and storage, a bioelectrochemical system will be modelled, build, and optimised, with the aim of recovering electrical energy from sulphide oxidation.

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Novel nickel-based electrodes for hydrogen production

Feb 2019 - 2023

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Motivation

Hydrogen is considered the most promising fuel for its high energy density, abundance, and no emissions during combustion. Today, however, it is almost entirely produced via steam methane reforming, a process which uses natural gas to produce syngas – H_2 mixed with CO_2. To avoid the use of natural gas, a non-renewable hydrocarbon, and the production of a greenhouse gas CO2, hydrogen can instead be sustainably produced by water electrolysis using renewable electricity.

Technological challenge

The performance of electrolysis depends heavily on the electrodes, which need to be highly catalytic to facilitate the gas' formation. Platinum group metals have outstanding catalytic performance but are expensive. Therefore, new cost-effective alternatives are necessary. Since the development of electrolysers, nickel-based materials have remained state of the art non-noble hydrogen evolution reaction (HER) catalysts for alkaline water electrolysis. While nickel is the most active non-noble metal, it does not outperform platinum group metals. Thus, much effort must be put into optimizing nickel-based catalysts' chemical structure and morphology.

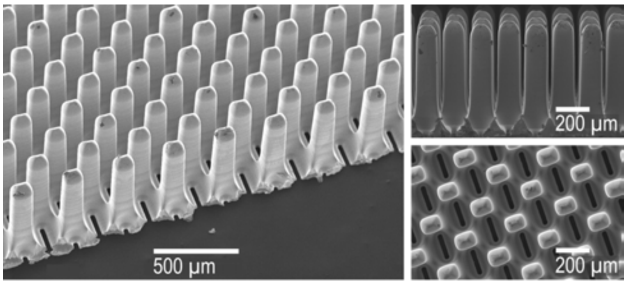


Fig 1. SEM images of the electrodes as provided by the manufacturer (Veco Precision BV).

Research goals

This project investigates pillared nickel electrodes and optimizes their design for H_2 production via alkaline water electrolysis.

Focus is put on three research objectives:

1. Testing the electrodes against state of the art alkaline HER catalyst (Raney nickel) and optimizing the electrode design (pillar spacing and length, electrode porosity) for improved performance.
2. Improving the electrodes' catalytic activity with noble and non-noble dopants.
3. Identifying and demonstrating novel applications for such electrodes.

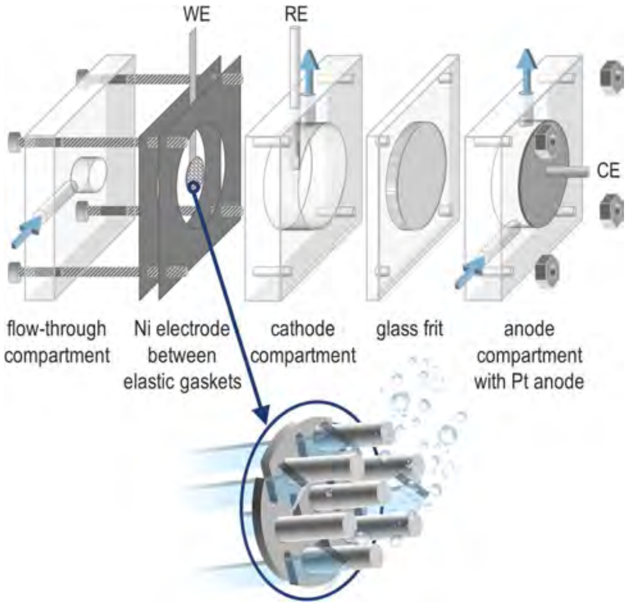
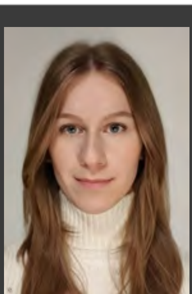


Fig 2. Experimental cell with a flow-through configuration for improved bubble detachment.



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Novel electrochemically assisted processes for electricity-driven CO_2 capture

Sept. 2021 - 2025

Researcher
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Supervisor
Dr. ir. Annemiek ter Heijne
Dr. Philipp Kuntke

Promotor
Dr. ir. Bert Hamelers

Biorecovery
Environmental Technology

Motivation

Capturing CO_2 from industrial emissions to prevent further increase in atmospheric CO_2 concentration is essential to mitigate climate change and shift towards a climate neutral industry by 2050. Conventionally, CO_2 is absorbed in amine solvents which then are thermally regenerated. However, high energy cost and solvent degradation associated to thermal regeneration raised the interest in developing alternative processes. Here, electrochemical systems offer the clear advantage to conveniently use green (renewable) electricity as energy input for a pH-swing based regeneration. The scope of the study is to demonstrate a novel CO_2 capture process based on pH-swing regeneration (Fig.1) in an electrochemical system (Fig. 2)."

Technological challenge

Previous studies on electrochemical CO_2 capture and regeneration system proves the feasibility of the idea of establishing an acidic trap for the depletion of CO_2 in the basic solvent [1-2].
However, both energy and CO_2 removal efficiency are still below the benchmark of the state-of-the-art CO_2 capture via amine scrubbing [3]. Additionally, a full understanding of such a process from a thermodynamic perspective is still lacking in literature, and it would be fundamental to guide the design and further scale-up of the electrochemical technology. The technological challenge remains to understand and reduce the electrical overpotentials while maintaining a high current density and energy efficiency.
This novel process will be also investigated on pilot-scale, and addressing potential challenges in the scale-up process will be crucial to provide input for follow-up studies towards full-scale implementation.

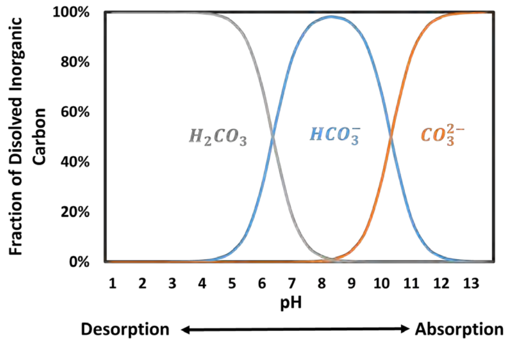

Fig. 1. Fraction of chemical species as function of the solution pH for the H_2O-CO_2 system at 25 °C.

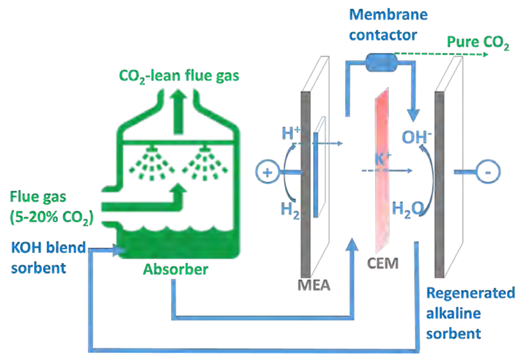

Fig. 2. Schematic illustration of the CO_2 capture process based on absorption in alkaline (KOH) blend and electrochemical regeneration.

References

[1] Legrand et al., Environmental Science & Technology (2018), 52(16), 9478-9485
[2] Shu et al., Environmental Science & Technology (2020), 54(14), 8990-8998
[3] Bui et al., Energy Environ. Sci. (2018), 11 (5), 1062–1176

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WAGENINGEN UNIVERSITY & RESEARCH

Electrochemical Technologies for Resource Recovery

Nov 2022 - 2025

Researcher
Dr. Sanne de Smit

Collaborators
Dr. Annemiek ter Heijne

Motivation

With technological developments comes an increasing amount of waste streams which need to be treated before they can be safely disposed into the environment. Waste streams can range from gases that are toxic (H_2S) or attributing to global warming (CO_2) to dissolved compounds (NH_4^+) that cause eutrophication. To treat these waste streams, various technologies can be used. One of these techniques is electrochemistry, where electrical energy is used to increase reaction speed of reactions or stored as chemical energy. In electrochemistry, a catalyst can be integrated, such as a metal-based catalyst or a microbial catalyst, which can make the reaction occur even faster. The application of electrochemical techniques for the treatment of waste streams and recovery shows promise to work towards a more circular use of nutrients and materials.

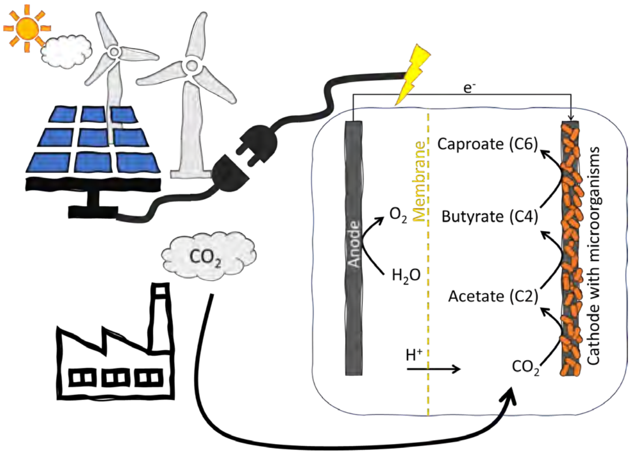

Figure 1. *Overview of bio-electrochemical system used for gaseous CO_2 recovery as volatile fatty acids, which can be used as precursor for food and chemical compounds.*

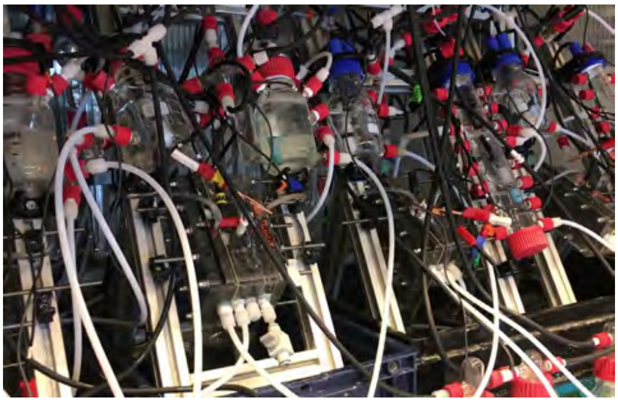

Figure 2. *Actual set-up of electrochemical systems as used in the laboratory.*

Technological challenge

Although promising, electrochemical technologies also offer several technological challenges that can be tackled. The conditions within the electrochemical cells are often unknown despite their important role in the process. Also in the field of catalysis, a great progress is yet to be made to find cheap and effective catalysts. More concrete, research aims that will be investigated are:

- Investigating local conditions inside (bio)electrochemical systems and understanding how these relate to performance
- Optimization of (bio)catalyst performance in (bio)electrochemical systems
- Investigation of biofilm structure properties and improvement thereof

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Biological Removal of Manganese as Pre-Treatment to Limit (Bio)Fouling in Oligotrophic Conditions

Sep 2023 - 2027

Researcher	Supervisor	Promotor
Elisavet Malea	Dr. M. Cristina Gagliano Dr. Ir. Annemerel Mol Dr. Amanda Larasati	Dr. Ir. Annemiek ter Heijne

Motivation

Manganese (Mn) is a common trace metal and a vital micro-nutrient for many organisms. Soluble Mn (Mn^{2+}) is naturally present in various water sources. When exposed to oxidizing agents (biotic or abiotic), Mn is oxidized to its insoluble forms (Mn^{3+} and Mn^{4+}), forming Mn oxides (MnOx). The accumulation of insoluble MnOx during water treatment can result in irreversible membrane fouling, recognizable by the black coloration of the fouling layers. Mn-oxidizing bacteria (MnOB) can remove Mn^{2+} efficiently and selectively under oligotrophic conditions (low carbon availability) by converting it into MnOx. Recent Wetsus research on a full-scale biological activated carbon (BAC) demonstrated that when MnOB grow as a biofilm on BAC granules, they continuously remove Mn^{2+} in oligotrophic conditions. This resulted in the likely protection of the reverse osmosis (RO) units placed after BAC from significant and irreversible biofouling. Therefore, this project aims to assess the effectiveness of using highly selective Mn biological removal as a common practice in various engineered systems to prevent irreversible fouling under oligotrophic conditions.

Technological challenge

Implementing selective Mn biological removal as a pre-treatment before fouling-prone engineered systems (e.g., RO) presents challenges that call for a nuanced understanding of biological functions and system parameters. Optimizing Mn oxidation for efficient removal, considering the diverse water and treatment system characteristics, is crucial in preventing irreversible fouling in oligotrophic conditions. This must ensure cost-effective, long-term operability.

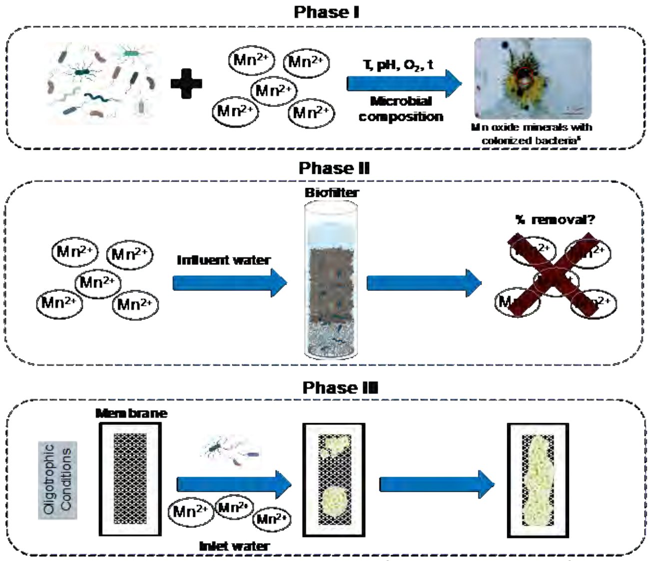
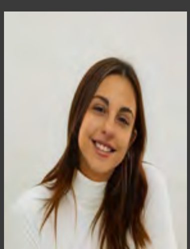


Fig. 1: Schematic representation of the three phases of the project.

The project consists of three phases (Fig. 1): (I) exploring the dynamics/kinetics of biogenic Mn oxidation by mixed microbial consortia, (II) studying Mn removal in diverse lab-scale biofilters, and (III) understanding the fouling dynamics related to Mn in oligotrophic conditions.

The goals are:

- Determine the kinetics of biological Mn removal in various biofilters (in carbon-limited conditions), connecting with operational parameter influence (e.g., oxygen availability or pH).
- Design the proper biofilter for efficient water pre-treatment.
- Understanding Mn-induced fouling in several engineered systems (RO etc.) using models.



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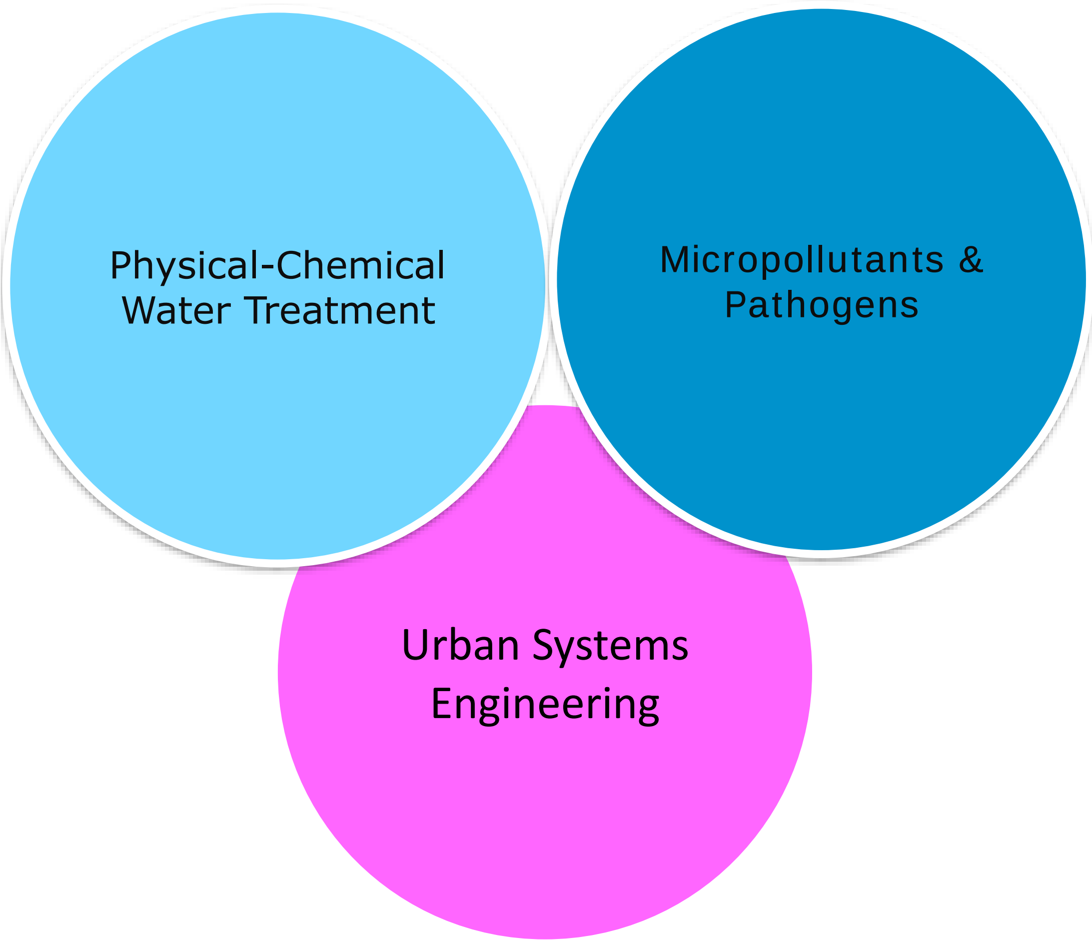
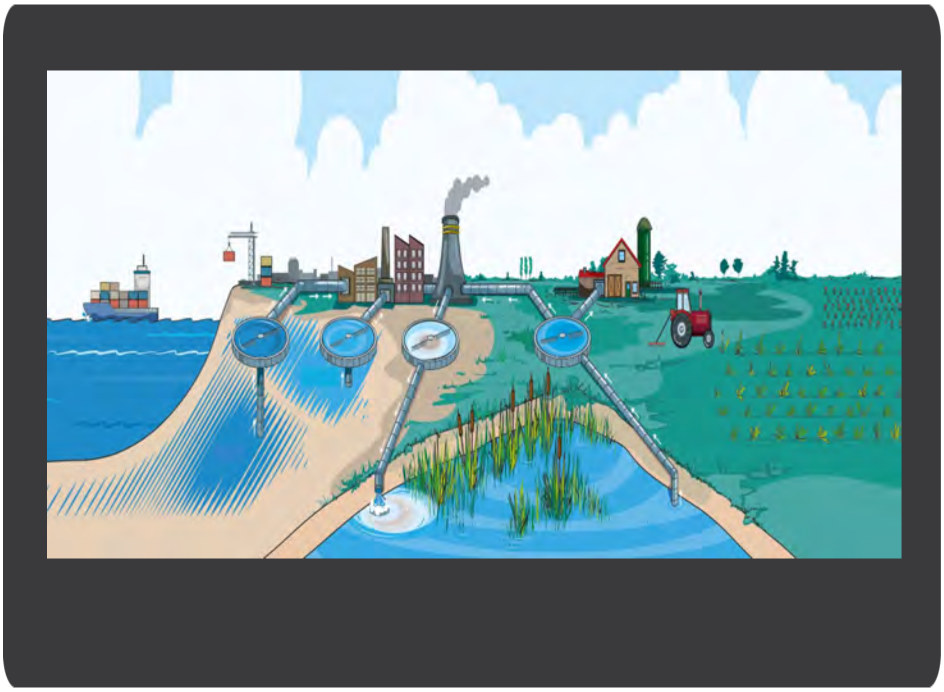
Environmental Technology

Reusable Water



Reusable Water



Water scarcity is just as much a water quality challenge as a water quantity problem. Often, sufficient water may be available, but of the wrong quality. Water reclamation is impeded by the presence of organic contaminants, like micropollutants, or excess salts. Sustainable technologies are required to remove these contaminants to allow for reuse of water.

The Reusable Water group aims at developing technologies to produce water of sufficient quality that it fits the demands for reuse. We research and develop technologies that remove contaminants from a variety of water types, including industrial wastewater, drinking water, domestic wastewater, and groundwater. Our technologies are implemented to close water cycles within and between urban, industrial, and agricultural uses. Our new treatment technologies are piloted together with end-users. And we conceptualize new water reuse cycles together with the USE group.

Micropollutants and pathogens

Organic micropollutants and pathogens are major hurdles to closing water cycles. Reclaimed and repurposed water can contain recalcitrant organic micropollutants, including pharmaceuticals, hormones, pesticides, POPs, chemicals in consumer products, and industrial chemicals, and pathogens, including antibiotic resistance genes (ARGs). These contaminants must be removed from water in order to protect human and environmental health.

Our research focuses on developing effective and sustainable technologies to remove micropollutants and pathogens from water and soil. We focus on biological technologies, relying on natural microorganisms to degrade micropollutants. Biological technologies are, when needed, integrated with physical-chemical technologies such as sorption and advanced oxidation. Our technologies treat many types of water, including wastewater treatment plant effluent, surface water, groundwater, and industrial water. The technologies are thus designed and tailored to be used in different applications, allowing us to produce water of sufficient quality for applications such as irrigation, industrial process water, (secondary) household water, and source for drinking water production.

Physical-chemical water treatment

Saline water provides an immense source for fresh process water and drinking water. Innovative electrochemical and membrane-based techniques including capacitive deionization, nanofiltration and electrodialysis are studied for fresh water production and for selective removal and recovery of ionic species from wastewater and natural water. Polymers and mineral colloidal particles hamper industrial (salt)water treatment and reuse, e.g. of produced water in the oil/gas industry, process water in the food and beverage industry, or in the production of drinking water from surface water. Removal and recovery of organics from wastewater, including methane or bio-flocculants, are studied in bioreactors, which are optimized for fluid and process dynamics, together with the Biorecovery group.

Enhancing biological stability of drinking water by membrane treatment

Apr 2016 - 2020

Researcher	Supervisor	Promotor
Rinnert Schurer	Prof. dr. ir. Albert van der Wal	Prof. dr. ir. Albert van der Wal

Motivation

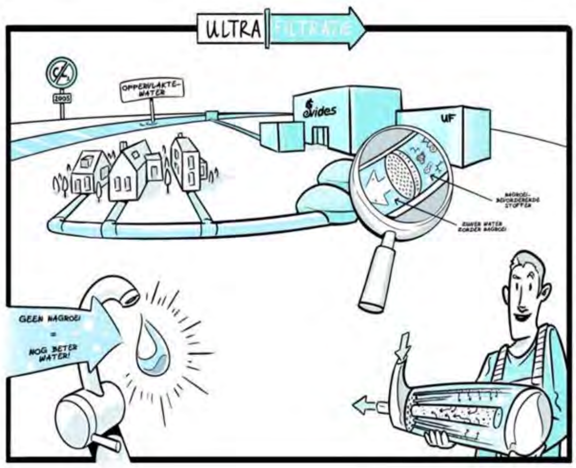
Distribution of potable water without any residual disinfectant eliminates DBP (disinfectant-byproduct formation) and maximizes consumer satisfaction in terms of taste and odor. However, biological stability, i.e. unobjectionable levels of microbial and invertebrate organisms, is to be maintained in the distribution network. Hereto, the drinking water treatment is to achieve production of potable water characterized by a low microbial growth potential (MGP), i.e., low in nutrients (e.g. organic compounds of natural origin) and other growth-promotors (e.g. biomass, particulate matter). Ultrafiltration and capillary nanofiltration membrane treatment have potential in addressing this challenge in surface water treatment. This constitutes a novel application of these existing technologies.

Technological challenge

Ultrafiltration rejects by size-exclusion particulate matter, microbial biomass and, depending on the selected molecular-weight cut-off (MWCO), biopolymeric organic carbon. Therefore, ultrafiltration as posttreatment to existing conventional surface water treatment plants potentially reduces associated MGP. Tighter capillary nanofiltration is to achieve a further reduction in lower Mw organic compounds. However, their impact on biological stability has not been studied extensively yet. Furthermore, although several analytical methods are available to determine waterborne MGP (e.g. Assimilable Organic Carbon, Biomass Production Potential), further extension is desired, whereas it is not yet established with certainty which compounds contribute to MGP.

The behavior of several membrane systems is studied on laboratory, pilot and practice scale. The first results indicate that ultrafiltration posttreatment is capable of significantly enhancing biological stability, and matter of relatively large dimensions is a major factor in MGP. Operational settings and membrane fouling conditions were found to have only marginal impact.

