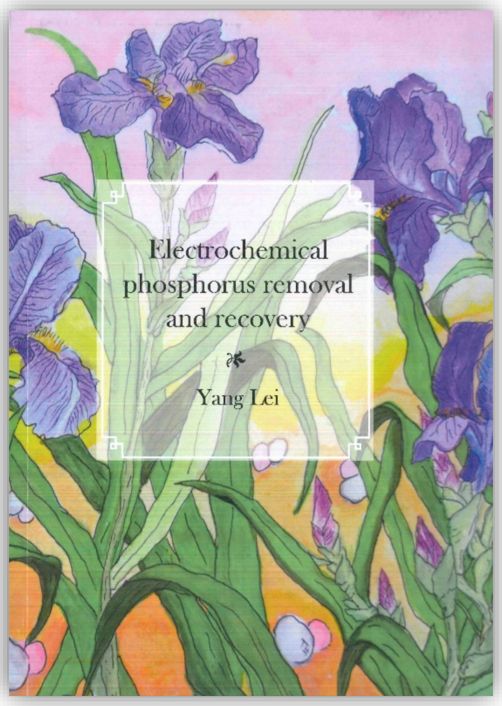