The technological challenge is to (continue to) establish the impact of membrane treatment processes of several MWCO on biological stability, derive in more detail which components govern MGP, and compare and improve analytical methods to quantify MGP predictively in grab samples as well as in practice conditions.



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Towards Mechanistic Understanding of the Interactions Between Per- and Polyfluoroalkyl Substances and Adsorption Materials in Drinking Water Treatment

Reusable Water
Environmental Technology

Aug 2021 - 2025

Researcher	Supervisor	Promotor
Marko Pranić	Dr. ir. Jouke Dykstra	Prof. dr. ir. Albert van der Wal

Motivation

Per- and polyfluoroalkyl substances (PFAS) are a family of anthropogenic micropollutants. They have been found in many water bodies, including drinking water sources. This is a problem since even at low concentrations, PFAS pose a risk to human health. Because of that, technologies for their removal during drinking water treatment are developed, and the current benchmark technology is adsorption. However, many physical and chemical interactions between PFAS and the adsorption materials are mechanistically not understood, and a better understanding can contribute to the development of the technology and a reduction of operational costs.

Methodology

In this project a combination of theoretical and experimental methods will be used. Theoretical models will describe the effect of the properties of PFAS and adsorption material on the adsorption. These models will describe conditions of relevance for drinking water treatment, i.e., the impact of the drinking water matrix on the PFAS adsorption. The theoretical models will be validated with batch and column experiments. As a result of the applied methodology, the design requirements for the adsorbents, and for the process conditions will be set. This knowledge will contribute to a more secure drinking water supply, free of PFAS.

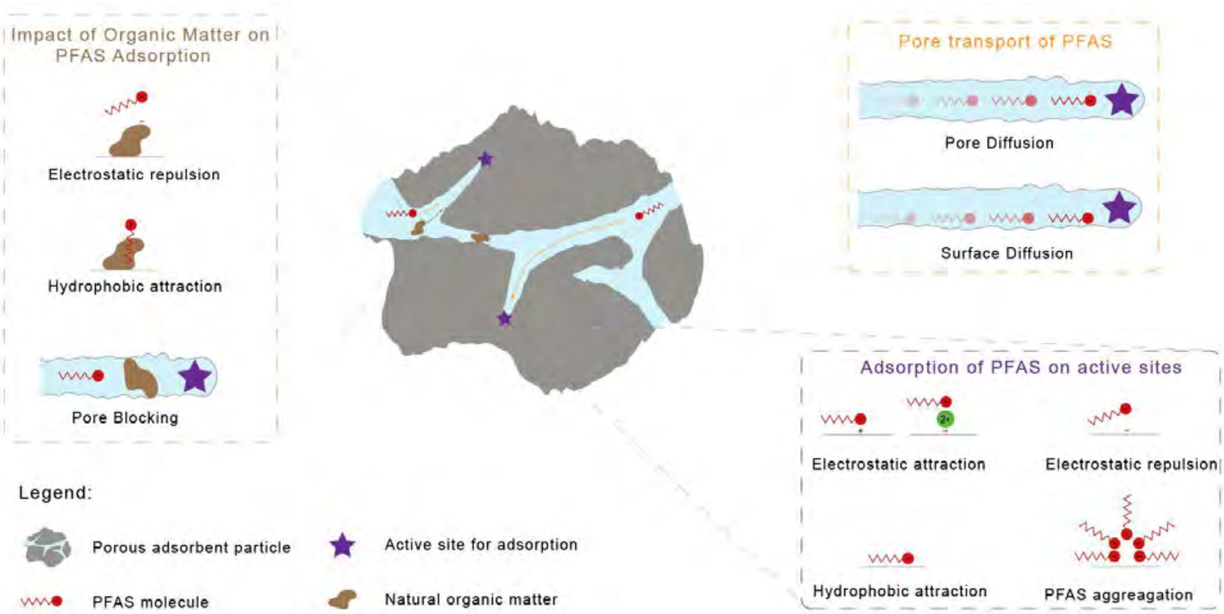

Figure 1. Mechanistic interactions between PFAS and adsorption material that will be studied

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WAGENINGEN UNIVERSITY & RESEARCH

Removal of toxic amphoteric solutes in drinking water treatment by electrochemical polishing

Oct 2022 - 2026

Researcher	Supervisor	Promotor
Kaiyue Li	Dr. ir. JE (Jouke) Dykstra Dr. ir. Slawomir Porada	Prof. dr. ir. HHM (Huub) Rijnaarts Dr. ir. JE (Jouke) Dykstra

Motivation

Several weak acids, of which the valency is dependent on solution pH, such as boron, arsenic, and some micropollutants, can be toxic even at low concentrations. The presence of these solutes challenges traditional membrane-based water treatment technologies since these small solutes are, at environmentally relevant pH conditions, present in uncharged form.

In this project, a chemical-free polishing technology will be developed, which can be applied after conventional treatment steps, and consequently it remove these amphoteric species. Besides, a model will be proposed to explain the mechanisms behind the removal process with a logically consistent theory.

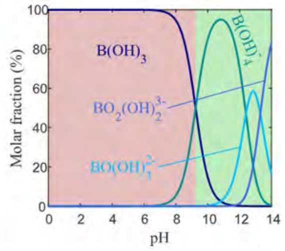

Figure 1 Speciation of boron as function of pH.

Technological challenge

Weak acids have a valency that is pH-dependent (see Fig. 1), which creates issues for conventional membrane-based separation technologies. Membrane separationis based on two mechanisms: charge repulsion, which leverages electrostatic force to repel particles carrying an opposite charge to the membrane, and size exclusion, which utilizes the membrane's micropores to filter particles.

For example, boron remains uncharged as $B(OH)_3$ in surface water with a pH between 7 and 8 (see Fig. 2A), making it difficult for the membrane to block the transport based on charge repulsion. Besides, not carrying an electric charge implies a small hydration shell of the molecules, leading to poor size exclusion and low removal rates in membrane processes (see Fig. 2).

Research goals

We will study the effect of the interplay between pH dynamics, ion electrosorption, and transport phenomena in general and develop a theoretical model to explain the fundamental mechanisms for competitive electrosorption between the target components and salt ions in particular.

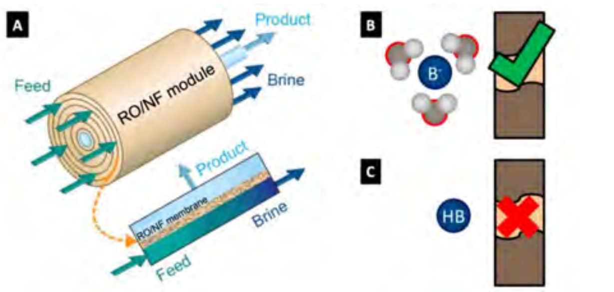

Figure 2. A) Reverse-osmosis and nanofiltration are pressure-driven separation technologies. B) Charged ions, in this case boron (B^-), are successfully rejected by the membrane, while C) uncharged solutes can pass.

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Efficiency and mechanism of intermittent reductive/oxidative defluorination of PFAS

Nov 2022 - 2026

Researcher	Supervisor	Promotor
Shuhao Liu	Dr. ir. Harry Bruning Dr. ir. C.H.M. Hofman	Prof. dr. ir. Huub Rijnaarts

Motivation

Nowadays per- and polyfluoroalkylated substances (PFAS) have caused broad attention due to their widely existence in the environment, persistence, bioaccumulation, and potential health risks. However, PFAS are highly resistant to conventional wastewater treatment due to their exceedingly stable C–F bonds.

As shown in Fig. 1, through traditional reductive or oxidative destructive techniques, PFAS can be degraded but not be completely defluorinated, which will cause the formation of fluorine-containing by-products with even greater toxicity. The produced fluorotelomers (C_nF_{2n+1}–$(CH_2)_m$–X) show high recalcitrance against further degradation during reductive defluorination processes, while hydroxyl radical (HO•) produced during oxidative processes can convert fluorotelomers into perfluorocarboxylates (PFCAs).

Based on these information, this PhD project aims to realize intermittent reductive and oxidative conditions through the combination of electrochemical, chemical and UV/VUV processes to develop new combinations of treatment technologies and find some strategies for the deep degradation and defluorination of PFAS.

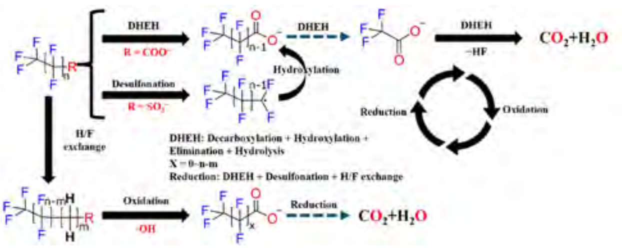


Figure 1 The degradation and defluorination of PFAS

Technological challenge

Complete defluorination is very difficult to realize just by single means of oxidation or reduction. To achieve the deep degradation and defluorination of PFAS, we propose two possible combinations of treatment technologies to realize intermittent reductive and oxidative conditions for the gradual defluorination of PFAS.

In the first scheme, we propose a circle of the UV/VUV/sulfite reductive process and the UV/VUV/H_2O_2 oxidative process, artificially controlling the structures of intermediate products and realize the further defluorination of PFAS degradation intermediates. The main challenge here is to control the mutual transformation of reduction and oxidation environment. Besides, to ensure the accuracy of the results, it is necessary to account for losses of PFAS by adsorption to reactor materials.

In the other scheme (Fig. 2), based on an electrochemical system, intermittent reductive/oxidative defluorination of PFAS is achieved by the circulation through the cathode and the anode compartments. According to literatures, the adsorption of PFAS by the electrode, especially the anode is not negligible. The main challenge here is to quantify the adsorption and desorption of PFAS during the circulation and to find some strategies to decrease the influence.

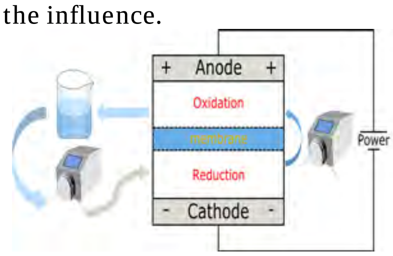
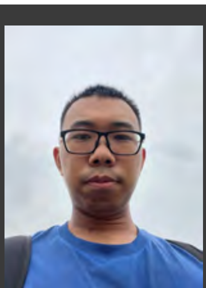


Figure 2 The process of the electrochemical system



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Towards a physical chemical understanding of membrane-based micropollutants removal from contaminated surface water

Sep 2020 - 2024

Researcher
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Dr. ir. Jouke Dykstra
Dr. ir. Evan Spruijt

Promotor
Prof. dr. ir. Bert van der Wal

Environmental Technology

Motivation

Recently, the number and occurrence of potentially hazardous micropollutants (MPs) in surface water has raised as a result of increased economic activity and the usage of pharmaceuticals and other substances in society. The presence of these organic anthropogenic compounds represents a risk for human health; therefore, achieving efficient removal of MPs from surface water is crucial for the production of safe drinking water.

The aim of this project is to develop a comprehensive physical-chemical model for micropollutant (MP) removal using nanofiltration (NF) and reverse osmosis (RO) systems. The model will provide a better process understanding and aims to contribute to the design of water treatment processes.

Technological challenge

Membrane-based technology for MP removal has already been implemented in the production of drinking water. However, the retention of these compounds and transport through membranes is only poorly understood.

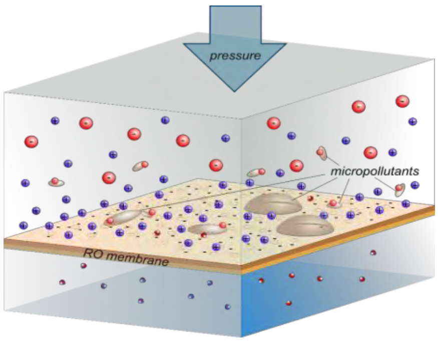

Fig 1 Schematic illustration of the processes at the high-pressure side of a membrane that retains micropollutants from surface water

For instance, because of the general hydrophobic nature of micropollutants, they may condense into nano-droplets on the membrane surface (Fig 1) and affect the transport and overall process. In this project, this phenomenon is explicitly considered together with intramolecular and particle-surface interactions.

Besides, this research will study and address the role of ions and charge regulation in MP retention using NF/RO. This integrated approach will provide valuable insights for MP removal using membrane processes. A general description of the methodology proposed is given in Fig 2.

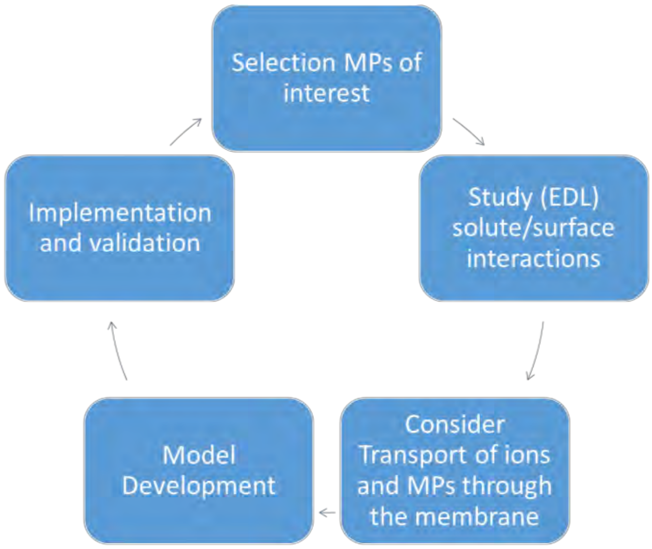

Fig 2 Methodological approached, (EDL) electrical double layer

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Fouling prevention through biological activated carbon and ultrafiltration

Oct 2019 - 2023

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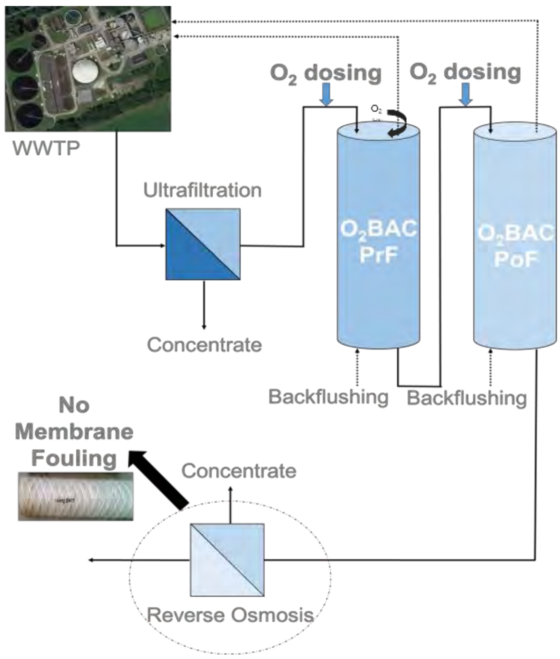
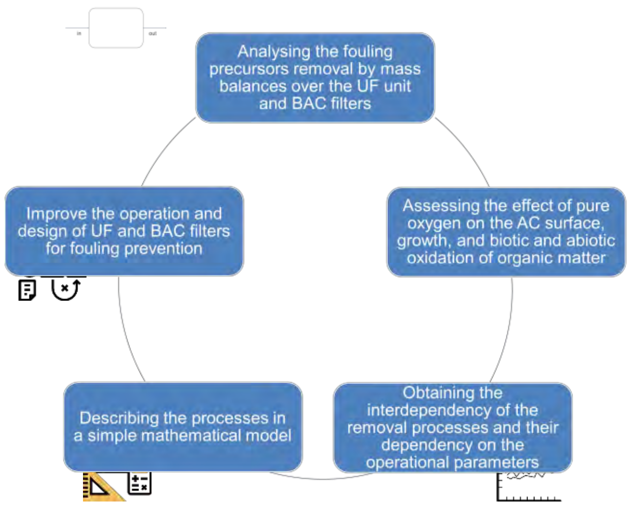
(Co-)Promotor
Dr. R. Kleerebezem
Prof. dr. ir. H.H.M. Rijnaarts

Motivation

Biological Activated Carbon (BAC) is a water purification process that combines physical adsorption onto granular activated carbon (AC) and pollutants/organics biodegradation through biofilms. The technology is eco-friendly and cost-effective, since the biodegradation helps to prevent the saturation and replacement of the AC. BAC is an established process in drinking water treatment[1], and also has potential for wastewater reclamation [2,3]. At the Puurwaterfabriek (Emmen, the Netherlands), ultrafiltration (UF), BAC Pre-filter (O2BAC PrF) and BAC Polishing Filter (O2BAC PoF), and ReverseOsmosis (RO) are applied in sequence to produce ultrapure water by treating the effluent of a wastewater treatment plant [5]. The important innovation of this plant, now in operation for over 10 years, is is the absence of fouling of the RO membranes , although in literature BAC treatment is often associated with downstream fouling [4]. This research aims to understand how UF and BAC canprevent downstream fouling of RO units.

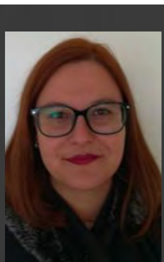




Technological challenge

The BAC filters at the Puurwaterfabriek are unique as they are constantly oxygenated and periodically back-flushed. The challenge is to investigate possible synergy between the biotic and abiotic processes contributing to the removal of fouling precursors, and to establish how these processes depend on the BAC operation and design.

[1] Korotta-Gamage, S. M., and Sathasivan, A., *Chemosphere*. 167 (2017) 120-138
[2] Riley, S. M. *et al. Sci. Total Environ*. 640-641 (2018) 419-428.
[3] Tammaro, M., *et al. J. Environ. Chem. Eng.* 2(3) (2014) 1445-1455.
[4] Im, D., *et al. Chemosphere.* 220 (2019) 20-27.
[5] NWTR, 2016.



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Biorecovery and Applications of Biopolymers from Wastewater

Reusable Water
Environmental Technology

November 2021-2025

Researcher	Supervisor	Promotor
Berke KISAOĞLAN	Assist. Prof. Dainis Sudmalis Dr. Cristina Gagliano	Prof. Dr. ir. Huub Rijnaarts

Motivation

Synthetic flocculants are often applied in coagulation/flocculation process to trigger agglomeration of destabilized particles. A major concern associated with synthetic flocculants is their environmental impact. Promising natural alternatives are extracellular polymeric substances (EPS), due to their ability to bind cations and organics. EPS-derived bioflocculants can be produced whilst treating wastewater by open mixed microbial cultures, thereby offering an environmentally friendly and cost-effective way for synthesis.

Technological challenge

EPS are secreted by microorganisms in their natural environment for several purposes such as adhering to the surfaces, storing nutrients, and retaining water. They contain polysaccharides and proteins as main components. EPS production can be stimulated by environmental stress (**Fig 1**). It can be achieved with single or mixed carbon sources, pure or mixed microbial cultures and under sterile or non-sterile conditions. Depending on the purity, EPS can be applied in several fields such as food, health, and water treatment.

In this research, EPS production will be achieved by utilizing wastewater as a nutrient source. Mixed microbial communities will be employed for EPS production under non-sterile conditions (**Fig 2**). This is accompanied by several challenges including:

- Long-term operation of EPS producing membrane bioreactors
- Extraction and characterization of produced EPS
- Application of EPS as natural flocculant and understanding the flocculation mechanism of EPS
- Investigating the changes in the microbial community during the EPS production process

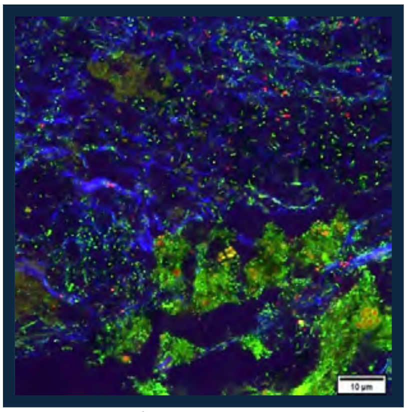

Figure 1*. CLSM image of mixed liquor sample taken from EPS-producing bioreactor run under nitrogen limitation. The sample was stained with fluorescent dyes to show individual components of EPS; Sypro Orange (green, proteins), Calcofluor white (blue, polysaccharides), Syto 63 (red, DNA).*

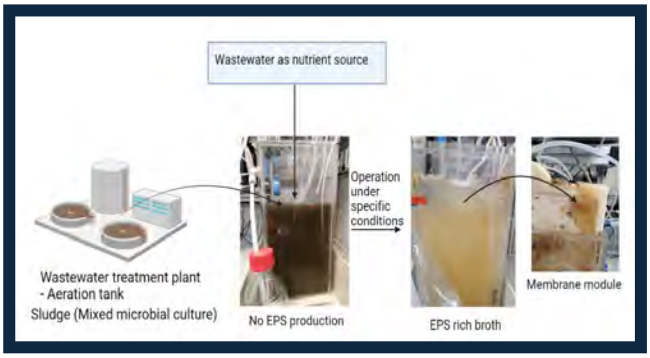

Figure 2*.Changes of membrane bioreactor inoculated with aerobic mixed microbial culture during EPS production process. EPS production starts under specific process conditions (nitrogen limitation coupled with short solid retention times). During the production mixed liquor becomes viscous as a sign of presence of EPS.*

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WAGENINGEN UNIVERSITY & RESEARCH

High-recovery & Chemical-free Desalination Using Electrodialysis Metathesis

May 2022 - 2026

Researcher	Supervisor	Promotor
Kecen Li	Dr. ir. Harry Bruning Dr. ir. Jan Post	Prof. dr. ir. HHM Rijnaarts

Motivation

Ascending water scarcity permits desalination for additional water supply. Membrane desalination is mature and cost-effective. However, its water recovery is limited due to the oversaturation of 2:2 salts (e.g., $CaSO_4$, $CaCO_3$) in the concentrate, eventually leading to scaling. Antiscalant dosing or ion-exchange processes mitigate this limitation, but these measures have negative operational and environmental impacts. Alternatively, studies have proposed Electrodialysis Metathesis (EDM; Fig 1). The EDM process avoids oversaturation of 2:2 salts; instead, it concentrates highly soluble 1:2 (e.g., $NaSO_4$) and 2:1 salts (e.g., $CaCl_2$) separately. However, the process requires the addition of NaCl. For a chemical-free goal, we develop our a high-recovery desalination scheme, including EDM, but with electricity and source water as sole inputs.

Technological challenge

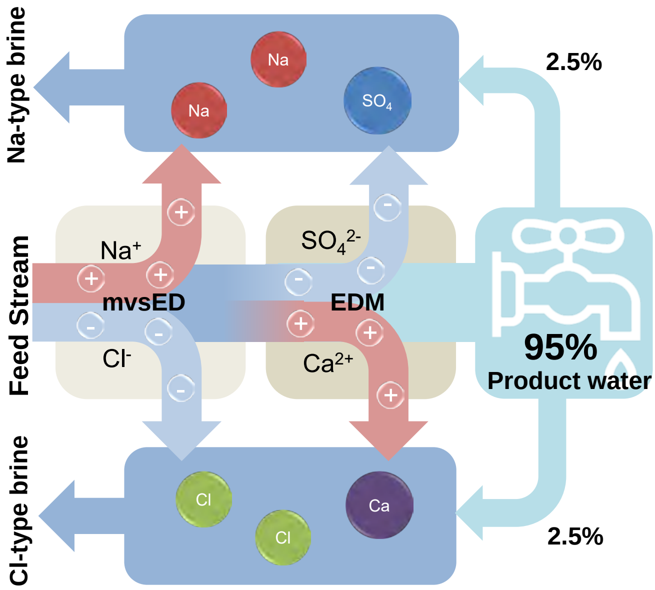
The process we propose consists of 2 steps. In step 1 monovalent ions migrate from the feed stream to form a 1:1 brine in a monovalent selective ED (mvsED) process. In step 2 divalent ions migrate from the feed to recombine with monovalent counter-ions from the 1:1 brine from step 1, forming a 1:2 brine (Na-type) and a 2:1 brine (Cl-type).

Regarding development and real-life applications, the main challenges are as follows:

➢ Without chemical additions, the source water's ionic composition fully defines the ability to rearrange ions into different brines, hence also the water recovery it can obtain.

➢ The scheme involves at least four types of ion-selective membranes which interact within the process. Essential are the properties of each of these membranes: e.g., counter-ion over co-ion selectivity, monovalent over divalent selectivity, water permeability.

➢ The process design is complicated since it includes multiple streams (feed, product, recycle, brines).



Research goals

Experimentally validating the performance of our concepts and investigating the optimum design and operational conditions for the various industrial applications (e.g., drinking water, oil, and membrane companies).

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Electrodialysis: towards ion-selective separations

Sep. 2021 - 2025

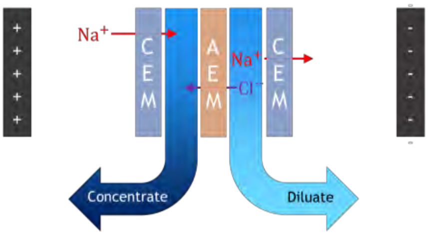
Researcher	Supervisor / co-promotor	Promotor
Alaaeldin Elozeiri	dr. ir. Jouke E. Dykstra prof. R.G.H. Lammertink	prof. H.H.M. Rijnaarts

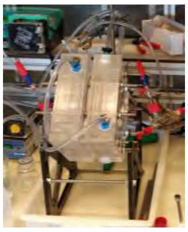
Motivation

Currently, several technologies are commercially available to reduce water salinity. These technologies were successfully employed to treat, for example, brackish groundwater. However, salinity is not the only water quality indicator of interest. For effective water re-use, technologies are required to control the ionic composition of water (i.e., removal of specific ions from water, while keeping the others).

Technological challenge

In this project, we focus on electrodialysis (ED), a desalination technology driven by an electric field. We aim to selectively remove specific ions from water. ED technology controls the exact degree of desalination based on the applied voltage. Still, it is not just the overall salt concentration that matters.

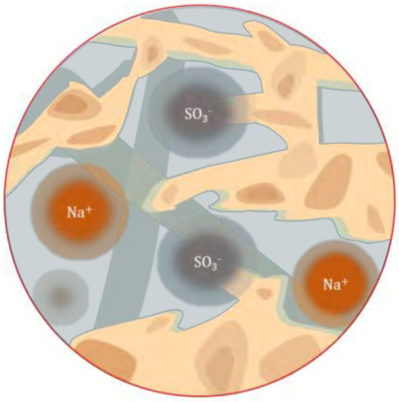




For many applications, the exact ionic composition is crucial. For example, the horticulture wastewater can be rich with nutrients (e.g., Ca^{2+}, NH_4^+), however, the high sodium concentrations limit its reuse. In this case, a selective removal of Na^+ is required. We will consider the effluent requirements of the desalinated water (diluate) as well as the environmental compatibility of the concentrate stream.

Key objectives:

- Modeling ion transport through selective membranes



- Developing electrodialysis process for selective separations

Case studies:
horticulture wastewater,
acid/base recovery

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Assessing the fate of contaminants of emerging concern in effluents during irrigation

Reusable Water
Environmental Technology

Apr 2021 - 2027

Researcher	Supervisor	Promotor
Jill Soedarso	Dr. ir. Nora Sutton	Prof. dr. ir. Huub Rijnaarts

Motivation

During drought periods, treated effluents can be a stable water supply for a more climate-resilient agricultural sector, to protect crop production and groundwater reservoirs. In the Netherlands, the focus is on reuse of the water, to either use it as irrigation water for agriculture and/or horticulture, nature conservation i.e. supplying water to drought endangered brooks and creeks, or for groundwater reservoir preservation by artificial recharge. Internationally, treated effluents are considered to be used as irrigation water in even a wider variety of applications, i.e. for non-food crop production and land greening programs in deserts or even for food-crop related irrigation in fresh water-stressed delta's. In all the situations we miss the knowledge on what is happening on the chemical interaction at the contaminants of emerging concern (CEC) (e.g. pharmaceuticals , PFAS) side and the soil side after irrigation. Therefore, we will focus on the reuse of water (treated effluent) and fate of CEC compounds.

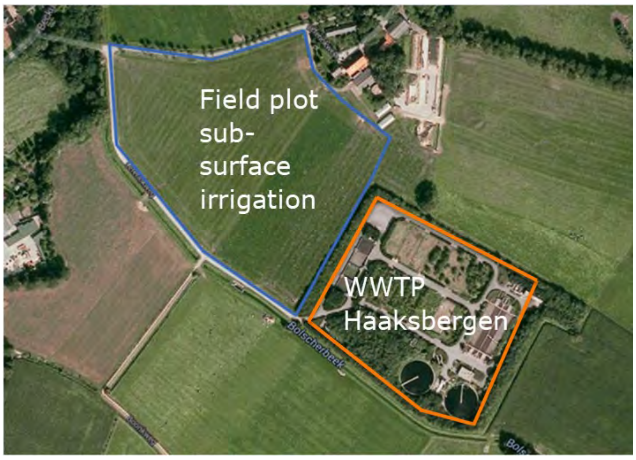

Figure 2 Field-scale pilots (lysimeter Qatar)

By understanding the soil CEC's interaction we can predict the effects on the soil and groundwater quality, in relation to risks associated with water resources and quality of crops. Effluents have the potential to be used as irrigation water during drought periods and other situations described on the left, while the fate of CEC pollutants should be thoroughly understood and the associated risks well managed.

Technological challenge

This research aims to understand the physical and chemical interaction of CEC's with soil and groundwater to understand the fate of CEC's in the environment. A combination of modelling, lab experiments and a field-scale pilot is applied to understand the interactions with CEC's and soils, to assess if treated effluents can be reused in a sustainable way as irrigation water without affecting the soil and ground water quality and surface water flow.

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WAGENINGEN
UNIVERSITY & RESEARCH

Formation and fate of micropollutant transformation products in subsurface water systems

Sep 2021 - 2025

Researcher	Promotor	Supervisor
Alessia Ore	Dr. Nora B. Sutton	Dr. Nora B. Sutton (WUR); Prof. dr. Annemarie P. van Wezel (UvA)

Motivation

Because of climate change, the Netherlands is currently facing seasonal problems with freshwater provision. Alternative water sources, such as surface water and wastewater treatment plant effluents, are being infiltrated to replenish aquifers and store water. However, micropollutants are widespread in the environment, including groundwater (GW) and surface water. The infiltration of alternative water sources may introduce more micropollutants into aquifer systems, threatening the quality of the drinking water produced. Furthermore, there is increasing concern about the underground formation, through microbial processes, of micropollutant transformation products (TPs), which can be more harmful than the parent compounds.

Technological challenge

During the travel time in the subsurface and once in GW systems, the fate of micropollutants is affected by biotic and abiotic processes. Microorganisms can biodegrade the contaminants changing their structure and forming TPs or, when the conditions are most favourable, they may be able to complete mineralization. A wide range of parameters affects biodegradation and TP formation, including redox conditions, dissolved organic carbon (DOC) availability and contaminant concentration. The presence of micropollutants and TPs in drinking water sources is most unwanted. TPs can, indeed, be more recalcitrant and mobile than the parent compounds, but the majority of those present in GW is still unknown. Even though GW systems have anaerobic and oligotrophic conditions that do not promote biodegradation, by studying the conditions that lead to different TPs formation, the process of mineralization can be stimulated. The composition of the microbial population plays an important role in biodegradation and, by studying it in correlation to the environmental conditions, we can better understand the metabolic pathways of micropollutants.

In the present research, laboratory experiments and field investigation are closely interconnected to study TPs' fate in subsurface water systems from a fundamental and applied perspective. In the lab, the influence of redox conditions and microbial diversity on TPs formation is assessed through batch experiments and DNA analyses. Sampling and data treatment of Dutch reuse water systems are performed to identify currently unknown TPs and their fate under real conditions, where subsurface or artificial infiltration is applied. Data analysis is done through state-of-the-art software for TPs identification. The study provides insights for the safer production, storage and reuse of freshwater.

Figure 1. Groundwater sampling in Haaksbergen (NL).

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AquaConnect

WAGENINGEN UNIVERSITY & RESEARCH

The role of organic substrate and shear forces in anaerobic sludge granulation

Jan 2021 – 2025

Researcher	Supervisor	Promotor
Chang Gao	Dainis Sudmalis	Prof.dr.ir. HHM Rijnaarts

Motivation

Anaerobic wastewater treatment is a well-established technology, which converts organic pollutants contained in wastewater into energy-rich biogas.

Design of compact anaerobic bioreactors requires formation of granular sludge, i.e. spherically shaped biofilm that has excellent settling properties. However, for sometimes unknown reasons granular sludge does not form at all, or only develops at very slow rates. The main goal of this project is to gain more knowledge about the granulation process and use this knowledge to improve it.

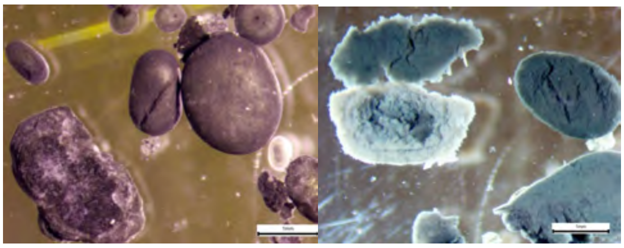
Figure 1 Lab-scale UASB reactors

Technological challenge

Anaerobic granulation is a complex process caused by various physical and chemical interactions between microorganisms and polymers (EPS) they excrete. In addition, these interactions are affected by operational conditions, substrate composition and indirectly by microbial population and activity. This also explains why the scientific literature on this topic often is conflicting. In particular, studies on effect of the type of organic substrate on granulation from dispersed biomass are still lacking.

In this research, the role of proteinaceous substrate on anaerobic granulation under fresh water conditions will be studied in an up-flow anaerobic sludge blanket (UASB) reactor (Figure 1).

Besides, the relationship between functional groups' abundancy of EPS in the granules and granules' strength will be investigated. This research will be carried out with granules (of different strengths) from full-scale plants of Paques treating various types of wastewater (Figure 2).



(a) Kitchen waste *(b) Rendering*

Figure 2 Macroscope pictures of anaerobic granules grown on different wastewaters.

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Improving microbiological urban surface water quality with nature-based technologies

Environmental Technology

Oct 2019 - 2023

Researcher	Supervisor	Promotor
Sha Gao	Dr. Nora B. Sutton (ETE) Dr. Paul van der Wielen (MIB)	Prof. dr. ir. Huub Rijnaarts

Motivation

The microbial quality of urban surface water bodies is important for urban quality of life and citizen health. Exposure to microbiologically contaminated water can result in many severe illnesses like gastroenteritis; fever; skin, ear, and eye complaints and respiratory disease. Currently, expanding uses for urban surface water such as undesignated swimming, intensified recreation, and other unregulated uses require a high water quality, which is not currently covered in existing regulation.

The aim of this project is to develop an understanding of microbiological urban surface water quality and develop mitigation technologies. This research is based in comprehensive screening and mechanistic understanding of microbiological quality of urban surface water.

Technological challenge

• Screening current microbiological water quality
A comprehensive monitoring campaign will be conducted at several vulnerable urban surface water locations in Amsterdam and Toronto. Sampling is performed monthly to investigate pathogens concentration (using qPCR combined with cultural method) and basic physio-chemical water parameters (pH, temperature, salinity, etc.) to look into the factors that influence microbiological urban surface water quality temporally and spatially.

• Mechanistic study of selected pathogens
Several important pathogens will be selected as indicators for research on their behavior in urban surface water bodies. Expriments are performed under highly controlled indoor tanks to understand the growth and/or die-off of selected fecal and opportunistic pathogens effected by environmental factors.

• Mitigation technology development
Nature-based technologies will be developed on laboratory and small-pilot scale that harness photodegradation in wetland or retention pond systems to mitigate point-source releases of pathogens, substrates and particles, and growth of opportunistic pathogens.

• Piloting monitoring strategy
The monitoring scheme and mitigation technology will be piloted in Amsterdam and Toronto to assess the effectiveness on improvement of microbiological water quality.

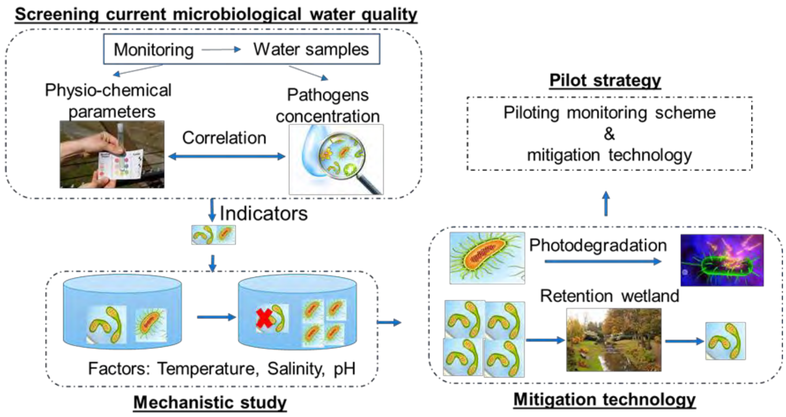

Fig 1 Research approach

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The influence of DOC quality on micropollutant biodegradation in drinking water aquifers

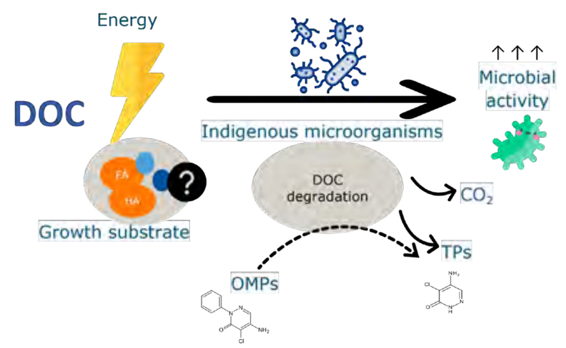
Oct 2022 - 2026

Researcher
Silvana Quiton Tapia

Supervisor
Dr. Nora B. Sutton

Motivation

In groundwater, Dissolved Organic Carbon (DOC) is used as main source of energy for microbial activity. As water infiltrates through the aquifer, some constituents of DOC are preferentially degraded by indigenous microorganisms. This results in a change of DOC quantity and quality that affects the overall microbial activity. However, in oligotrophic conditions, microbes also develop strategies in order to survive, like being able to consume different substrates at high substrate affinities (i.e. different DOC qualities and even organic micropollutants OMPs as carbon source). This metabolic flexibility allows the expression of a larger pool of catabolic enzymes that can boost *in-situ* biodegradation of OMPs.



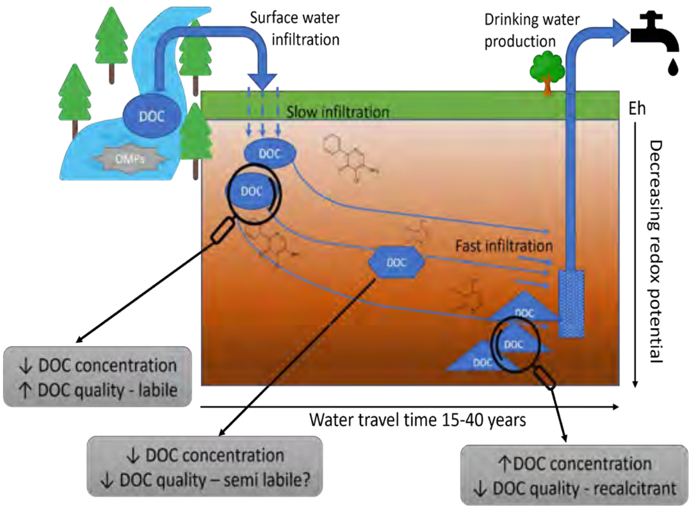
Technological challenge

We hypothesize that DOC quality is driving OMP removal. Therefore, we will characterize DOC quality by combining fluorescence spectroscopy and parallel factor analysis (PARAFAC). Understanding the relationship between microbial kinetics, DOC quality and OMP biodegradation will be paramount to provide an in-situ biodegradation strategy for drinking water aquifers.

Research goals

In this project, a series of microcosm studies aim to provide fundamental knowledge will be performed using field groundwater and microorganisms to address the following goals:

- Identifying changes in the DOC structure during its biodegradation
- Determining substrate affinity of different DOC (from labile to recalcitrant) for groundwater microbiome
- Identifying minimal threshold of DOC to induce OMP biodegradation
- Evaluation of in-situ oxygen dosing as an strategy to synergistically enhance OMP biodegradation with iron precipitation.



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Biological treatment of organic micropollutants present in nanofiltration membrane concentrate

Jul 2022 - 2026

Researcher	Supervisor	Promotor
Claudia Rodriguez	Dr. ir. Alette Langenhoff	Prof. dr. ir. Huub Rijnaarts

Motivation

There is growing awareness and concern about the presence of so called organic micro-pollutants (OMP) in our surface water. OMP originate from consumer products or from medicinal, agricultural or industrial activities. Although they are present in very low concentrations (ng-ug/l) in wastewater, they have the potential to cause long-term harm to human and the environment.

Municipal wastewater treatment plants (MWTP) are considered as hotspots for the release of OMP into the environment as they were not designed to include the removal of OMP. We are studying a new process that might significantly increase OMP removal by MWTPs, without having to increase their footprint.

Recycling of the OMP to the MWTP's aerobic reactor increases the contact time between the microorganisms and OMP, further increasing the chances of OMP biodegradation. This study focusses on biodegradation of the OMP and the effect of recirculation of the OMP on the biological functions of the MWTP, i.e. oxidation of bulk organic pollutants, nitrogen removal and digestion of the waste sludge. Partners in our project are studying the (multi-layered) nanofiltration membranes that can selectively remove OMP. The treatment of the concentrate of these nanofiltration membranes (NF) is the topic of our study.

Technological challenge

- Perform several lab-scale experiments in reactors to identify removal mechanisms of OMPs in activated sludge reactors such as biodegradation, sorption or adsorption.
- Use different TOC/COD concentrations in the reactors to identify the effect on the degradation of OMP on the microbial activity.
- Identify the effect of recirculation of the concentrate in the reactors on microbial activity.
- Perform bioassays to test the toxicity of parent OMP and transformation compounds present in the reactor effluent.

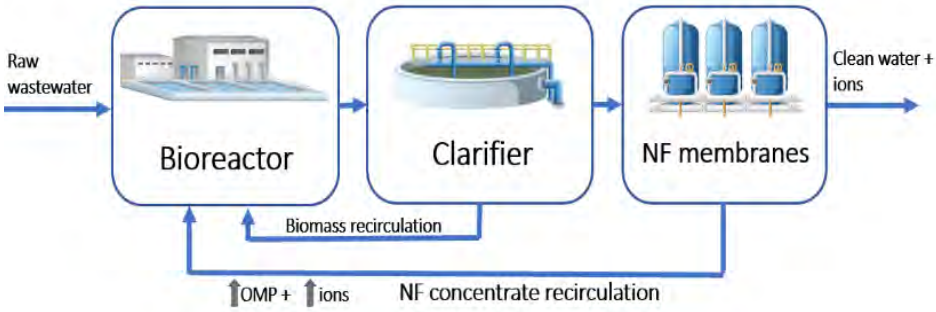
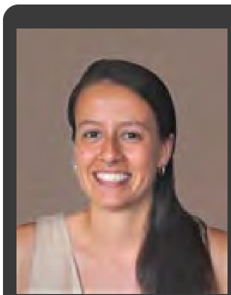


Figure 1 The proposed process, a combination of nanofiltration and biological treatment.



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No plastic to waste: Use microplastics to remove micropollutants

Apr 2020 - 2022

Researcher
Dr. Nora B. Sutton

Motivation

Microplastics and micropollutants are two emerging contaminants that threaten environmental and human health. Microplastics are small plastic particles (<5 mm) composed of polymers and additives. They can be unintentionally formed when larger plastic pieces wear. Micropollutants are organic chemicals, such as pesticides and pharmaceuticals, detected in wastewater at low concentration from ng/l to µg/l. Due to their persistency, bioaccumulation and potential toxicity, both microplastics and micropollutants are a rising concern for our modern society.

Technological challenge

Recent studies showed that organic micropollutants can be absorbed by microplastics. This new discovered property might help to reduce the total amount of organic micropollutants reaching the downstream water systems. Treatment of organic micropollutants via adsorption is already widely used in water treatment technologies with activated carbon filters, however, adsorption to another pollutants is a new field that deserves to be developed.
Furthermore, microplastic particles are colonized by microorganisms that can degrade micropollutants. Thus, microplastics act as an adsorbent material for micropollutants and as a biofilm carrier for the microorganisms able to degrade micropollutants. Recent studies show that recalcitrant plastics can be partly metabolized by microbial communities as well. Therefore, we focus on removing micropollutants in wastewater treatment plants (WWTP), which are an important source of discharging micropollutants to the environment, by using microplastics that are present in wastewater.

Research goal

In this project, as represented in fig.1, we aim to use the adsorbent capacity of microplastic to remove micropollutants, such as pesticides and medicines, from water. Adsorbed micropollutants will then be consumed by microbial biofilm growing on the microplastic particles. This project will provide insight on the fate and transformation of microplastics and micropollutants in water. This will be the first step to assess the treatment feasibility of both pollutions.

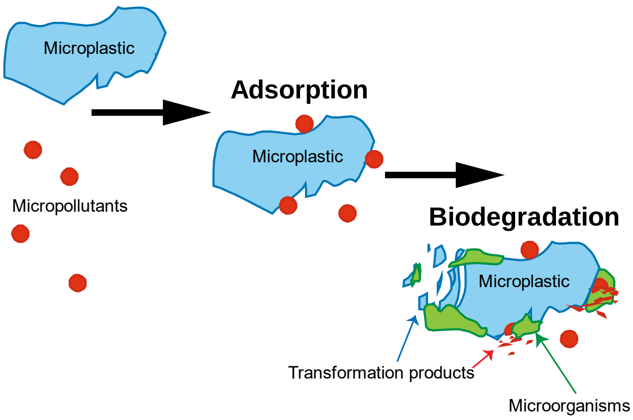

Fig. 1: Experimental approach to investigate the adsorption of organic micropollutants to microplastics and their biodegradation by microbial communities

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The fate and removal of antibiotics and antibiotic resistance in aerobic granular sludge systems

Sept 2021 - 2025

Researcher	Supervisor	Promotor
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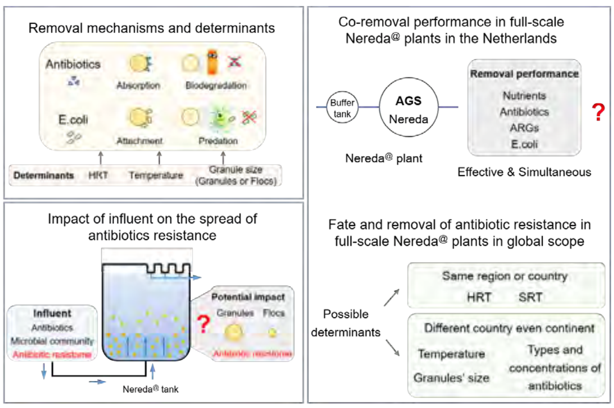
Motivation

Wastewater is an important source of micropollutants (MPs), antibiotics, and antibiotic resistance. However, the main goal of wastewater treatment plants (WWTPs) is to remove organic components and nutrients from wastewater instead of MPs, bacteria, and genes. Thus, the effectiveness of wastewater treatment technologies in removing MPs and antibiotic resistance has received widespread attention.

Aerobic granular sludge (AGS) is becoming a well-established technology for wastewater treatment due to its compactness, energy savings, and good effluent quality. With the development of AGS technology, it has been adapted to the commercial scales (Nereda@ technology). However, the effectiveness of Nereda@ technology in removing MPs and antibiotic resistance remains unclear, and the most important mechanisms controlling the removal of these contaminants and the dissemination of antibiotic resistance genes (ARGs) still need to be studied. Thus, the aim of this study is to investigate the fate and removal of antibiotics and antibiotic resistance, explore their possible determinants, and clarify the potential removal and dissemination mechanisms in full-scale Nereda@ plants.

Technological challenge

- Antibiotics and fecal indicator organisms (E.coli) have multiple removal pathways, such as sorption, biodegradation, attachment, and predation. In this study, the main removal pathway of antibiotics and E.coli and the different dissemination patterns of antibiotic resistance genes in granules and flocs will be clarified. The possible determinants of removal and dissemination, like hydraulic retention time, will be explored.
- Influent, including antibiotic, microbial communities, and antibiotic resistome, is an essential vector for the spread of antibiotic resistance. The potential contribution of antibiotic resistome in the influent to the antibiotic resistome in granules and flocs will be studied.
- To explore the effectiveness of Nereda@ technology in removing antibiotics, E.coli, and ARGs, the co-removal performance of nutrients, antibiotics, ARGs, and E.coli, and their possible determinants will be explored in the full-scale Nereda@ plants in the Netherlands.
- Different types and concentrations/abundances of antibiotics and ARGs exist in wastewater from different regions. To explore key determinants of antibiotics' removal and ARGs' dissemination, the removal and fate of antibiotics and antibiotic resistance in the full-scale Nereda@ plants in the global scope will be investigated.



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Engineering bioremediation of organic micropollutants in drinking water aquifers

Reusable Water
Environmental Technology

Oct 2023 - 2027

Researcher	Supervisor	Promotor
Merel Nederend	Silvana Quiton Tapia Dr. Nora B. Sutton	Dr. Nora B. Sutton

Motivation

The majority of Dutch drinking water is produced from groundwater resources. The quality of drinking water aquifers is threatened by the presence of organic micropollutants (OMPs) originating from various sources. Research concluded that OMP concentrations surpassed the intervention value of 0.1 µg/L in more than one third of Dutch drinking water aquifers. To protect water security, it is essential for drinking water companies (DWCs) to find cost-effective ways to treat OMPs.

Technological challenge

Research has shown that in-situ bioremediation is a viable and sustainable way to remove OMPs from aquifers. With the addition of oxygen and a biodegradable carbon source (DOC), the indigenous microbial community in aquifers has shown to be effective in biodegrading a large pool of OMPs.

In the translation of these findings to in-field conditions, the heterogeneity of aquifers creates variables essential to consider (Figure 1). Extraction wells create shifting groundwater flow patterns. Local differences in flow rate, contact time, substrate flux, redox conditions and biodegradability of DOC, create niche conditions which foster specific microbial communities able to degrade OMPs.

Laboratory experiments and field work are combined to investigate the ways in which redox conditions, DOC and microbial diversity can be utilized to promote OMP biodegradation. Laboratory results are linked to reactive transport models to interpret the effect of flow and flux on OMP biodegradation. OMPs are analyzed through Ultra High Pressure Liquid Chromatography.

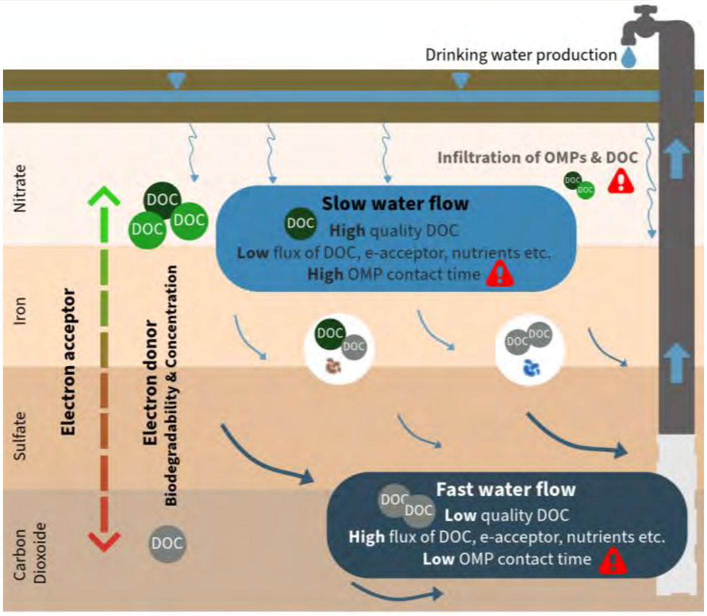

Figure 1 – Schematic representation of heterogeneity in aquifers, variability through DOC biodegradability and quantity, redox conditions and flow regimes foster microbial niches affecting biodegradation capacity.

Research goals

The following research aims contribute to deepening our understanding of dynamic aquifer interactions with regards to OMP biodegradation:

- Survey the biodegradation capacity of Dutch drinking water aquifers.
- Operate a 2D-flow reactor to optimize OMP biodegradation under different conditions.
- Engineer aquifer conditions to steer away from recalcitrant transformation product formation.
- Investigate the effect of DOC addition on extracted water quality.

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WAGENINGEN UNIVERSITY & RESEARCH

Using organic amendments to prevent pesticide leaching in soils

Oct 2022 - 2026

Researcher	Supervisor	Promotor
Marija Gadžimuradova	Dr. Valentina Sechi Dr. Peter van der Maas	Assoc.prof.dr. Nora B. Sutton

Motivation

More than 2.4 million active pesticide ingredients are applied worldwide annually to control the occurrence of weeds, insects, and other unwanted organisms. European Union Directive 2020/2184 sets a limit of 0.1 µg/L for pesticides in the water intended for human consumption. Despite the regulations, one or more pesticides in concentrations above 0.1 µg/L are detected in 30 % of all EU water monitoring sites, posing hazard to humans and ecosystems. Alternative methods for pesticide removal from drinking water are imperative to protect human health.

Organic amendment (OA) application is an agricultural practice that increases soil nutrient and organic matter content. Additionally, organic residue application modifies the sorption behavior of pesticides. This effect has potential to enhance future pesticide transformation and reduce their transport through the soil profile. Thus, OA application for direct pesticide remediation in the soil is a promising approach to preventing water pollution.

This research aims to develop a fundamental understanding of factors responsible for the fate of pesticides in soil, as well as interactions between pesticides and organic amendments. Obtained knowledge will be used to propose soil management and organic amendment application guidelines for pesticide leaching prevention.

The main benefits would be:

- Obtaining nature-based solution for pesticide removal in soil.
- Preventing surface and groundwater pollution.

Technological challenge

- Accounting for the complexity and abundance of the physical, chemical, and biological interactions in the soil-water matrix.
- Accounting for the variable nature of the organic amendments, and pesticide intrinsic properties.
- Establishing the influence of soil management practices on pesticide environmental fate.
- Combining the obtained knowledge to propose soil management and OA application guidelines. OAs should first adsorb and then desorb the pesticide at the optimal rate for its degradation in soil.

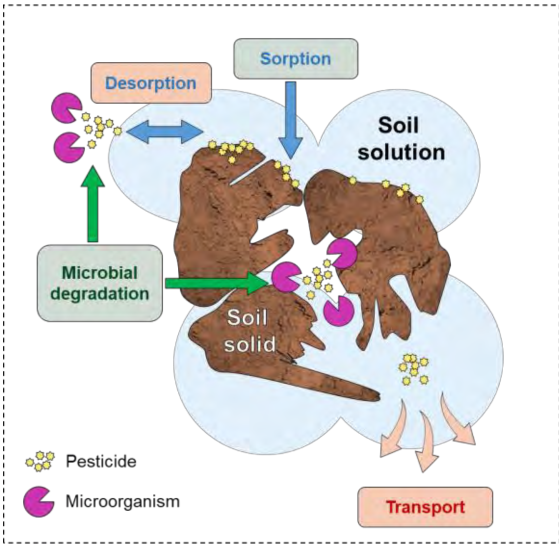

Figure 1. Schematic of processes governing pesticide fate in soil solution.

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Three phase flow behaviour of granular upflow anaerobic sludge blanket reactors

April 2021 - 2025

Researcher	Supervisor	Promotor
Hooman Eslami	Dr. ir. Dainis Sudmalis Dr. ir. Harry Bruning	Prof. dr. ir. Huub Rijnaarts

Motivation

Anaerobic granule-based bioreactors, such as up-flow anaerobic sludge blanket (UASB) reactors are attractive technologies for effective biological purification of high-strength wastewaters, and simultaneous energy recovery in the form of methane gas. In these reactors, the biomass retention is promoted by bacterial self-aggregation into dense granules and hence the formation of a strong, active granular sludge bed becomes important for optimal operation of the bioreactors.
Hydrodynamic forces are one of the key factors that affect the physical, chemical, and biological characteristics of granules, and consequently, the performance of the anaerobic process. However, their quantitative effect on granulation and mechanisms by which they affect granulation are yet to be fully understood.

Technological challenge

In UASB reactors, relative motion between liquid, gas bubbles, and granular sludge and particle-particle collisions generate normal and shear forces on anaerobic granules. As there is a continuous

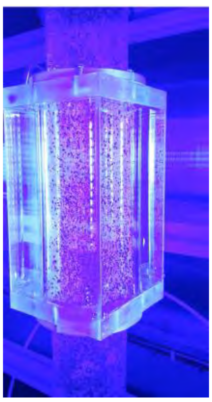


Figure 1 Experimental set-up for fluid flow visualization

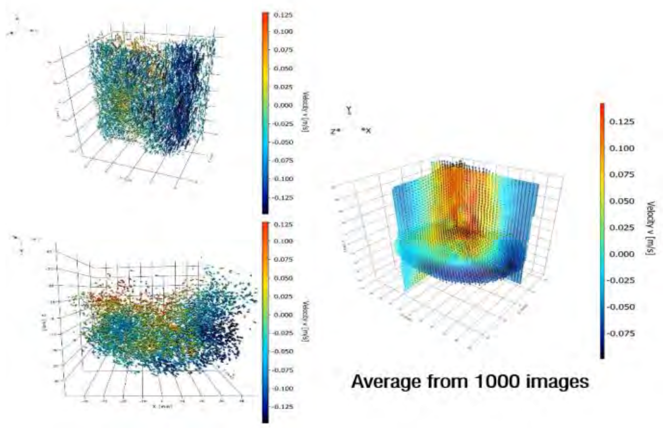
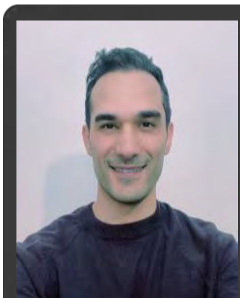


Figure 2 Time-resolved (left) an time-averaged (right) velocity distribution of liquid in the reactor

three-phase flow in the reactor, the hydrodynamic environment is complex. Complimentary experimental and numerical fluid mechanics methods are required to be applied in such complex bioreactors. Therefore, the ETE lab was equipped with new advanced high-speed cameras (Fig 1) to measure velocities and trajectories of moving particles in order to validate the numerical model.
The main focus of this research is to investigate the effect of mechanical stresses originating from both fluid-granule and granule-granule interactions on the properties of granular sludge utilizing a combination of these new advanced in situ optical tools, computational fluid dynamics (CFD), and bio-chemical characterization of granular sludge. In this way, we can develop operational strategies to provide a hydrodynamic condition favouring the development of dense, strong, and active granules, which is very important for applying these technologies in practice. In this project, we cooperate with companies that market granular sludge technology.



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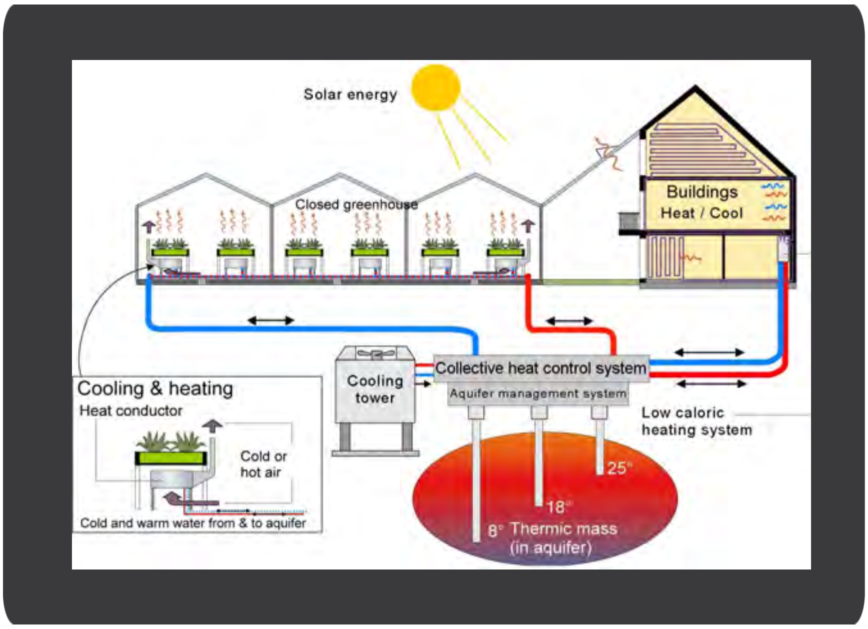
Urban Systems Engineering

Urban Systems Engineering and Biorecovery

Urban Systems Engineering and Reusable Water

Urban Systems Engineering



Environmental Issues

The intensity and scale of global urbanization pose major challenges to sustain basic urban services such as food, water and energy supply and sanitation in cities. For example, 780 million people do not have access to safe drinking water at this moment, and 2.5 billion people lack adequate sanitation services[1]. The depletion of resources and the growing demand for renewable energy, clean water, materials and minerals results in an increasing worldwide recognition that new approaches and paradigm shifts are needed, away from the current linear thinking to manage our resources.

Our Research

Our vision is to reduce environmental impact and mitigate resource depletion by closing resource cycles to achieve a circular (urban) metabolism. We focuses on creating new concepts and smart integration of technologies and practices for sustainable urban water, nutrients, materials and energy cycles. These new concepts cover the entire chain of collection, transport, treatment, supply and use of energy, water, nutrients and materials, aiming to preserve these essential resources. We select appropriate technologies for these concepts which are compatible with the local social and economic context and urban typologies. The focus is on (peri-) urban areas and industrial sites, for which we aim at an effective balance between supply and demand of water, energy, nutrients and material resources. We a) apply and further extend own concepts and approaches such as *Urban Harvest*, and b) provide frameworks and tools to evaluate and quantify technological concepts such as *New Sanitation* which is based on separation of wastewater and material streams at source, in order to facilitate recovery and reuse of water and other resources such as energy and nutrients.

Biorecovery

The Urban Systems Engineering (USE) division of the Biorecovery group addresses the recovery of essential resources from domestic, agricultural and industrial residues. As a result of the growing world population there is increased need for food and thus for fertilizers and soil amendments to facilitate crop growth. Furthermore, soils get depleted so resources in organic residues need to be recovered for the restoration of soil quality and ecosystem. The aim is to assess the potential for recovery of organic matter, nutrients and energy for implementation in circular agrofood and other (urban) systems. To this end we develop insights in supply and demand of these different resources and match these within different temporal and spatial scales. We work in the Netherlands but also within the European and African context.

Water Reuse

The USE division of Reusable Water group addresses the analysis, engineering and planning of urban and industrial water systems. We aim to assist the transition to a circular and localized water system. We develop models that trace water quality and quantity dynamics in cities and industrial areas. Using the modelling outcome, we simulate and assess the feasibility of systemic implementation of novel water technologies and infrastructures including, source-diverting sanitation in densely-populated urban area, saline wastewater treatment or reuse for coastal industrial zones and nature-based solutions for securing surface water quality in and around cities.

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[1] UNICEF & World Health Organisation (2012). Progress on Drinking water and Sanitation; 2012 update. UNICEF & World Health Organisation, Pg 1-59

Urban circular cities – Optimisation of recovery of organic matter and nutrients

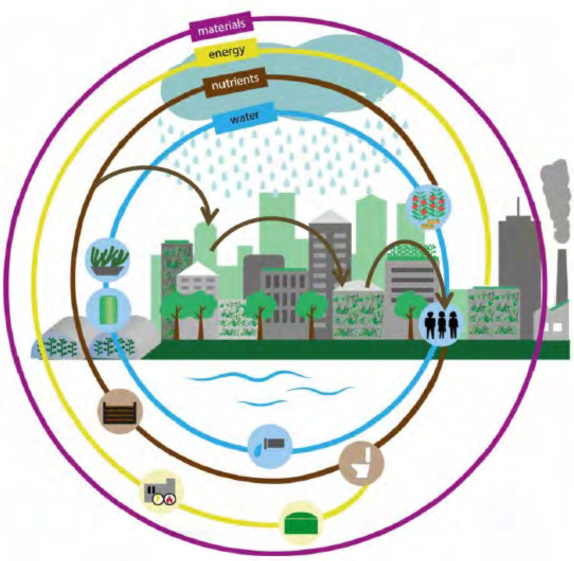
Jan 2022 - 2024

Researcher
Dr. ir. Miriam H.A. van Eekert

Prof. dr. ir. Cees Buisman

Motivation

The world population is growing and this poses an increasing challenge on food security. Besides the depletion of organic carbon in soil there is also an increasing demand for nutrients (NPK) for growing more crops. A pressing problem of our current food system is that it depends on finite resources, like phosphorus rock while at the same time nutrients are lost for agriculture via diffuse emissions. To conserve nutrients for future generations, they must be recycled. There is already a variety of (nature based) technologies in place for the recovery and reuse of nutrients from biomass and waste streams in the urban environment. Nutrients (N, P, K) are recovered in a variety of forms which may be more or less applicable for fertilization purposes.



Adapted from doi: 10.2166/bgs.2020.930

Research challenge

The variety of waste streams used as input, recovery technologies and nutrient products (CNPK, others) make a comparative assessment for the optimal recycling strategy in the urban environment very complex. Flows, but also organic matter and nutrient content, purities, additives may vary and as a result some strategies thought feasible from one criterion may not be suitable for other criteria. However, getting a clear overview is essential to design new circular recovery strategies. To enable structural analysis of nutrient recycling strategies we will develop on overview of recycling schemes and quantify the products for each nutrient source. The result will be a database containing a variety of (nature based) technologies, their inputs and nutrient "products" with their specific characteristics: e.g. origin, composition, purity and concentration of the produced nutrient as well as amount of energy used or produced. In addition, the residual stream remaining after production of the nutrient will be taken into account as this is often overlooked. This approach can be used to get a better quantitative understanding of nutrient cycles on an urban scale.

This project will align with the COST action Circular cities (https://youtu.be/eN0Bjt9RTyQ) and the results of the EU H2020 project Run4Life (https://run4life-project.eu/)

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BioTherm- Use of emerging biotechnologies for upgrading products from thermochemical conversion of municipal solid waste

Jan 2021 - 2024

Researcher	Supervisor	Promotor
Jinyang Lu	Dr.ir. DPBTB (David) Dr.ir. Wei-Shan Chen Strik Dr.ir. Ming Zhao	Prof.dr.ir. HHM (Huub) Rijnaarts

Motivation

The current major treatment methods (incineration and landfill) for the organic fraction of municipal solid waste (OFMSW) cause greenhouse gas emissions like CO_2 and CH_4 and have low-value products. OFMSW treatment needs to pursue higher carbon recovery and product value, on the premise of rapid processing and volume & weight reduction. Valuable chemicals and alternative fuels can be produced by integrating thermochemical processes (gasification and pyrolysis) and biological processes using OFMSW as feedstock. Combining thermochemical and biological methods to treat OFMSW allows higher carbon recovery rates and product values to be pursued, on the premise of quick treatment and reduced volume/weight of OFMSW.

Technological challenge

In the combined technical route of thermochemistry and biological methods, the thermochemical method is at the front end to complete the decomposition of OFMSW in a short time. Biological methods are at the back end. Microorganisms use small molecule products produced by thermochemistry to ferment to produce high-value products such as ethanol, protein, medium-chain fatty acids, etc. Although there are many types of thermochemical methods and there are many mature technical routes, they all have their limitations because the thermochemical technical routes were not originally designed to connect with biological methods. Thermochemical methods need to adjust their reaction conditions to produce product components suitable for subsequent biological methods. Even if the thermochemical process is theoretically designed, as the size of thermochemical reactors continues to increase, reaching theoretical values requires the support of continuous optimization of simulations and pilot-scale experiment data.
The OFMSW is a heterogeneous feedstock, the thermochemical method produces not only chemicals that can be used for microbial fermentation but also potentially bio-toxic chemicals that need to be removed. The impact of these additional products on microorganisms will determine the yield of the final product and even disrupt the coupling of thermochemical and biological methods. Although some bio-toxic substances also have pollution properties, their removal technologies have been discussed in depth. However, purification technologies for potentially bio-toxic substances produced by thermochemistry have not yet been systematically studied and integrated.
The technical challenge is to design and optimize thermochemical methods to produce the feedstock needed for biological methods while inhibiting and removing bio-toxic chemicals.

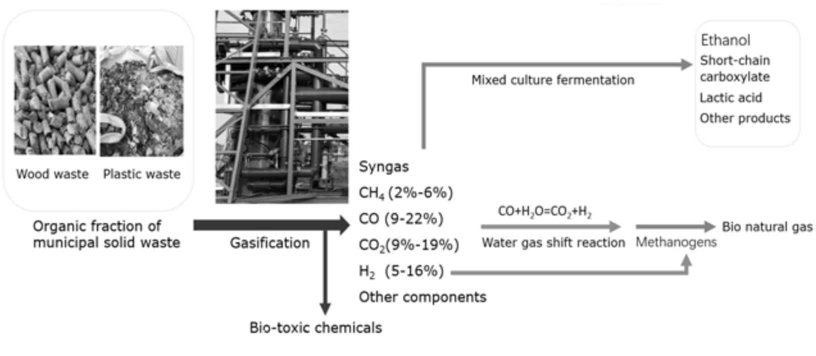

Figure 1: One type of technical route of combining thermochemistry and biological methods using gasification

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Micronutrients: recycling for a circular agro food chain

Jan 2022-2024

Researcher
Dr. ir. Miriam van Eekert

Prof. dr. ir. Cees Buisman

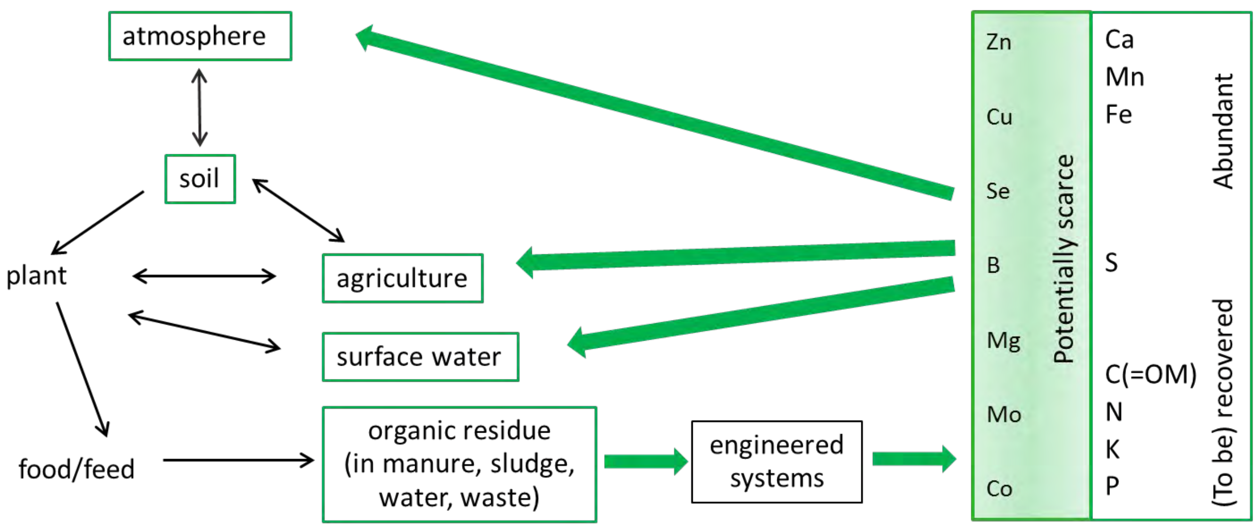
Motivation

Nutrient cycles need to be closed in view of the circular economy, and food security for all humans. For this, management strategies are to be developed.

Several chemical elements are essential for plant growth and human health. Among these are macronutrients like carbon, nitrogen, phosphorous, potassium, calcium and magnesium and micronutrients like zinc, copper, selenium, boron, molybdenum, cobalt and manganese. For some of the macronutrients, recovery technologies and management strategies have been developed, which could be implemented and in some cases are already applied. Methods for micronutrients, that are expected to become scarce on human timescales, often still need to be developed. However, currently there is a lack of knowledge on the flows and speciation of these elements from plants via food/feed and organic residues back to agriculture and losses to (other) environmental compartments. Identification of the sources, sinks and flows will set the stage for development of technologies directed towards the recovery of these specific micronutrients.

Research challenge

The research aims to assess the flows and speciation of micronutrients in the food chain, especially in waste fractions and organic residues like manure, sludge residues, wastewater, (the organic fraction of) municipal of solid waste. The fate and speciation of the micronutrients after treatment (composting, digestion and others) of these organic residues and their application in agriculture will be addressed as well as their fate in surface water and other environmental compartments.



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Upcycling food waste in low income & developing areas- Technological options and economic feasibility

April 2021-2025

Researcher	Supervisor	Promotor
Halimat Abdul-Rahman	Dr. ir. Wei-Shan Chen	Prof. dr. ir. Huub Rijnaarts Dr. Hans- Peter Weikard

Motivation

Continuous urbanization and degradation of our environment can propel humanity into an environment that cannot sustain society. Proper food waste (FW) management will mitigate GHGs emissions and climate change, water footprints, sanitation, ecological and economic impacts. Upcycling is a circular approach of creating sustainable and value added products. It is a promising strategy that can be used to address existing FW challenge in low-income and developing areas. Upcycling food waste offers environmental and social benefits. Economically, value added products can be a market opportunity.

Technological challenge

Possibilities for improving food waste management system remains pronounced in low-income and developing areas, where waste management is characterized by lack of data, lack of collection coverage, lack of treatment technologies, inadequate disposal and finances, and lack of viable business models.

As part of global effort to achieve sustainable development goals, countries are attempting to reduce landfilling and promote environmentally sustainable methods. Different technology options have been used for the treatment of FW. However, some technologies are more limiting in their requirements than others. While this may be true, considering technologies that can treat a wide range of feedstock type and quality is regarded, with consideration of investment and operational cost for low-income and developing areas.

A thorough evaluation of FW quantities and characteristics, in combination with different treatment technologies, upcycled products and how products fit into local market demand is fundamental for informed decision making in low-income and developing areas.

Potential BSc/MSc thesis topics include (but not limited to):

I. Characterize FW generation dynamics (quantity, quality, time) in low-income areas via innovative methods like crowdsourcing.
II. Analyze & compare the economic cost & environmental sustainability of FW treatment technologies in developed v.s. developing context.
III. Analyze the market sizes for potential FW-derived products and their spatial-temporal dynamics in a low income, developing area.
IV. Identify the social-economic opportunities & barriers for implementing circular FW management in developing context.

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Valorizing fruit and vegetable surpluses and side-streams: decisions, technologies, and sustainability

Oct 2020 - 2024

Researcher	Supervisor	Promotor
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Environmental Technology

Motivation

According to FAO, around 32% of the world's food produced for consumption is lost or wasted annually. Furthermore, estimates suggest that the carbon footprint of food loss and waste (FLW) could be as high as 3.49 Gt CO_2 equivalent per year. Against this backdrop, food waste valorization has emerged as a promising solution to combat this pressing issue. By means of converting or reusing food waste into useful products or resources, food waste valorization (FWV) holds the potential to mitigate the detrimental environmental, economic and societal effects of FLW, whilst simultaneously promoting a more sustainable and circular food system.

To address this issue, some researchers have turned to life cycle assessment and material flow analysis to evaluate all potential valorization scenarios. However, this approach can be time-consuming, and trade-offs may arise when assessing multiple criteria during decision-making. For instance, while deep processing can increase the value of products, such energy-intensive processes may not be environmentally desirable. In contrast, simple valorization methods may not meet stakeholders' economic expectations. Therefore, the challenge persists to create practical decision-making tools and models that can enhance the efficiency and accuracy of FWV decision-making.

Challenge

In order to advance the implementation of FWV, decision-makers often rely on the food waste hierarchy as a guiding principle (Figure 1). However, the ranking of valorization technologies in the FWH does not always align with their practical performance.

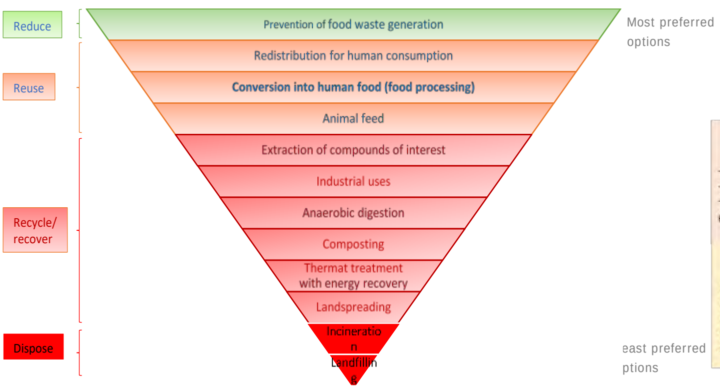

Figure 1. Food waste hierarchy.

Possible research topics:

- Develop a technical matchmaking tool to connect FLW with FWV opportunities.
- Modelling and analysis of the feasibility and potentiality of valorization for FLW.
- Research on developing a circular model for the food industry in a specific area to reduce environmental impact and improve economic sustainability.

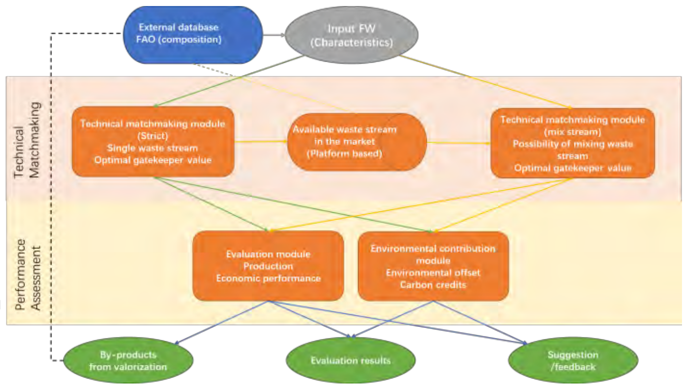

Figure 2. The proposed modules of decision-making framework.

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WAGENINGEN UNIVERSITY & RESEARCH

Circular Management of Urban Organic Residues to Restore Ecosystem Services of Agricultural Soil (CURESOIL)

Sep 2018 - 2022

Researcher	Supervisor	Promotor
Jiyao Liu	Dr. ir. Miriam van Eekert Dr. ir. Wei-Shan Chen	Prof. dr. ir. Cees Buisman

Motivation

The continuous decrease of soil organic carbon (SOC) results in the soil quality degradation and poses an increasing challenge with respect to food production and environmental protection. Meanwhile, the amount of urban organic residues (UOR) is steadily increasing with the growing world population and urbanization. Matching the SOC demand with the OC from UOR may be a win-win solution for both the soil ecosystem services restoration and the UOR circular management.

It is hypothesized that the nature of urban organic residues determines the way of OC recovery and the most appropriate scale for recovery and reuse.

Practical Challenge

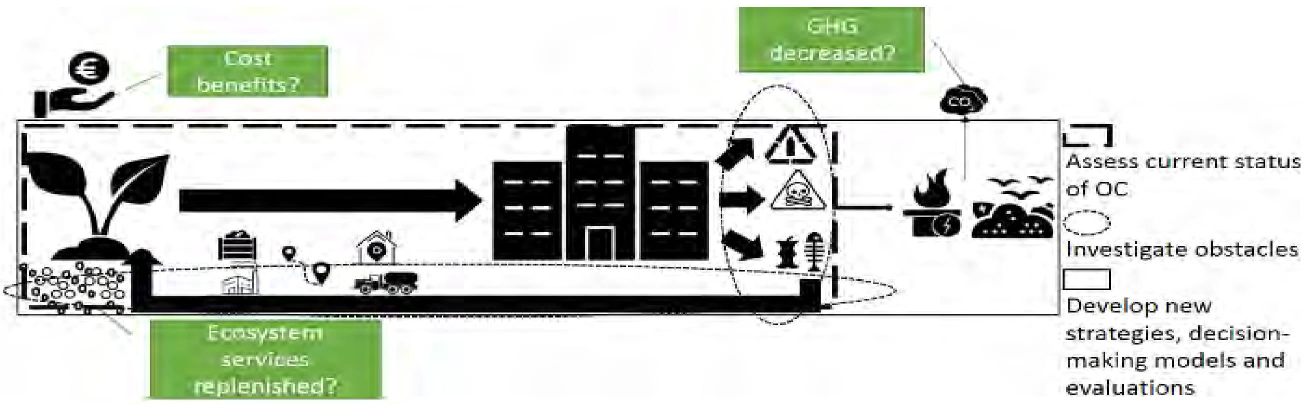
The variety of urban organic residue streams used as input, technologies applied and nutrients (mainly N,P,K) produced make a difficult comparative assessment for the applicability of the products and their effect on the SOC content and the different ecosystem services that agricultural soil could provide.

Objective

To maximize the effectiveness and impact of using urban organic residues for replenishing soil organic carbon to restore multiple ecosystem services provided by agricultural soil.

Approach

- Assess the current status of OC required by agricultural soil and supplied by urban organic residues;
- Investigate obstacles that hinder the carbon recycling. Three aspects are included:
  - The quality of urban organic residues;
  - The rationality of processing strategies;
  - The suitability of applying treated products to particular soil.
- Simulate strategies to match the actual SOC demand with the OC supply. Build a decision-making model;
- Evaluate the proposed strategies and complete the model with judgmental indicators.



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Inorganic solid waste & modeling. Nanoparticles.

Dr. Renata D. van der Weijden

Prof. dr. ir. Cees Buisman
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Motivation

The earth's resources are limited. Waste is becoming the new ore. Inorganic solid waste is usually divided in various categories, metal-, construction-,nuclear-, plastic-, and E-waste. In order not to waste the waste, knowledge of its composition, its present (managed) fate, and new knowledge about options to create alternative infrastructures for maximum (re-)use of the waste are desired. Data collection on quantities, character and management (in context) of the waste stream is therefore gathered to design innovative treatment plans that will close the resource cycles most efficiently. In order to estimate the quantity of a waste stream with a focus on a certain chemical element, fluxes from various reservoirs need to be known. These fluxes and reservoir sizes are not static ,but can change as the actors related to the reservoir change behavior. A well-known sink (a dead end flux) are the old cell-phones that disappear in drawers. The latter therefore represents an enormous reservoir for, for instance, precious metals. When consumers (actors) are diligent at handing in these used-materials, then the reservoir will decrease in size, the cycling of precious elements is increased and mining for those elements, with all its environmental repercussions, can be "mine-mized". A waste stream of concern with respect to possible environmental impact are the precious metal nanoparticles (size < 100nm), such as silver. Silver nanoparticles have a wide range of applications, amongst others; in the medical field, in anti-bacterial and anti-fungal treatments of products (like silver nano-particle containing kitchen cloths or as anti-biotic in animal food), in sensing and imaging applications and lasers. At the same time, when released into the environment they can cause great harm by creating toxic conditions.

Research aims and challenges

Silver nanoparticles are valuable, so being able to recover them is also important from an economic point of view. Since there is a rise in the use of nanoparticles, the number of potential reservoirs is increasing as well. The infrastructure for nanoparticle in silver recycling is not yet in place, and losses occur easily when used in household settings. Therefore the aim is:

- Investigate the types of silver nanoparticles, their properties and matrix of occurrence.
- Define silver nanoparticle reservoirs, their fluxes, and losses to create a model for the existing pathway of nanoparticles.
- Analyze the impact on the existing silver resource cycle.
- Analyze the use of other resources required (energy, water, space) to close the resource cycle.

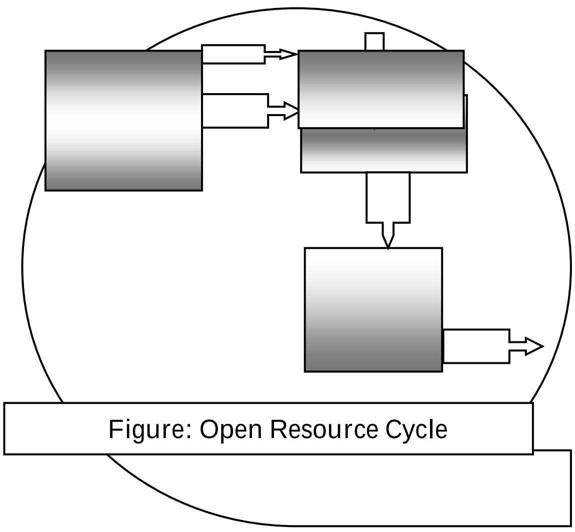

Figure: Open Resource Cycle

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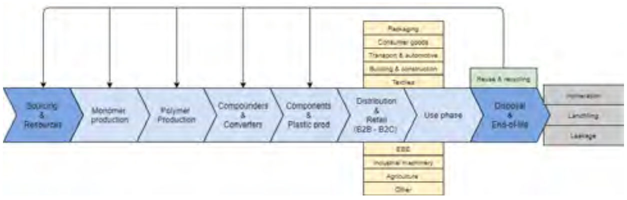
Renewable and sustainable plastic transition pathways - developing roadmaps with a co-creation design tool

Sep 2022 - 2026

Researcher	Supervisors	Dr. ir. David Strik (ETE)
Yme van Lith	Dr. Wei-Shan Chen (ETE)	Marieke Brouwer MSc. (FBR)
	Dr. Judith v. Leeuwen (ENP)	Dr. Ulphard T.v.Velzen (FBR)

Motivation

Plastics have a large impact on global society. There are 7 major and many more plastics/polymers which are embedded in thousands of different (complex) commodities and products in our daily life. A transition in the world of plastics is of priority and urgency, given the fact that plastic production accounts for ~10% of all fossil resources. Estimate is that 32% of all plastics are leaking into the environment, posing serious threats to nature and health. Many plastic transition developments are ongoing, like new recycling techniques and the development of biobased as well as or biodegradable plastic products.



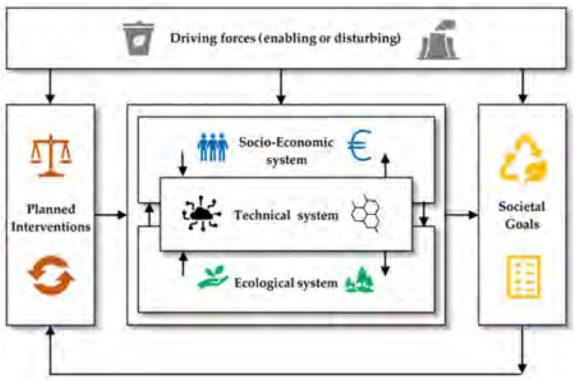
However, current initiatives often fail to facilitate the plastic transition due to the lack of understanding of the current plastic system and its value chain. In addition, there are uncertainties regarding the incorporation of various social-economic transition enablers and barriers. The transition is influenced by various policies, directives, societal behaviors and stakeholders. It is therefore essential to understand how this system works and to forecast how the transition and future society will potentially look like.

Objective

The research project aims to showcase plastic transitions will look and identify critical steps that will have to be made to realize set goals. For this, a novel design tool will be made which tackles crucial interventions and barriers to deliver plausible transition pathways for our society. The conceivable best answers for this will be found by bringing relevant stakeholders together and connecting them to co-create the 'optimal' transition pathway scenario based on real-world cases and the latest scientific and technological insights.

Research approach

To provide the plastic transition pathways and provide quantitative answers, relevant stakeholders have to be included to address the topic in an integrated way. The *'Butterfly Framework'*, developed by Bos, De Haas and Jongschaap (2022), will be used as the basis to stud the transition toward a circular and sustainable economy. Furthermore, a novel transdisciplinary and co-creative methodology will be developed, which should be able to design quantitatively different transition pathways.



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Improving Circularity in Plastic Packaging Waste

Oct 2023 - 2027

Researcher
Dalia Carbonel

Supervisor
Dr. ir. Wei-Shan Chen
Dr. ir. Kamonashish Haldar

Promotor
Dr. Hans-Peter Weikard

Motivation

Plastic waste accounts for 12% of the global municipal solid waste (MSW) composition, amounting to 288 million tons of plastic waste per year. Plastic packaging (PP) is a significant category of plastic due to its high production and disposal rates, environmental impacts, public health hazards, and economic consequences. According to The Ellen MacArthur Foundation only 14% of PP is collected for recycling worldwide, while 14% is destined for energy recovery, 40% is landfilled, and 32% leaks into the environment. This poses both a pollution and a resource recovery challenge.

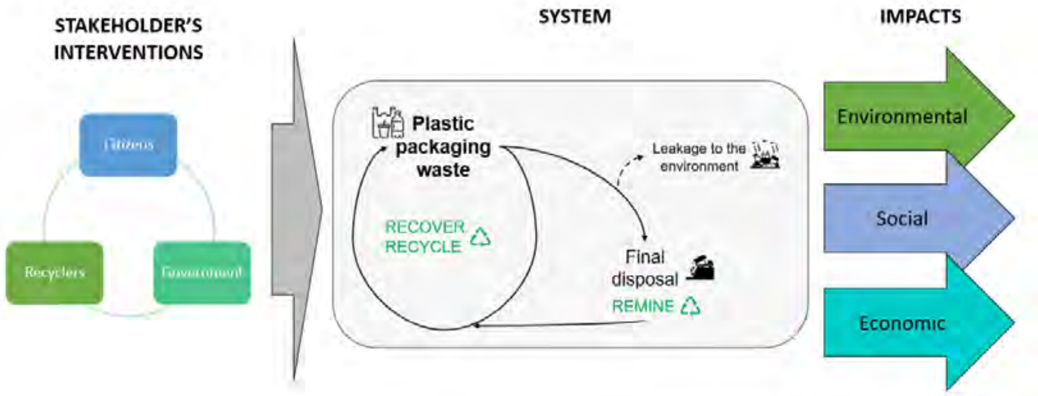
Effective segregation and recycling at the individual level, increase of formal recycling and effective local policies, could enhance the overall system's performance. However, the potential impact and interaction of these interventions is often underestimated or not well understood. A better knowledge and recognition of individual and local contributions could inform and improve policy formulation. The consequences of this problem are significant. Citizens do not segregate their waste. Formal and informal recyclers are often undervalued. Governmental officials implement ineffective policies. This, in turn, leads to the loss of plastic resources and pollution from MSWPP that are being final disposed of and leaked into the environment.

Practical challenge

The study aims to simulate the impact of agent interventions to identify efficient and sustainable strategies for improving segregation, recycling, and recovery of MSWPP. The focus is on assessing the social, economic and environmental impacts of these interventions.

The specific research questions are:

- What are the existing components, processes, and dynamics of the MSWPP system in Lima?
- Which agents need to change behavior and how to coordinate this behavioral change to enable more recycling options and improve the resource circularity?
- Does the increase in recycled plastic packaging in the MSWPP system have any direct or indirect rebound effects?
- Which recovery technologies and policy interventions are recommended in the MSWPP system to enhance sustainability and efficiency?



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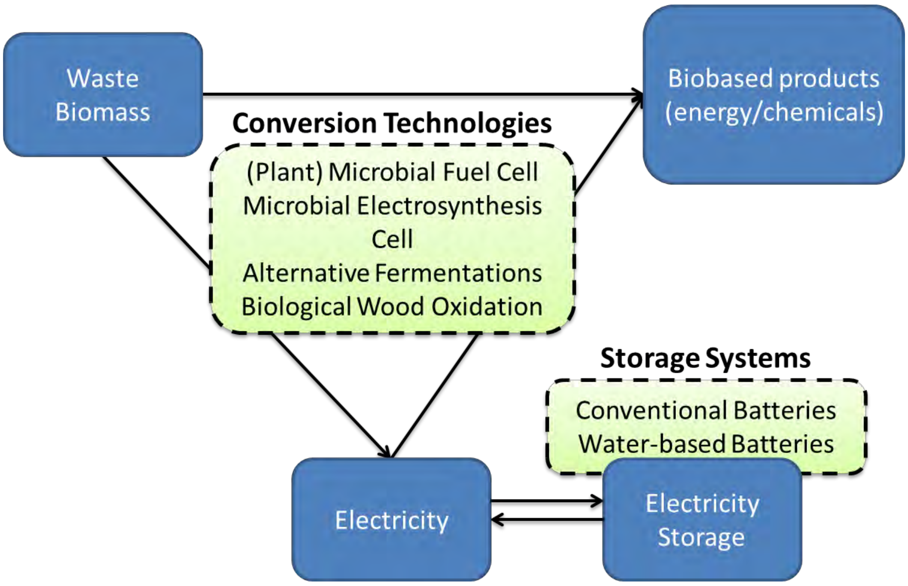
Renewable Energy

Dr. ir. Annemiek ter Heijne
Dr.ir. David Strik

Motivation

In a sustainable future, all our energy and chemicals are produced from renewables. Hereby supply and demand must be matched with the right storage facilities. Waste biomass (e.g. wastewater, household green waste, crop residues) is an attractive renewable source for biobased products, both in the form of energy and chemicals. Also CO2 waste streams are considered as potential feedstock for bioproducts. Due to the intermittent nature of solar and wind power, sustainable storage solutions in the form of batteries are required.

Novel technologies are being developed (e.g. at our own lab at Environmental Technology) to produce biobased products and produce or store electricity. These technologies have the potential to be applied in various ways. To reveal the state of the technology, one should compare the requirements of the actual application (i.e. design criteria) with the state-of-art. This way, the most promising implementations can be identified, as well as alternative technological solutions.



Challenge

Our aim is to assess the potential and performance of new conversion technologies for the production of electricity and biobased products from waste biomass. In addition, the potential for renewable electricity storage systems, using water-based batteries (e.g. conversion of electricity into a salt gradient) will be assessed and compared to conventional batteries.

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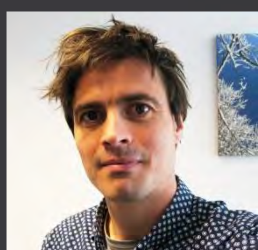


Coherent seasonal heat storage management to avoid electrical grid overload

Environmental Technology

Oct 2022 - 2026

Researcher	Supervisor	Promotor
Ir. Aad de Klerk	Dr. ir. Wei-shan Chen Prof. dr. ir. Cees Buisman	Prof. dr. ir. Cees Buisman

Motivation

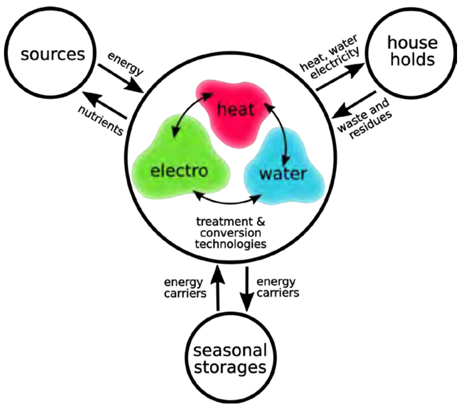
Current domestic heating demands are dominantly fulfilled by burning natural gas or other fossil fuels which are neither renewable nor sustainable. The strongly encouraged use of heat pumps as a replacement of natural gas heating boilers can overload the current electricity grid infrastructure and its renewability and sustainability is questionable and heavily dependent on national electricity sources. This research will develop knowledge and tools to assist the adoption and implementation of alternative heat sources, their seasonal storage and use in residential areas and mitigate foreseeable overload of the centralized electrical grid.

Technological challenge

The energy required for home heating forms the bulk of households' up till 83,5% of the total energy requirements. Given the large quantity of energy consumption for heating and their current non-renewable supplies, achieving sustainable home heating is crucial and plays a significant role in energy transition. The large seasonal variation in heat demand is typical for homes; it has high demand in winter and low or no demand in summer. This variation in demand should be matched with energy supply of sustainable sources by means of different kinds of seasonal energy storage system : thermal, biomass and bio-methane.

Alternative heat supply sources and means that are potentially more renewable and sustainable have emerged in recent years, but how residential areas can optimally adopt and implement these innovations to achieve energy transition is not yet clear.

Another challenge is interconnecting renewable water, electricity and heat sources and seasonal energy storages in an intelligent manner which could result in a decentralized, renewable, sustainable, circular, non-toxic and nutrients producing system. An autonomous local energy and sanitation organisation for a group of household could come into existence without or minimal use of large interregional, national of supra-national energy and water networks.



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WAGENINGEN UNIVERSITY & RESEARCH

Potential Sustainable (Renewable-based) Energy Mixes for Urban Use in Java and Bali Islands, Indonesia

Nov 2021-2025

Researcher	Supervisor	Promotor
Diyono Harun	Dr. Hans Cappon Dr. Katarzyna Kujawa-Roeleveld	Prof. Dr. Karel J Keesman

Background

Indonesia is an archipelago country in a tropical area with abundant renewable energy resources. Yet, this country still relies on non-renewable forms of energy resources. The project aims to investigate, model and design sustainable energy mixes from renewables for urban use in Java and Bali Island, Indonesia. The potential energy mixes regarding technical performance and economical, environmental, and infrastructural indicators will be evaluated using dynamic spatially distributed mathematical models.

Technological challenge

Indonesia has significant potential for renewable energy, but its conversion remains low due to its reliance on fossil fuels. The country's primary energy supply of 2,605 TWh in 2018 exceeded its final energy demand of 1,591 TWh, resulting in around 1000 TWh of wasted energy. While the country has 71 GW of installed capacity from renewable and non-renewable sources, only 6.81 GW comes from renewables, with a potential of 430.90 GW.

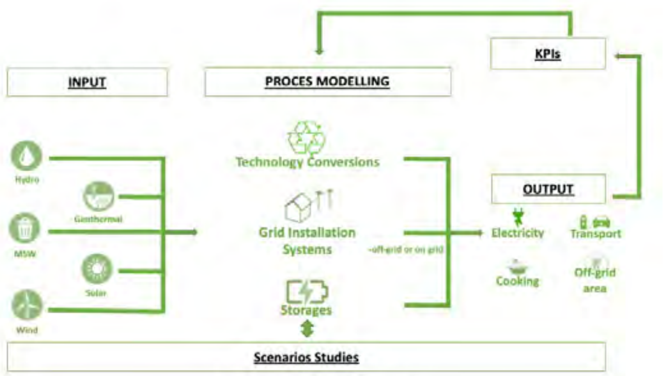

Figure 1. Methodological Framework.

Renewable energy has the potential to meet various energy demands in Indonesia. It can protect against the risk of future energy crises while reducing greenhouse gas emissions. However, achieving this potential requires well-informed decisions to create sustainable energy mixes. Flexibility in power systems is also crucial since Indonesia experiences two seasons with varying levels of sunlight and wind, affecting the potential of solar and wind power. Additionally, energy demand has its own trends, such as higher electricity demand in households at night than during the day.

The electrification ratio in Indonesia was 99.2% in 2020 and was not evenly distributed, with some areas lacking access to electricity, particularly in suburban areas, mountainous regions, and small islands.

Research Questions

This research aims to help improve the sustainable energy system in Java and Bali Island, Indonesia, by investigating feasible mixes of renewable energy resources on both on-grid and off-grid power systems. The GRQ formulated is "*What are the most feasible options for renewable energy generation to match the domestic energy demand of households in Java and Bali Island, Indonesia, throughout a whole year in both on-grid and off-grid power systems?*". To answer this, the SRQs are: (i) What are the sustainable (renewable) energy resources available and what is their potential?; (ii) What is the energy demand?; (iii) What are the options for renewable energy generation (energy conversion)?; (iv) What are the energy storages options?; (v) What are the potential designs of an autonomous house and/or neighbourhood in off-grid regions?; (vi); What KPIs qualify the most appropriate renewable energy mixes?

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Designing a Framework for an Integrated, Market-based Electricity and Water Coordination Mechanism at Regional and Local Levels.

Nov 2020 - 2024

Researcher	Supervisor	Promotor
Ir. Alessio Belmondo Bianchi	Dr.ir. Shahab Torbaghan Ir. Joeri Willet	Prof.dr.ir Huub Rijnaarts

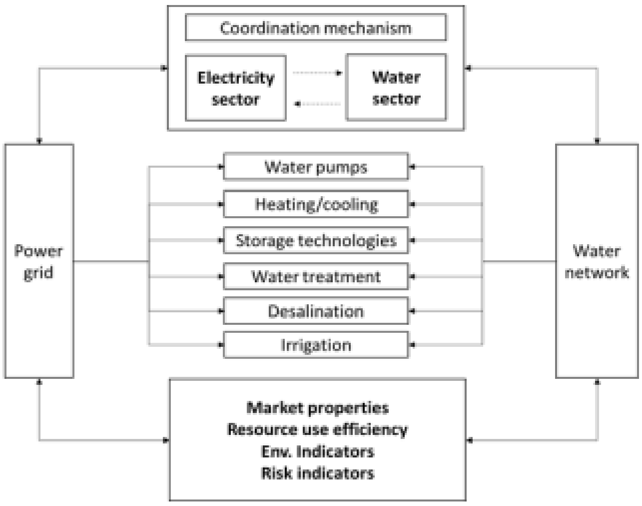
Motivation

Energy and water are two of the world's most critical resources for the sustainable development of human societies. As these resources are intrinsically interconnected, both physically and technologically, there are synergies across the two sectors that could be exploited, to obtain a higher (economic) efficiency. A novel approach to study these synergies is to design/implement integrated, market-based electricity and water coordination mechanisms to evaluate the planning and operation of electricity and water systems at different temporal levels and geographical scales, under centralized and decentralized settings.

Technological challenge

Due to the depletion of fossil fuels and the increased need of reducing energy-related greenhouse gas (GHG) emissions, the energy sector is currently facing the transition from non-renewable to renewable energy sources (RES). The increasing share of RES in the energy mix is posing new challenges in operating the power system (i.e., periods of high renewable energy generation and low price and vice versa). Consequently, system operators (SOs) need to increase their generation and dispatch flexibility. There are different ways to source such flexibility including sector integration, and demand-response (DR) measures. On the supply side, the treatment, transport, and storage of water link the water and the electricity sectors: one could exchange quality water for electricity and vice versa. On the demand side, technologies such as heating/cooling via water (e.g., district heating, heat pumps, etc.) and agricultural irrigation systems could provide additional flexibility. Such flexibility through integrated, market-based coordination of coupling technologies could alleviate the pressure on the energy sector while offering the water sector lower energy costs.

The technological challenge lies in the formulation and algorithmic implementation of appropriate mathematical programming problems to address the planning and operational aspects of the two systems. The coordination mechanism is implemented in the appropriate programming language (i.e., Python and/or Julia) and then used to study the price formation for water and energy. Further, a set of key performance indices (KPIs) is defined, to compare the effect of the proposed coordination mechanism under centralized vs. distributed market settings and for different penetration levels of coupling technologies that link the electricity and water sector, such as pumps, heating/cooling, etc. As an MSc student, you will investigate the modelling and optimization of one or more coupling technologies with regards to the proposed coordination mechanism.



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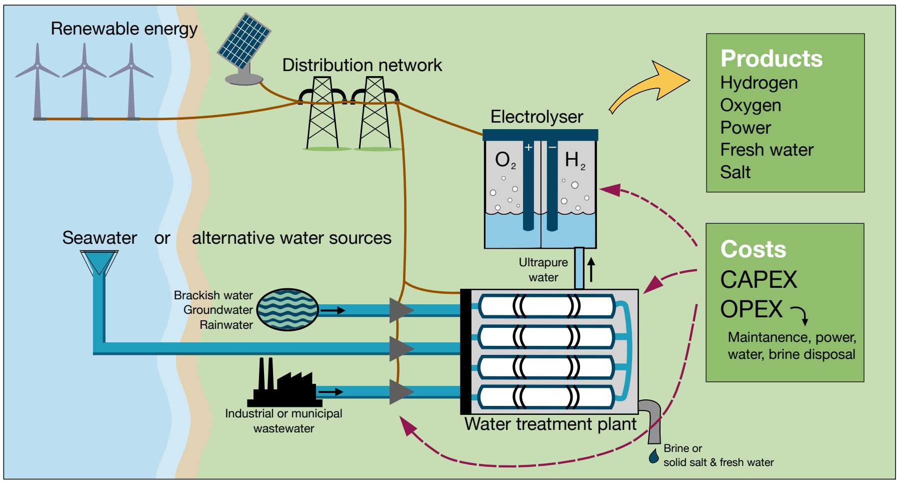
Alternative water resources for green hydrogen production:
from Zeeland to delta regions worldwide

Environmental Technology

Nov 2022—2026

Researcher	Supervisor	Promotor
Elizabeth Carlisle	Dr. Hans Cappon	Prof. Dr. Huub Rijnaarts



Motivation

In recent decades, hydrogen has gained attention as a potential solution for a low-carbon energy future. Renewable hydrogen, also known as green hydrogen, is produced through the electrolysis of water and is considered carbon neutral. However, its production requires large amounts of water and electricity, increasing the production cost and raising concerns about water scarcity. This project, focusing on a case study in the province of Zeeland, seeks to describe the alternative water sources available for hydrogen production and explore the costs and impacts of their usage compared with freshwater or seawater.

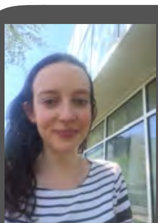
Ultimately, this project aims to answer the following questions:

1. Which water source(s) is/are least expensive considering all infrastructure and treatment costs?
2. Which solutions are most sustainable and robust?
3. Should the hydrogen production schedule be based on seasonal availability of water & energy?

Technological challenge

The goal of this project is to set up an optimization framework to decide an optimal hydrogen production schedule, hydrogen plant location, and any required infrastructure investments to provide the hydrogen plant with energy and water, including the water network to connect water sources and water treatment plants. We also plan to model various water treatment technologies. Several different options for water treatment can be used, based on the quality of the source water: reverse osmosis, forward osmosis, membrane distillation, or electrodialysis, for example. In addition, the future energy and water availability are uncertain, necessitating the use of stochastic programming or similar methods.

The technological challenge comes from the formulation and implementation of mathematical optimization methods to solve this problem. Accurate models to represent water treatment technologies must be used, but a complicated model could make the optimization problem infeasible to solve. Thus, it may be necessary to use techniques such as convex relaxation, decomposition, or machine learning.



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Investment and operation planning under uncertainty for future urban energy systems

Urban Systems Engineering
Environmental Technology

Mar 2023 - 2028

Researcher	Supervisor	Promotor
ir. Tim Zonjee	dr.ir. Shahab Torbaghan	prof.dr.ir Huub Rijnaarts

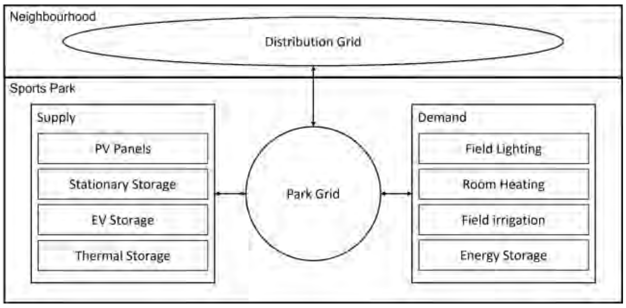
Motivation

As part of the challenge to reduce human-induced climate change, energy systems need to transition to a more sustainable operation. This energy transition has caused a quick and significant increase in electrical energy demand and the deployment of the renewable electricity supply technologies associated with it. To match supply and demand at all times, local distribution networks need to be carefully operated and expanded where required. In this study, we aim to find novel strategies that optimize the operation of and investment in electricity related networks and technologies on a local level, while considering the uncertainties of the future.

Technological challenge

The transition towards more sustainable energy systems implies a need for increased electrification. As a consequence, local electricity supply and demand have been increasing. On the supply side, the conventional renewable energy technologies are often non-dispatchable and reliant on energy sources with variable output (solar, wind). This, together with increasing supply capacity overall, causes increased supply peaks. On the demand side, the general increase in electricity demand, also causes increased demand peaks. To accommodate for both developments, the capacity and flexibility of distribution networks should be expanded. The problem is that this very development is lagging behind. As a consequence, local prosumers cannot expand the capacity of their distribution network connection, and therefore need to find smart ways to exploit the flexibility on their side (e.g. increase on-site supply, load shifting, energy storage) to match the growing demand and supply.

In this project we consider such a real-life case where sports parks of the municipality of Amsterdam act as prosumers. The challenge lies in finding a way to fulfil the parks' short-term energy needs while ensuring their long-term sustainability transition. Therefore, we develop a decision-support toolbox that optimizes for the parks' operation and suggests optimal investment plans on technology and park network infrastructure expansion. This optimization factors in municipal policies as potential objectives (e.g. minimizing costs, CO2 emissions) and uncertainties of the future (e.g. demand growth, variability in supply profiles). Finally, the model will be expanded to not only describe the parks' electricity systems, but also related energy systems (e.g. heat, water), objectives of other parties on the parks, and energy needs of the neighbourhood (function as an energy hub). As MSc student you would work on a project that might look something like this: Design an optimization code in Python in which you model part of the sports parks' energy system and minimize the investment cost and CO2 emissions (often conflicting objectives) simultaneously.



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WAGENINGEN UNIVERSITY & RESEARCH
python Programming
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Water for Nature: Exploration of Technological Interventions for Wastewater Quality Improvement in Urban Coastal Areas

2023 - 2027

Researcher	Supervisor and Co-promotor	Promotor
Erbi Setiawan	Dr. Katarzyna Kujawa-Roeleveld Dr. Ir. E. M. Erik Horstman	Prof. Dr. Ir. HHM (Huub) Rijnaarts, Erik

Motivation

Nowadays, urban areas are host to over 50% of the world's population, and it is predicted that in 2045, there will be an increase of up to 6 billion, or 2/3 of the world's population (United Nations, 2015; World Bank, 2023). One of the unique/fascinating forms of urban typology is coastal areas, where the tourism sector contributes significantly to socio-economic activities and is considered as one of the biggest and fastest-growing tourism sectors in certain regions of the world (Garcés-Ordóñez et al., 2020; Jarratt & Davies, 2020; Leposa, 2020). However, tourism induces intensive anthropogenic activities in urban coastal areas, causing unprecedented resource demand and resulting in environmental pressures. Interventions must be taken, therefore, to prevent stress on urban coastal environments and increase their resilience. One possible intervention is to improve the wastewater quality before discharge. Wastewater is a land-based stressor to the coastal ecosystem as it contains a wide arrange of pollutants and constituents like nutrients (N and P). At the same time, the same nutrients offer opportunities for reuse and recycling, especially in irrigation, making wastewater an important alternative for coping with intensive resource demand in (peri-) urban coastal areas and hinterlands.

Research Design and Technical Challenge

Technological interventions addressing wastewater management from intensive activities in urban coastal areas are the main focus of this research, aiming to improve the wastewater quality before being discharged and recover the remaining nutrient-rich contaminations. A baseline assessment of the existing practice related to wastewater production in urban coastal areas is conducted at the beginning of this research, followed by the development of technological interventions and social acceptance of the interventions' implementation. Nusa Penida, an intensive, well-known touristic urban coastal area in Bali, Indonesia, has been chosen to represent this research.

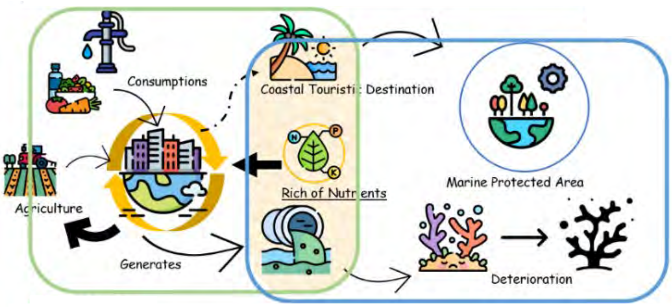
Research Objective and Questions

This research aims to explore land-based water system improvement through technological interventions that focus on wastewater, especially domestic wastewater, as a strategy to cope with environmental pressure with additional value of resource recovery in urban coastal areas; with the following activities will be performed:

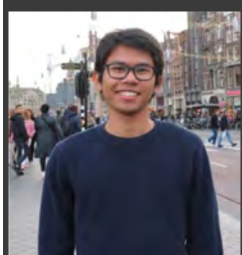
- Baseline assessment of coastal areas' water system profile, specifically wastewater;
- Technological interventions for domestic wastewater quality upgrade with added value of resource recovery;
- Design guidelines for scaling up coastal areas' water management focus on wastewater from pilot studies to widespread implementation.

The above research objective is followed by the research question:

How does wastewater improvement, especially human wastewater, from tourism activities contribute to overcoming the environmental pressure of biodiversity depletion and unprecedented resource demand in urban coastal areas?



Research Mind Map



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Physics-Informed Neural Networks for Optimal Water Flow Modeling

Mar 2023

Researcher	Supervisor	Promotor
TBD	dr.ir. Shahab Torbaghan	prof.dr.ir Huub Rijnaarts

Motivation

Countless instances of optimal water flow (OWF) need to be solved when it comes to evaluating uncertain scenarios, finding optimal control setpoints, and determining the optimal investment strategy in critical water infrastructure. However, the exact formulation of the OWF equations in the OWF problem is non-linear and nonconvex, which could result in significant difficulties for long computational times. A large body of literature exists on deriving approximations of the OWF problem, with the most popular ones being the linearized OWF, other linear or convex approximations, and convex relaxations, that will ensure fast computation speed and convergence guarantees.

Technological challenge

There is a revived interest in machine learning methods to accurately estimate the OWF solution which have demonstrated a computation speedup of 100–1000 times compared with the conventional methods. This means that in the time it would take to assess one scenario by solving one OWF instance, we can now assess up to 1'000 scenarios simultaneously. However, these machine learning algorithms experience two significant challenges. First, **the availability and quality of training datasets**: to train a neural network with considerable accuracy, we need OWF results for a huge set of operating points that will cover both normal and abnormal situations. Such datasets often do not exist, or it is often challenging to generate. Convex relaxation techniques were proposed to efficiently generating such large datasets, concentrating closer to the security boundary. Along the lines of improving the performance of such Machine Learning algorithms, a method was proposed in to identify and include adversarial examples in the training data set during training. The second major issue limiting the Neural Network (NN) widespread adaptation is that, so far, **none of the proposed machine learning algorithms have supplied any worst-case performance guarantee**. With OWF often used for safety–critical applications, the neural network estimates must not violate any OWF constraints, e.g., pressure, or pump capacity. To mitigate these limitations, the NN predictions can be post-processed to satisfy operational constraints as proposed in for OWF. However, this could negatively impact the optimality of the solution.

This research attempts to address these challenges by using a physics-informed neural network for OWF applications. It aims to introduce the physical equations in the form of the OWF Karush–Kuhn–Tucker (KKT) conditions inside the neural network training. By doing that, the neural network can reduce its dependency on the size and quality of the training dataset, and instead, it can determine its optimal parameters based on the actual equations that it aims to emulate. Efforts will be made to determine that extract worst-case guarantees for generation and line flow constraint violations of the neural network OWF predictions. In summary the aim is to (i) determine the worst violations that can result from any neural network output across the whole input domain, and (ii) propose methods to reduce them.

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Sustainable Technology Integration: How to combine technologies and demand and supply?

Researchers
Dr.ir. Katarzyna Kujawa
Dr. Wei-Shan Chen

Motivation

The question how and when to supply resources such as water and energy in a sustainable way to the user is one of the challenges we are working on. Here, we have to deal with a transition towards more decentralized technologies and therefore more decentralized systems as well as an increased complexity. We therefore aim at smart combinations of technologies in order to develop concepts for these systems, which can help to improve the resource efficiency and eventually lead to the closing of resource cycles.
Combined application of technologies, especially on small local and decentralized scale, and the evaluation of their potential based on temporal demand patterns (*How much energy do I need in the morning and how much in the evening?*) and local settings (*How much rainwater can I harvest here?*) offers the opportunity to develop custom-made and highly-efficient concepts for resource management, yet is not free of challenges due to its multi-disciplinary / multi-scalar nature. These concepts would be a milestone in the transition towards more sustainable urban systems.

Objective

The demand and possible supply of a resource depends on the local conditions of a site and the available technologies. We investigate therefore the performance of technologies and the demand of the user in a dynamic way, as the systems have a highly dynamic character. Based on these results, we want to develop concepts that match demand and supply of a resource by smart usage of technologies and combinations thereof. Here, we combine technology know-how, system analysis, user experiences and scenario studies in order to produce guidelines and decision support for planners, engineers, resource suppliers and technologists.

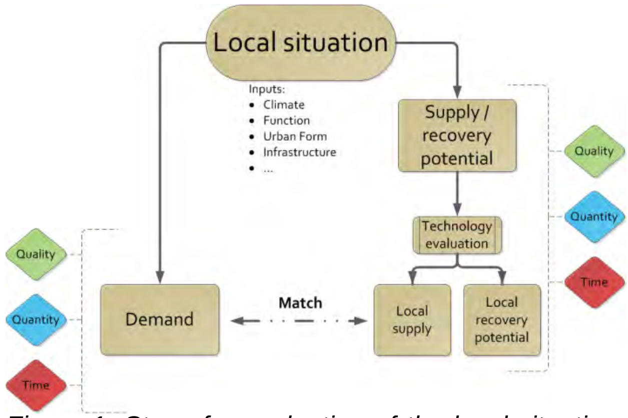

Figure 1: Steps for evaluation of the local situation and technology selection

Points of Interest

In the following, a number of points are mentioned, on which we are working on right now and which represent starting points for possible MSc topics:

- Evaluation of technologies for the supply of electricity and heat (e.g. PV panels and solar collectors) and the storage/supply of heat and cold (e.g. Aquifer Thermal Energy Storage)
- Modeling and analysis of combined resource systems (e.g. parallel energy supply and water treatment)
- Investigation of demand and supply patterns based on user data and / or spatial, demographic or statistical parameters (e.g. How much electricity is used by building YYZ in 2012 and what is the actual usage?)
- Development of methods and tools for the evaluation of systems and technologies (e.g. indicators, which can be used to evaluate a technology and which can be used for comparison)
- Brownfield redevelopment

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Transition of urban infrastructure towards circular & resilient cities

Dec 2018 – Sep 2020

Researcher	Supervisor	Promotor
Recruiting	Dr.ir. Wei-Shan Chen	Prof. dr. ir. Huub Rijnaarts

Motivation & Technological Challenge

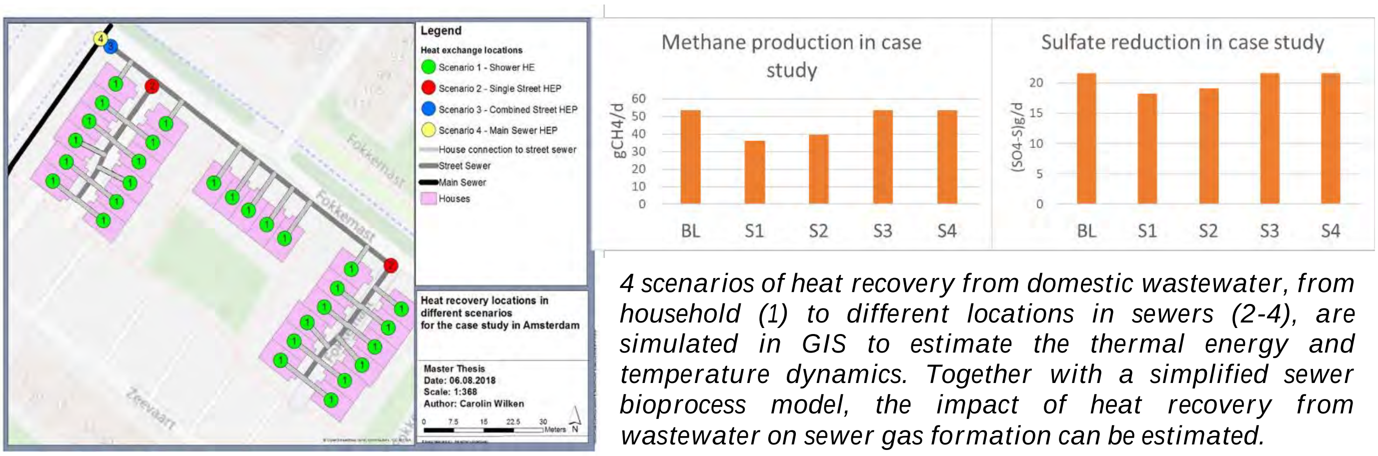
In 2050, there will be likely 10 billion people on the Earth and more than 70% of them will live in urbanised area. At least doubled urban infrastructures are needed to provide the basic services in the coming decades for both new and existing cities, especially for safe ty and sanitary purpose. Existing cities, especially those in the industrialised countries, have established extensive drainage and sanitary infrastructure that are designed based on a centralised and end-of-pipe paradigm, which may require substantial investment and efforts to renovate or even rebuilt in the coming decade.

The current paradigm of designing and building urban infrastructures lacks a systematic and interdisciplinary approach. The conventional urban infrastructural engineering approach mostly focuses on optimising a single infrastructure to provide an improved service but ignores the interdependences among the resources or services these infrastructures use or provide.

Research approaches

We integrate LCA, dynamic modelling and geo-spatial modelling to synthesis a decision-support tool for planning and designing urban infrastructural transition. Dynamic modelling is used to describe and simulate the resource dynamics within urban infrastructure. Geo-spatial modelling connects various infrastructural components and reveal the spatial dynamic of the resources within the entire urban infrastructural chain. LCA will be used for characterising and improving the environmental and economic performance.

An example is given in the figure below. A tool is developed to track carbon resources and thermal energy in domestic wastewater. The benefits and impact of decentralised v.s. centralised heat recovery from domestic waste water is assessed using this tool. Both organic carbons and thermal energy start degrading already in the sewer, which may induce environmental and economic challenges like global warming and sewer pipe corrosions.



4 scenarios of heat recovery from domestic wastewater, from household (1) to different locations in sewers (2-4), are simulated in GIS to estimate the thermal energy and temperature dynamics. Together with a simplified sewer bioprocess model, the impact of heat recovery from wastewater on sewer gas formation can be estimated.

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Assessment and Localization of Sewer Infiltration and Inflow

Mar 2022 - 2024

Researcher	Supervisor	Promotor
Hao Zhang	Dr. ir. Wei-shan Chen Dr. ir. Alida Alves Beloqui Prof. dr. ir. Haifeng Jia (Tsinghua University)	Prof. dr. ir. Huub Rijnaarts

Motivation

Especially in older cities high infiltration and inflow (I/I) input into the sewer network can arise from area drains, manhole covers, defective pipes, leaky connections. The global average share of I/I has been assessed to be about 30-50 percent. The situation is often further aggravated by extreme rainfall, i.e. due to climate change. Take Suzhou (China) as example, for a situation of 36mm precipitation in 24 hours, the I/I would account for 73%. The regular and extreme event related extraneous water causes tremendous negative effects on the sewage system, such as larger energy consumption of pumping stations, larger use of chemicals at wastewater treatment plant (WWTP), sewage overflow, flooding, etc. This research aims to develop an I/I assessment and localization method. This can help urban stakeholders to quantify the I/I situation in their regional sewer network and to localize places for most effective measures for I/I reduction, such as renewing sewer pipes and/or creating local storage facilities for excessive pluvial water.

Technological challenge

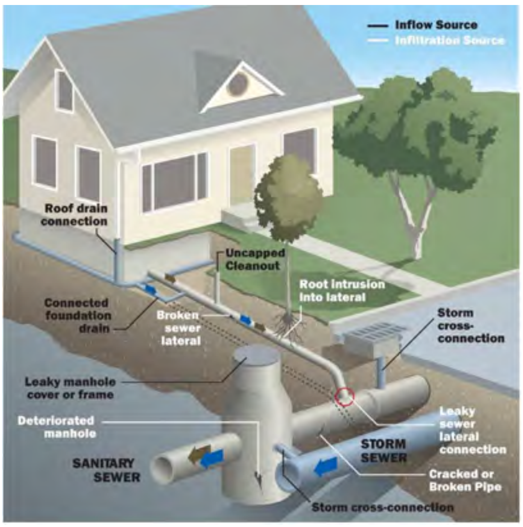
I/I is an inevitable problem due to continuous aging of sewer and WWTP components. What we can do is try to alleviate this problem and its corresponding negative effects. This research starts with qualitative I/I assessment and followed with I/I hotspot localization. The I/I process is influenced by numerous factors, such as pipe attributes (length, diameter, age, etc.), surrounding soil characteristics, groundwater level, maintenance, etc. However, there is a lack of an assessment method, which could well take into account all the factors of influence, due to insufficient basic network data or monitoring data.

The assessment process developed here aims to provide information on the regional I/I situation, which could qualitatively assess the I/I contribution for a certain subarea.

Nevertheless, this regional assessment result, is unable to tell in what specific part of the network I/I actually occurs. For this a more accurate I/I localization method is required, which could directly point out where I/I happens. Based on the assessment result and principles of pollutant transport, this part aims to combine sewer model and algorithms such as genetic algorithm and swarm particle algorithm to localize I/I.

Three research topics are listed below.

1) Using pharmaceuticals as tracers in quantifying regional I/I amount
2) Assessment of I/I, based on influencing factors
3) Localization of I/I, based on assessment result, sewer model and genetic algorithm



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Urban Systems Engineering
Environmental Technology

Environmental technology integration for transitioning towards a circular society

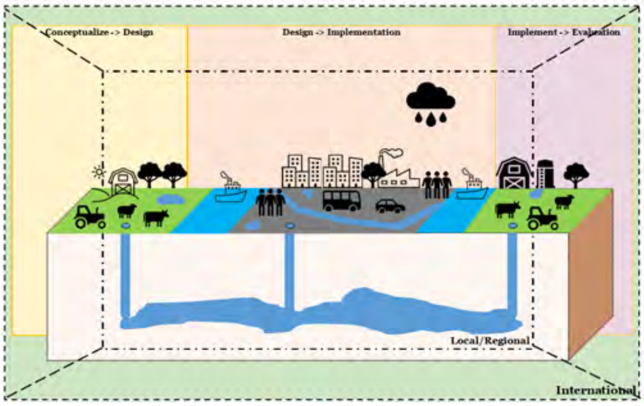
Researcher	Supervisor	Timeline
Dr. Kamonashish Haldar	Prof. dr. ir. Huub Rijnaarts	2021 - 2025

Motivation

Urban areas consume around 75% of natural resources and emit around 60-80% of greenhouse gases. The demand for natural resources has increased several folds in the recent past, whereas the availability and supply of resources are shrinking. Thus, transitioning towards a circular economy will reduce waste production and enable high-grade raw materials recycling and reuse. In addition to technical transition, societal inclusion is equally important to the change. Collaborative efforts from all societal actors are imperative for a successful transition towards a circular society.

Circular Society (CS)

The alliance of TU/e, WUR, UU and UMC Utrecht aims to bring together researchers, students and stakeholders to enable transitions to a circular society via **two hubs**: a) **Circular Safe Hospital**, focuses on the shift from disposables to reusables, reduction of pharmaceutical emissions to enable reusable water, stakeholder perception and energy transition; b) **Urban-Rural Circularity** focuses on socio-technological, nature based and organizational solutions, promoting resource circularity through inclusive rural-urban connections.



Anticipated topics related to Circular Society:

1. **Defining a circular, inclusive society**
   - *Defining a circular society requires looking beyond the current definition of the circular economy. A systematic literature review will be used to construct a holistic definition.*
2. **Impact evaluation of circular paradigms**
   - *Using a systematic approach to the applicability of circularity frameworks (UHA) for efficient use of an available resource. Next, we would investigate how indices are currently used to evaluate the circularity and ways to improve the evaluation.*
3. **Technology integration in built environment**
   - *Aspects such as resource flows, the scope of reuse, robustness of spatial planning in technology integration, resource forecasting, and technologies for resource recovery and reuse will be investigated. We also aim to study how societal perceptions (NIMBY) and actions influence wider technology adoption.*
4. **Urban-rural linkages & circular food system**
   - *Resources (waste)water, nutrients from urban areas have the potential to be reused in (peri)urban/rural agriculture. We aim to explore how to reduce the spatial barriers and enhance the urban-rural linkages in creating a circular food system.*
5. **Circular transition in the global South**
   - *Global South has barriers and opportunities related to circular transition. We hypothesize that by leapfrogging the conventional stages of transition global South could avoid the mistakes made by the global North. We aim to study the technological, social and governance scope/challenges of transition.*

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CHALLENGING FUTURE GENERATIONS

WAGENINGEN UNIVERSITY & RESEARCH

Gamified Decision Support Systems for Sanitation and Resource Recovery

2018 - 2023

Researcher	Supervisor	Promotor
Darja Kragić Kok	Dr. K. Kujawa -Roeleveld	Prof. Dr. Huub Rijnaarts

Motivation

It is projected that in the near future the majority of the world's population will live in urban areas located in low income countries. Consequently large volumes of urban waste and water will be generated where most of it is likely to end up dumped untreated in the environment, if the current practices continue. Yet, the urban waste and water is rich in nutrients and organic matter that can be recovered for agricultural applications. When properly collected and treated, urban streams can provide hygienically safe fertilizers and soil conditioners, which can reduce farmers' dependence on expensive chemical fertilizers and contribute to sustainable urban waste management in general.

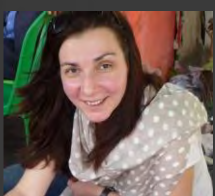
Technological challenge

Making the concept of resource recovery from urban waste work, calls for mobilization of a large number of different actors and applying a combination of approaches to work towards integrated solutions. Technological, economic, institutional, cultural, and social aspects all need to be addressed when aiming at resource recovery. In particular, a range of social factors play a crucial role in acceptance of the use of human waste in agricultural systems.

Serious games can be used to address complex processes and in this research they will be developed to support selection of sustainable urban waste and water management options under given context. The role of gamification for assisting decision makers in low-income countries on sanitation technologies for resource recovery will be further explored. The focus is on designing and validating a gamified decision support system (DSS) for sanitation technologies.

This research will be executed in close collaboration with a group of potential DSS users from several Sub-Saharan countries that will be identified and consulted when designing and testing the gamified DSS platform.
The FAO databases will be used to calculate nutrients present in different waste streams per capita per country.

The main challenge lies in designing a gamified DSS for sanitation technologies that can and will be used in real-life settings – thus making resource recovery and circular economy work.



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Publication List Environmental Technology 2023

Refereed article in a journal

- Bioaugmentation has temporary effect on anaerobic pesticide biodegradation in simulated groundwater systems
  Aldas-Vargas, Andrea ; Kers, Jannigje G. ; Smidt, Hauke ; Rijnaarts, Huub H.M. ; Sutton, Nora B. (2023)
  Biodegradation .
- Polymer and alcohol-based three-phase partitioning systems for separation of polysaccharide and protein
  Antunes, Evelyn ; Temmink, Hardy ; Schuur, Boelo (2023)
  Journal of Chemical Technology and Biotechnology 99 (1). - p. 259 - 269.
- Separation of polysaccharide and protein by ionic liquid-based extraction techniques
  Antunes, Evelyn C. ; Oliveira, Felipe ; Temmink, Hardy ; Schuur, Boelo (2023)
  Journal of Ionic Liquids 3 (2).
- Microbial dynamics and bioreactor performance are interlinked with organic matter removal from wastewater treatment plant effluent
  Atasoy, M. ; Scott, W.T. ; Gijn, K. van; Koehorst, J.J. ; Smidt, H. ; Langenhoff, A.A.M. (2023)
  Bioresource Technology 372 . - 11 p.
- Integrated data-driven cross-disciplinary framework to prevent chemical water pollution
  Ateia, Mohamed ; Sigmund, Gabriel ; Bentel, Michael J. ; Washington, John W. ; Lai, Adelene ; Merrill, Nathaniel H. ; Wang, Zhanyun (2023)
  One Earth 6 (8). - p. 952 - 963.
- Is sorption technology fit for the removal of persistent and mobile organic contaminants from water?
  Aumeier, Benedikt M. ; Georgi, Anett ; Saeidi, Navid ; Sigmund, Gabriel (2023)
  Science of the Total Environment 880 .
- Indene, indane and naphthalene in a mixture with BTEX affect aerobic compound biodegradation kinetics and indigenous microbial community development
  Aydin, Dilan Camille ; Faber, Suzanne Catherina ; Attiani, Valentina ; Eskes, Jordie ; Aldas-Vargas, Andrea ; Grotenhuis, Tim ; Rijnaarts, Huub (2023)
  Chemosphere 340 . - 1 p.
- Distribution robust water-based demand side management in power transmission networks
  Belmondo Bianchi, A. ; Willet, J. ; Rijnaarts, H.H.M. ; Torbaghan, S.S. (2023)
  Sustainable Energy, Grids and Networks 36 .
- Stakeholder-based decision support model for selection of alternative water sources - A path towards sustainable industrial future in Vietnam
  Bhatta, Astha ; Le, Truong Minh ; Wetser, Koen ; Kujawa-Roeleveld, Katarzyna ; Rijnaarts, Huub H.M. (2023)
  Journal of Cleaner Production 385 .
- Cyanophycin production in turbidostat cultivation of cyanobacteria under phosphorus limitation on synthetic urine media
  Canizales, Sebastian ; Hilderink, Loes ; Apkhazava, Merab ; Temmink, Hardy ; Wijffels, René H. ; Janssen, Marcel (2023)
  Algal Research 72 .
- Cyanobacteria cultivation on human urine for nutrients recovery
  Canizales, Sebastian ; Chen, Pei Hsuan ; Temmink, Hardy ; Wijffels, René H. ; Janssen, Marcel (2023)
  Algal Research 71 .
- Benchmarking biochar with activated carbon for immobilizing leachable PAH and heterocyclic PAH in contaminated soils
  Carlini, Carlotta ; Chaudhuri, Sampriti ; Mann, Oliver ; Tomsik, Daniel ; Hüffer, Thorsten ; Greggio, Nicolas ; Marazza, Diego ; Hofmann, Thilo ; Sigmund, Gabriel (2023)
  Environmental Pollution 325 .
- Effect of pre-treatment processes of organic residues on soil aggregates
  Chavez-Rico, Vania Scarlet ; Bergh, Stijn van den; Bodelier, Paul L.E. ; Eekert, Miriam van; Luo, Yujia ; Nierop, Klaas G.J. ; Sechi, Valentina ; Veeken, Adrie ; Buisman, Cees (2023)
  Environmental Technology and Innovation 30 .

- Hybrid Donnan dialysis–electrodialysis for efficient ammonia recovery from anaerobic digester effluent
  Dai, Zhinan ; Chen, Cong ; Li, Yifan ; Zhang, Haoquan ; Yao, Jingmei ; Rodrigues, Mariana ; Kuntke, Philipp ; Han, Le (2023)
  Environmental Science and Ecotechnology 15 . - 8 p.
- Designing Sustainable Domestic Electricity Supply from Renewable Energy Mixes: Application to Java and Bali, Indonesia
  Diyono, Diyono ; Cappon, Hans ; Kujawa-Roeleveld, Katarzyna ; Keesman, Karel (2023)
  Energies 16 (22).
- Nutrient recovery and pollutant removal during renewable fuel production : Opportunities and challenges
  Elzinga, Margo ; Haan, Desiree de; Buisman, Cees J.N. ; Heijne, Annemiek ter; Klok, Johannes B.M. (2023)
  Trends in Biotechnology 41 (3). - p. 323 - 330.
- Ecotoxicity attenuation by acid-resistant nanofiltration in scandium recovery from TiO_2 production waste
  Fekete-Kertész, Ildikó ; Stirling, Tamás ; Vaszita, Emese ; Berkl, Zsófia ; Farkas, Éva ; Hedwig, Sebastian ; Remmen, Kirsten ; Lenz, Markus ; Molnár, Mónika ; Feigl, Viktória (2023)
  Heliyon 9 (4). - 15 p.
- Low-energy ammonium recovery by a combined bio-electrochemical and electrochemical system
  Georg, S. ; Puari, A.T. ; Hanantyo, M.P.G. ; Sleutels, T. ; Kuntke, P. ; Heijne, A. ter; Buisman, C.J.N. (2023)
  Chemical Engineering Journal 454 .
- Removal of micropollutants and ecotoxicity during combined biological activated carbon and ozone (BO_3) treatment
  Gijn, K. van; Dam, M.R.H.P. van; Wilt, H.A. de; Wilde, V. de; Rijnaarts, H.H.M. ; Langenhoff, A.A.M. (2023)
  Water Research 242 .
- Influence of redox condition and inoculum on micropollutant biodegradation by soil and activated sludge communities
  H.R. Branco, Rita ; Meulepas, Roel J.W. ; Veelen, H.P.J. van; Rijnaarts, Huub H.M. ; Sutton, Nora B. (2023)
  Science of the Total Environment 897 .
- From Trace to Pure : Pilot-Scale Scandium Recovery from TiO_2 Acid Waste
  Hedwig, Sebastian ; Yagmurlu, Bengi ; Peters, Edward Michael ; Misev, Victor ; Hengevoss, Dirk ; Dittrich, Carsten ; Forsberg, Kerstin ; Constable, Edwin C. ; Lenz, Markus (2023)
  ACS sustainable chemistry & engineering 11 (15). - p. 5883 - 5894.
- Continuous single-stage elemental sulfur reduction and copper sulfide precipitation under thermoacidophilic conditions
  Hidalgo-Ulloa, Adrian ; Graaf, Charlotte M. van der; Sanchez-Andrea, Irene ; Buisman, Cees J.N. (2023)
  Water Research 236 . - 10 p.
- Improvement of nutritional quality of food crops with fertilizer : a global meta-analysis
  Ishfaq, Muhammad ; Wang, Yongqi ; Xu, Jiuliang ; Hassan, Mahmood Ul ; Yuan, Hao ; Liu, Lianlian ; He, Boyi ; Ejaz, Irsa ; White, Philip J. ; Cakmak, Ismail ; Chen, Wei Shan ; Wu, Jiechen ; Werf, Wopke van der; Li, Chunjian ; Zhang, Fusuo ; Li, Xuexian (2023)
  Agronomy for Sustainable Development 43 (6).
- Long-term performance of pilot-scale tubular plant-microbial fuel cells in a brownfield-constructed wetland
  Jager, Pim de; Groen, Daniel ; Strik, David P.B.T.B. (2023)
  Renewable Energy 219 .
- Microbial Recycling of Bioplastics via Mixed-Culture Fermentation of Hydrolyzed Polyhydroxyalkanoates into Carboxylates
  Jin, Yong ; leeuw, Kasper D. De; Strik, David P.B.T.B. (2023)
  Materials 16 (7). - p. 2693 - 2693.

- Polysulfide Concentration and Chain Length in the Biological Desulfurization Process : Effect of Biomass Concentration and the Sulfide Loading Rate
  Johnston, Kestral A.K.Y. ; Lankveld, Mark van; Rink, Rieks de; Roman, Pawel ; Klok, Johannes B.M. ; Mol, Annemerel R. ; Keesman, Karel J. ; Buisman, Cees J.N. (2023)
  Environmental Science and Technology 57 (36). - p. 13530 - 13540.
- Comparing theoretical and practical biomass yields calls for revisiting thermodynamic growth models for electroactive microorganisms
  Korth, Benjamin ; Pereira, João ; Sleutels, Tom ; Harnisch, Falk ; Heijne, Annemiek ter (2023)
  Water Research 242 .
- The removal of micropollutants from treated effluent by batch-operated pilot-scale constructed wetlands
  Lei, Yu ; Wagner, Thomas ; Rijnaarts, Huub ; Wilde, Vinnie de; Langenhoff, Alette (2023)
  Water Research 230 . - 9 p.
- Phytoremediation of micropollutants by Phragmites australis, Typha angustifolia, and Juncus effuses
  Lei, Yu ; Carlucci, Livio ; Rijnaarts, Huub ; Langenhoff, Alette (2023)
  International Journal of Phytoremediation 25 (1). - p. 82 - 88.
- Electric discharge by sulphide shuttling bacteria
  Linssen, Rikke ; Heijne, Annemiek ter (2023)
  Journal of Chemical Technology and Biotechnology 98 (1). - p. 2971 - 2980.
- Anaerobic sulphide removal by haloalkaline sulphide oxidising bacteria
  Linssen, Rikke ; Slinkert, Thomas ; Buisman, Cees J.N. ; Klok, Johannes B.M. ; Heijne, Annemiek ter (2023)
  Bioresource Technology 369 .
- Environmental selenium volatilization is possibly conferred by promiscuous reactions of the sulfur metabolism
  Liu, Ying ; Schäffer, Andreas ; Martinez, Mathieu ; Lenz, Markus (2023)
  Chemosphere 345 .
- Potential reuse of domestic organic residues as soil organic amendment in the current waste management system in Australia, China, and The Netherlands
  Liu, Jiyao ; Haan, Jesse de; Montaño Rey, Iván Felipe ; Bai, Zhanguo ; Chen, Wei Shan ; Eekert, Miriam H.A. van; Buisman, Cees J.N. (2023)
  Journal of Environmental Management 344 .
- Integrated life cycle assessment of biotreatment and agricultural use of domestic organic residues : Environmental benefits, trade-offs, and impacts on soil application
  Liu, Jiyao ; Nauta, Julia ; Eekert, Miriam H.A. van; Chen, Wei Shan ; Buisman, Cees J.N. (2023)
  Science of the Total Environment 897 .
- Effect of organic amendments obtained from different pretreatment technologies on soil microbial community
  Luo, Yujia ; Chavez-Rico, Vania Scarlet ; Sechi, Valentina ; Bezemer, Martijn ; Buisman, Cees J.N. ; Heijne, Annemiek ter (2023)
  Environmental Research 232 .
- Peat fires and the unknown risk of legacy metal and metalloid pollution
  McCarter, Colin P.R. ; Clay, Gareth D. ; Wilkinson, Sophie L. ; Page, Susan ; Shuttleworth, Emma L. ; Davidson, Scott J. ; Taufik, Muh ; Sigmund, Gabriel ; Waddington, James M. (2023)
  Environmental Research Letters 18 (7).
- Improving suitability of urban canals and canalized rivers for transportation, thermal energy extraction and recreation in two European delta cities
  Meulen, E.S. van der; Ven, Frans H.M. van de; Oel, Pieter R. van; Rijnaarts, Huub H.M. ; Sutton, Nora B. (2023)
  Ambio 52 (1). - p. 195 - 209.
- Transport mechanisms in electrodialysis : The effect on selective ion transport in multi-ionic solutions
  Ozkul, Selin ; Daal, Jonathan J. van; Kuipers, Norbert J.M. ; Bisselink, Roel J.M. ; Bruning, Harry ; Dykstra, Jouke E. ; Rijnaarts, Huub H.M. (2023)
  Journal of Membrane Science 665 .

- Quantification of charge carriers and acetate diffusion lengths in intermittent electro-active biofilms using Electrochemical Impedance Spectroscopy
Pereira, João ; Mediayati, Yuniki ; Sleutels, Tom ; Fabregat-Santiago, Francisco ; Heijne, Annemiek ter (2023)
Journal of Power Sources 588 .
- Starvation combined with constant anode potential triggers intracellular electron storage in electro-active biofilms
Pereira, João ; Neves, Patrícia ; Nemanic, Vivian ; Pereira, Maria Alcina ; Sleutels, Tom ; Hamelers, Bert ; Heijne, Annemiek ter (2023)
Water Research 242 . - 11 p.
- Prioritization of micropollutants based on removal effort in drinking water purification treatment
Pronk, Tessa ; Fischer, Astrid ; Berg, Annemijne van den; Hofman, Carola (2023)
Water Quality Research Journal 58 (3). - p. 184 - 198.
- Origin of Limiting and Overlimiting Currents in Bipolar Membranes
Pärnamäe, Ragne ; Tedesco, Michele ; Wu, Min-Chen ; Hou, Chia-Hung ; Hamelers, Hubertus V.M. ; Patel, Sohum K. ; Elimelech, Menachem ; Biesheuvel, P.M. ; Porada, Slawomir (2023)
Environmental Science and Technology 57 (26). - p. 9664 - 9674.
- Bacteria Determine the Measured Oxidation Reduction Potential in the Biological Gas Desulfurization Process
Rink, Rieks de; Liu, Dandan ; Heijne, Annemiek ter; Buisman, Cees J.N. ; Klok, Johannes B.M. (2023)
ACS sustainable chemistry & engineering 11 (1). - p. 38 - 46.
- Characterization of the organic micropollutants behavior during electrochemical ammonia recovery
Rodrigues, Mariana ; Roman, Malgorzata ; Heijne, Annemiek ter; Sleutels, Tom ; Cornelissen, Emile R. ; Verliefde, Arne ; Buisman, Cees J.N. ; Kuntke, Philipp (2023)
Journal of Environmental Chemical Engineering 11 (3).
- Effluent pH correlates with electrochemical nitrogen recovery efficiency at pilot scale operation
Rodrigues, Mariana ; Molenaar, Sam ; Barbosa, Joana ; Sleutels, Tom ; Hamelers, Hubertus V.M. ; Buisman, Cees J.N. ; Kuntke, Philipp (2023)
Separation and Purification Technology 306 (Part A).
- Heat-activated peroxydisulfate and peroxymonosulfate-mediated degradation of benzotriazole : Effects of chloride on kinetics, pathways and transformation product toxicity
Saha, Pradip ; Zhou, Chenyu ; Moradi, Mahsa ; Rijnaarts, Huub H.M. ; Bruning, Harry (2023)
Chemical Engineering Journal Advances 14 . - 12 p.
- Process modelling to facilitate model-based decision-making for resource recovery from urban wastewater - A grey-box approach applied to nanofiltration
Schaik, Maria O. van; Silva Mendonça, Iarima ; Cappon, Hans J. ; Chen, Wei Shan ; Rijnaarts, Huub H.M. (2023)
Journal of Water Process Engineering 54 .
- Organic solvent free PbI_2 recycling from perovskite solar cells using hot water
Schmidt, Felix ; Amrein, Meret ; Hedwig, Sebastian ; Kober-Czerny, Manuel ; Paracchino, Adriana ; Holappa, Ville ; Suhonen, Riikka ; Schäffer, Andreas ; Constable, Edwin C. ; Snaith, Henry J. ; Lenz, Markus (2023)
Journal of Hazardous Materials 447 . - 6 p.
- Enabling efficient phosphorus recovery from cow manure : Liberation of phosphorus through acidification and recovery of phosphorus as calcium phosphate granules
Schott, Chris ; Yan, Liwen ; Gimbutyte, Ugne ; Cunha, Jorge Ricardo ; Weijden, Renata D. van der; Buisman, Cees (2023)
Chemical Engineering Journal 460 . - 12 p.
- Innovation in valorization of cow manure : Higher hydrolysis, methane production and increased phosphorus retention using UASB technology
Schott, Chris ; Cunha, Jorge Ricardo ; Weijden, Renata D. van der; Buisman, Cees (2023)
Chemical Engineering Journal 454 (Part 2).

- Advanced drinking water production by 1 kDa hollow fiber nanofiltration - Biological activated carbon filtration (HFNF - BACF) enhances biological stability and reduces micropollutant levels compared with conventional surface water treatment
  Schurer, R. ; Ridder, D.J. de; Schippers, J.C. ; Hijnen, W.A.M. ; Vredenbregt, L. ; Wal, A. van der (2023)
  Chemosphere 321 . - 16 p.
- Conflicts of Interest in the Assessment of Chemicals, Waste, and Pollution
  Schäffer, Andreas ; Groh, Ksenia ; Sigmund, Gabriel ; Azoulay, David ; Backhaus, Thomas ; Bertram, Michael ; Carney Almroth, Bethanie ; Cousins, Ian ; Ford, Alex ; Grimalt, Joan ; Guida, Yago ; Hansson, Maria ; Jeong, Yunsun ; Lohmann, Rainer ; Michaels, David ; Mueller, Leonie ; Muncke, Jane ; Öberg, Gunilla ; Orellana, Marcos ; Sanganyado, Edmond ; Schäfer, Ralf ; Sheriff, Ishmail ; Sullivan, Ryan ; Suzuki, Noriyuki ; Vandenberg, Laura ; Venier, Marta ; Vlahos, Penny ; Wagner, Martin ; Wang, Fang ; Wang, Mengjiao ; Soehl, Anna ; Ågerstrand, Marlene ; Diamond, Miriam ; Scheringer, Martin (2023)
  Environmental Science and Technology 57 (48). - p. 19066 - 19077.
- Order-of-magnitude enhancement in boron removal by membrane-free capacitive deionization
  Shocron, Amit N. ; Uwayid, Rana ; Guyes, Eric N. ; Dykstra, Jouke E. ; Suss, Matthew E. (2023)
  Chemical Engineering Journal 466 . - 8 p.
- Optimization of an electrochemical direct air capture process with decreased CO_2 desorption pressure and addition of background electrolyte
  Shu, Qingdian ; Sin, Ching Shing ; Tedesco, Michele ; Hamelers, Hubertus V.M. ; Kuntke, Philipp (2023)
  Chemical Engineering Journal 470 .
- Addressing chemical pollution in biodiversity research
  Sigmund, Gabriel ; Ågerstrand, Marlene ; Antonelli, Alexandre ; Backhaus, Thomas ; Brodin, Tomas ; Diamond, Miriam L. ; Erdelen, Walter R. ; Evers, David C. ; Hofmann, Thilo ; Hueffer, Thorsten ; Lai, Adelene ; Torres, Joao P.M. ; Mueller, Leonie ; Perrigo, Allison L. ; Rillig, Matthias C. ; Schaeffer, Andreas ; Scheringer, Martin ; Schirmer, Kristin ; Tlili, Ahmed ; Soehl, Anna ; Triebskorn, Rita ; Vlahos, Penny ; vom Berg, Colette ; Wang, Zhanyun ; Groh, Ksenia J. (2023)
  Global Change Biology 29 (12). - p. 3240 - 3255.
- Controlling Nitrogen Removal Processes in Improved Vertical Flow Constructed Wetland with Hydroponic Materials : Effect of Influent COD/N Ratios
  Sithamparanathan, Elackiya ; Sutton, Nora B. ; Rijnaarts, Huub H.M. ; Kujawa-Roeleveld, Katarzyna (2023)
  Water 15 (6). - 15 p.
- Trace metals from microbial growth media form in situ electro-catalysts
  Smit, Sanne M. de; Mameren, Thomas D. van; Xie, Yiduo ; Strik, David P.B.T.B. ; Bitter, Johannes H. (2023)
  Electrochimica Acta 462 .
- Alternating direction of catholyte forced flow-through 3D-electrodes improves start-up time in microbial electrosynthesis at applied high current density
  Smit, Sanne M. de; Langedijk, Jelle J.H. ; Bitter, Johannes H. ; Strik, David P.B.T.B. (2023)
  Chemical Engineering Journal 464 .
- Methodology for In Situ Microsensor Profiling of Hydrogen, pH, Oxidation-Reduction Potential, and Electric Potential throughout Three-Dimensional Porous Cathodes of (Bio)Electrochemical Systems
  Smit, Sanne M. de; Langedijk, Jelle J.H. ; Haalen, Lennert C.A. van; Lin, Shih Hsuan ; Bitter, Johannes H. ; Strik, David P.B.T.B. (2023)
  Analytical Chemistry 95 (5). - p. 2680 - 2689.
- A 20-year satellite-reanalysis-based climatology of extreme precipitation characteristics over the Sinai Peninsula
  Soltani, Mohsen ; Hamelers, Bert ; Mofidi, Abbas ; Fletcher, Christopher G. ; Staal, Arie ; Dekker, Stefan C. ; Laux, Patrick ; Arnault, Joel ; Kunstmann, Harald ; Hoeven, Ties Van Der; Lanters, Maarten (2023)
  Earth System dynamics 14 (5). - p. 931 - 953.

- Microbial Recycling of Polylactic Acid Food Packaging Waste into Carboxylates via Hydrolysis and Mixed-Culture Fermentation
  Strik, David P.B.T.B. ; Heusschen, Brian (2023)
  Microorganisms 11 (8). - p. 2103 - 2103.
- Use of ion chromatographic pulsed amperometric method (IC-PAD) for measuring aqueous sulfide in synthetic and real domestic wastewater
  Sun, Yue ; Soedarso, Jill A.R. ; Wang, Jiamin ; Gremmen, Pieter ; Rijnaarts, Huub ; Chen, Wei Shan (2023)
  Chemosphere 313 .
- Chemical characteristics of wildfire ash across the globe and their environmental and socio-economic implications
  Sánchez-García, C. ; Santín, C. ; Neris, J. ; Sigmund, G. ; Otero, X.L. ; Manley, J. ; González-Rodríguez, G. ; Belcher, C.M. ; Cerdà, A. ; Marcotte, A.L. ; Murphy, S.F. ; Rhoades, C.C. ; Sheridan, G. ; Strydom, T. ; Robichaud, P.R. ; Doerr, S.H. (2023)
  Environment International 178 .
- Dimensionless Thermal Efficiency Analysis for Aquifer Thermal Energy Storage
  Tang, Darrell W.S. ; Rijnaarts, Huub H.M. (2023)
  Water Resources Research 59 (11).
- Local moisture recycling across the globe
  Theeuwen, Jolanda J.E. ; Staal, Arie ; Tuinenburg, Obbe A. ; Hamelers, Bert V.M. ; Dekker, Stefan C. (2023)
  Hydrology and Earth System Sciences 27 (7). - p. 1457 - 1476.
- Evaluation of long-term performance of plant microbial fuel cells using agricultural plants under the controlled environment
  Tongphanpharn, Natagarn ; Guan, Chung Yu ; Chen, Wei Shan ; Chang, Chao Chin ; Yu, Chang Ping (2023)
  Clean Technologies and Environmental Policy 25 (2). - p. 633 - 644.
- Reversible fouling by particulate matter from natural seawater reduces RED performance while limiting biofouling
  Vital, Bárbara ; Sleutels, Tom ; Gagliano, M.C. ; Hamelers, Hubertus V.M. (2023)
  Desalination 548 .
- Key constructed wetland design features for maximized micropollutant removal from treated municipal wastewater : A literature study based on 16 indicator micropollutants
  Wagner, Thomas V. ; Rempe, Fleur ; Hoek, Mirit ; Schuman, Els ; Langenhoff, Alette (2023)
  Water Research 244 .
- The abiotic removal of organic micropollutants with iron and manganese oxides in rapid sand filters for groundwater treatment
  Wang, Jinsong ; Ridder, David de; Sutton, Nora B. ; Poursat, Baptiste A.J. ; Saha, Pradip ; Wal, Albert van der (2023)
  Water Research 241 .
- Seasonal variation in antibiotic resistance genes and bacterial phenotypes in swine wastewater during three-chamber anaerobic pond treatment
  Wang, Yi ; Sutton, Nora B. ; Zheng, Yunhao ; Dong, Hongmin ; Rijnaarts, Huub H.M. (2023)
  Environmental Research 216 .
- Challenges and opportunities for nutrient circularity : an innovation platform approach
  Wiel, Bernou Zoë van der; Neuberger, Sabine ; Darr, Dietrich ; Wichern, Florian (2023)
  Nutrient Cycling in Agroecosystems .
- Impact of wastewater characteristics on the removal of organic micropollutants by Chlorella sorokiniana
  Wu, Kaiyi ; Atasoy, Merve ; Zweers, Hans ; Rijnaarts, Huub ; Langenhoff, Alette ; Fernandes, Tânia V. (2023)
  Journal of Hazardous Materials 453 . - 8 p.
- Enhancement of Ammonium Oxidation at Microoxic Bioanodes
  Yan, Xiaofang ; Liu, Dandan ; Klok, Johannes B.M. ; Smit, Sanne M. de; Buisman, Cees J.N. ; Heijne, Annemiek ter (2023)
  Environmental Science and Technology 57 (31). - p. 11561 - 11571.

- Polylactic acid films reinforced with chitin nanocrystals: Biodegradation and migration behavior
  Yanat, Murat ; Muthurajan, Madhumitha ; Strubel, Maurice ; Grolle, Katja ; Schroën, Karin (2023)
  Food Packaging and Shelf Life 40 .
- Basket anode filled with $CaCO_3$ particles : A membrane-free electrochemical system for boosting phosphate recovery and product purity
  Zhan, Zhengshuo ; Wang, Runhua ; Saakes, Michel ; Weijden, Renata D. van der; Buisman, Cees J.N. ; Lei, Yang (2023)
  Water Research 231 .
- CaO_2/UV Process for One-Step Phosphorus Removal and Recovery from Hypophosphite : Simultaneous Oxidation and Precipitation
  Zhang, Shaopeng ; Song, Bingnan ; Wang, Runhua ; Zhan, Zhengshuo ; Saakes, Michel ; Weijden, Renata D. van der; Buisman, Cees J.N. ; Lei, Yang (2023)
  ACS ES&T Water 3 (3). - p. 866 - 875.
- Transport characterization and modelling of Donnan dialysis for ammonium recovery from aqueous solutions
  Zwijnenberg, Harmen J. ; Elozeiri, Alaaeldin A.E. ; Grooth, Joris de; Meer, Walter G.J. van der; Wood, Jeffery A. (2023)
  Journal of Membrane Science 674 .

Non-refereed article in a journal

- Correction to: Enhanced Oxygen Volumetric Mass Transfer in a Geometrically Constrained Vortex
  Agostinho, Luewton ; Pecnik, Rene ; Woisetschläger, Jakob ; Kroon, Esther de; Şişcanu, Nicolae ; Griend, Maarten V. van de; Loiskandl, Willibald ; Fuchs, Elmar C. (2023)
  Water 15 (13).
- Corrigendum to “Anaerobic sulphide removal by haloalkaline sulphide oxidising bacteria”
  Linssen, Rikke ; Slinkert, Thomas ; Buisman, Cees J.N. ; Klok, Johannes B.M. ; Heijne, Annemiek ter (2023)
  Bioresource Technology 385 .

Refereed book chapters

- Nano- and microplastics in water
  Hofman-Caris, Roberta ; Bäuerlein, Patrick (2023)
  In: Industrial Applications of Nanoparticles / Litter, M.I., Ahmad, A., Taylor & Francis, - p. 135 - 152.

PhD Theses internally prepared

- Organic residue engineering to increase organic matter in agricultural soils
  Chavez-Rico, Vania Scarlet (2023)
  Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): M.H.A. van Eekert; P.L.E. Bodelier. - Wageningen : Wageningen University, - 188
- Exploring the degradation of organosulfur compounds at biocathodes
  Elzinga, Margo (2023)
  Wageningen University. Promotor(en): A. ter Heijne; C.J.N. Buisman, co-promotor(en): J.B.M. Klok. - Wageningen : Wageningen University, - 189
- The BO3 process for removal of micropollutants from wastewater treatment plant effluent : exploring the synergies between biological treatment and ozonation
  Gijn, Koen van (2023)
  Wageningen University. Promotor(en): H.H.M. Rijnaarts, co-promotor(en): A.A.M. Langenhoff; H.A. de Wilt. - Wageningen : Wageningen University, - 212

- Thermoacidophilic elemental sulfur reduction for the recovery of metals from hydrometallurgical streams
  Hidalgo-Ulloa, Adrian Alejandro (2023)
  Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): A.R. Mol. - Wageningen : Wageningen University, - 198
- Functional quality of urban surface water
  Meulen, Suzanne van der (2023)
  Wageningen University. Promotor(en): H.H.M. Rijnaarts, co-promotor(en): N.B. Sutton; F.H.M. van de Ven; P.R. van Oel. - Wageningen : Wageningen University, - 185
- Sustaining Industrial water provision in Vietnam : Strategies and technologies
  Minh Truong, Le (2023)
  Wageningen University. Promotor(en): H.H.M. Rijnaarts, co-promotor(en): K. Kujawa-Roeleveld; Tran Thi My Dieu. - Wageningen : Wageningen University, - 209
- Biofilm growth and electron storage at anodes
  Pereirã, João (2023)
  Wageningen University. Promotor(en): A. ter Heijne, co-promotor(en): H.V.M Hãmelers; T.H.J.A. Sleutels. - Wageningen : Wageningen University, - 214
- Recovery of phosphorus from animal manure
  Schott, Chris (2023)
  Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): R.D. van der Weijden; J.R.M.A. Cunha. - Wageningen : Wageningen University, - 214
- Design and development of an electrochemical direct air capture Process
  Shu, Qingdian (2023)
  Wageningen University. Promotor(en): H.V.M Hamelers, co-promotor(en): P. Kuntke; M. Tedesco. - Wageningen : Wageningen University, - 165
- Improving vertical flow constructed wetlands with novel filter materials to treat wastewater
  Sithamparanathan, Elackiya (2023)
  Wageningen University. Promotor(en): H.H.M. Rijnaarts, co-promotor(en): K. Kujawa-Roeleveld; N.B. Sutton. - Wageningen : Wageningen University, - 262
- Strategies for hydrogen evolution catalyst integration in microbial electrosynthesis
  Smit, Sanne Mensje de (2023)
  Wageningen University. Promotor(en): C.J.N. Buisman; J.H. Bitter, co-promotor(en): D.P.B.T.B. Strik. - Wageningen : Wageningen University, - 253
- Fouling and process design in reverse electrodialysis: a study with natural waters
  Vital, Bárbara (2023)
  Wageningen University. Promotor(en): H.V.M. Hamelers, co-promotor(en): T. Sleutels; M.C. Gagliano. - Wageningen : Wageningen University, - 194
- Removal of organic micropollutants from drinking water in rapid sand filters
  Wang, Jinsong (2023)
  Wageningen University. Promotor(en): A. van der Wal, co-promotor(en): N.B. Sutton. - Wageningen : Wageningen University, - 256
- Microalgae-based technology for wastewater treatment: exploring organic micropollutants removal
  Wu, Kaiyi (2023)
  Wageningen University. Promotor(en): H.H.M. Rijnaarts, co-promotor(en): T.V. Fernandes; A.A.M. Langenhoff. - Wageningen : Wageningen University, - 204

Refereed conference paper

- A Classification of Existing and Emerging Hydrogen Storage Technologies
  Bosch, Niamh ; Bianchi, Alessio Belmondo ; Torbaghan, Shahab Shariat (2023)
  In: 2023 IEEE Belgrade PowerTech, PowerTech 2023. - IEEE, (2023 IEEE Belgrade PowerTech, PowerTech 2023) 2023 IEEE Belgrade PowerTech, PowerTech 2023, Belgrade, 2023-06-25/2023-06-29

- Energy Storage Arbitrage in Day-Ahead Electricity Market Using Deep Reinforcement Learning
  Zonjee, Tim ; Torbaghan, Shahab Shariat (2023)
  In: 2023 IEEE Belgrade PowerTech, PowerTech 2023. - IEEE, (2023 IEEE Belgrade PowerTech, PowerTech 2023) 2023 IEEE Belgrade PowerTech, PowerTech 2023, Belgrade, 2023-06-25/2023-06-29

Professional publications

Article in journal

- Nieuwe technologie voor vergaande verwijdering medicijnresten praktijkklaar
  Bechger, M. ; Gijn, K. van; Langenhoff, A.A.M. ; Rijnaarts, H.H.M. ; Piai, L. ; Wilt, H.A. de (2023)
  Water Matters : Kenniskatern voor Waterprofessionals - Dutch edition (17). - p. 4 - 7.
- Drijvende helofytenfilters verwijderen nutriënten en microverontrenigingen uit oppervlaktewater
  Waijjen, H.B.G. van; Bles, F. de; Buschgens, A. ; Kujawa-Roeleveld, K. (2023)
  Water Matters : Kenniskatern voor Waterprofessionals - Dutch edition (17). - p. 8 - 11.

Reports

- Innovatieve stalsystemen voor verwaarding van varkens-, kalver- en rundveemest : NL Next Level Mestverwaarden
  Boxmeer, Emma van; Groeneveld, Ilse ; Verdoes, Nico ; Maasdam, Rik ; Gastel, Jos van (2023)
  Wageningen : Wageningen Livestock Research, (Rapport / Wageningen Livestock Research 1409) - 47
- Micronutriënten in de Kringloop : eindrapportage WP4 : afvalwater en huishoudelijk organisch afval, herkomst, bestemming en stofstroom analyse, scenariostudies voor terugwinning uit huishoudelijke organische reststromen
  Eekert, Miriam van; Bisschops, Iemke (2023)
  Wageningen : Wageningen University & Research, - 151
- Methaanlekkage bij mestvergisters : kwalitatieve screening van 10 Jumpstart mono-mestvergisters
  Maasdam, E. (2023)
  Wageningen : Wageningen Livestock Research, (Rapport / Wageningen Livestock Research 1439) - 31
- Verificatie van het Farmer Technologies BV zeolieten filter : Pilottest ammoniak- en geurverwijdering uit varkensstallucht
  Maasdam, E. (2023)
  Wageningen : Wageningen Livestock Research, (Rapport / Wageningen Livestock Research 1408) – 23

Other output

Patent

- Removal of micropollutants from water and installation for use therein
  Wilt, Henrik Arnoud de; Gijn, Koen van; Langenhoff, Alette Anna Maria ; Rijnaarts, Hubertus Henricus Martinus (2023)
  Octrooinummer: WO2023078839, gepubliceerd: 2023-05-11.

Abstract

- Air filtering as alternative approach to combat emissions from cattle facilities
  Kuipers, A. ; Galama, P.J. ; Maasdam, E. ; Spoelstra, S.F. ; Groot Koerkamp, P.W.G. (2023)
  In: Book of Abstracts of the 74th Annual Meeting of the European Federation of Animal Science. - Wageningen : Wageningen Academic Publishers, (Book of Abstracts 29) EAAP - 74th Annual Meeting (2023), Lyon, 2023-08-26/2023-09-01 - p. 305 - 305.

Remaining Output

- Bioaugmentation simulated gw systems
  Aldas Vargas, Andrea ; Kers, Jannigje G. ; Smidt, Hauke ; Rijnaarts, Huub ; Sutton, Nora (2023)
  Wageningen University and Research Centre,
- Health, food, water and sustainability at the rural-urban interface in the global south
  Bailey, Ajay ; Zwietering, Marcel ; Feskens, Edith ; Kujawa, Katarzyna (2023)
- Experimental data: Starvation combined with continuous anode potential triggers intracellular electron storage in Geobacter dominated electro-active biofilms
  Fontes Pereira, João Pedro ; Sleutels, Tom ; Neves, Patricia ; Nemanic, Vivian ; Hamelers, Bert ; Heijne, Annemiek ter; Pereira, Maria Alcina (2023)
  Wageningen University & Research,
- Mapping the potential of the food loss and waste flows for circularity applications in the Amsterdam Metropolitan Area
  Guo, X. ; Rodriguez Illera, M. ; Vollebregt, H.M. ; Wei, Y. ; Chen, W.S. (2023)
- Data underlying the publication: Microbial Recycling of PLA Food Packaging Waste into Carboxylates via Hydrolysis and Mixed-Culture Fermentation
  Heusschen, Brian ; Strik, David (2023)
  Wageningen University & Research,
- Data underlying the publication "Electric discharge by sulphide shuttling bacteria"
  Linssen, Rikke ; Heijne, Annemiek ter (2023)
  Wageningen University & Research,
- Data underlying the publication "Anaerobic sulphide removal by haloalkaline sulphide oxidising bacteria"
  Linssen, Rikke ; Heijne, Annemiek ter; Slinkert, Thomas ; Buisman, Cees ; Klok, Jan (2023)
  Wageningen University & Research,
- Experimental data: Quantification of charge carriers and acetate diffusion lengths in intermittent electro-active biofilms using Electrochemical Impedance Spectroscopy
  Pereira, João ; Heijne, Annemiek ter; Sleutels, Tom ; Mediayati, Yuniki ; Fabregat-Santiago, Francisco (2023)
  Wageningen University & Research,
- Experimental Data: Optimization of an electrochemical direct air capture process with decreased CO2 desorption pressure and addition of background electrolyte
  Shu, Qingdian ; Shing Sin, Ching ; Tedesco, M. ; Hamelers, Hubertus V.M. ; Kuntke, Philipp (2023)
  Wageningen University,
- Alternating direction of catholyte forced-flow though 3D-electrodes improves start-up time in microbial electrosynthesis at applied high current density
  Smit, Sanne M. de; Langedijk, Jelle J.H. ; Bitter, Johannes H. ; Strik, David P.B.T.B. (2023)
  Wageningen University & Research,
- Data underlying the publication: Trace metals from microbial growth media form in situ electro-catalysts
  Smit, Sanne de; Mameren, Thomas D. van; Xie, Yiduo ; Strik, David ; Bitter, Johannes H. (2023)
  Wageningen University & Research,
- Dataset "Alternating direction of catholyte forced flow-through 3D-electrodes improves start-up time in microbial electrosynthesis at applied high current density"
  Smit, Sanne de; Langedijk, Jelle J.H. ; Bitter, Harry ; Strik, David (2023)
  Wageningen University & Research,
- Data underlying the publication: Microbial Recycling of Bioplastics via Mixed-Culture Fermentation of Hydrolyzed Polyhydroxyalkanoates into Carboxylates
  Strik, David ; Leeuw, Kasper de; Jin, John (2023)
  Wageningen University & Research,
- Local moisture recycling across the globe
  Theeuwen, Jolanda J.E. ; Staal, Arie ; Tuinenburg, Obbe A. ; Hamelers, Bert V.M. ; Dekker, Stefan C. (2023)
  Utrecht University,

- Dataset for Evaluation of chemical free cleaning techniques for RED fed with natural waters and stacks with profiled membranes
  Vital, Barbara ; Sleutels, Tom ; Gagliano, Maria Cristina ; Hamelers, Bert ; Martinez Baron, D. (2023)
  Wageningen University & Research,
- Dataset for the article: Unravelling the contribution of nitrifying and methanotrophic bacteria to micropollutant co-metabolism in rapid sand filters
  Wang, Jinsong ; Zhang, Chen ; Poursat, Baptiste A.J. ; Ridder, David de; Smidt, Hauke ; Wal, Albert van der; Sutton, Nora B. (2023)
  Wageningen University,
- Dataset for the article: Exploring organic micropollutant biodegradation under dynamic substrate loading in rapid sand filters
  Wang, Jinsong ; Poursat, Baptiste A.J. ; Feng, Jiahao ; Ridder, David de; Zhang, Chen ; Wal, Albert van der; Sutton, Nora B. (2023)
  Wageningen University,
- Retaste: Rethink food resources, losses and waste 2023
  Wei, Yujun ; Rodriguez Illera, Marta ; Guo, Xuezhen ; Vollebregt, Martijntje ; Chen, Wei-Shan (2023)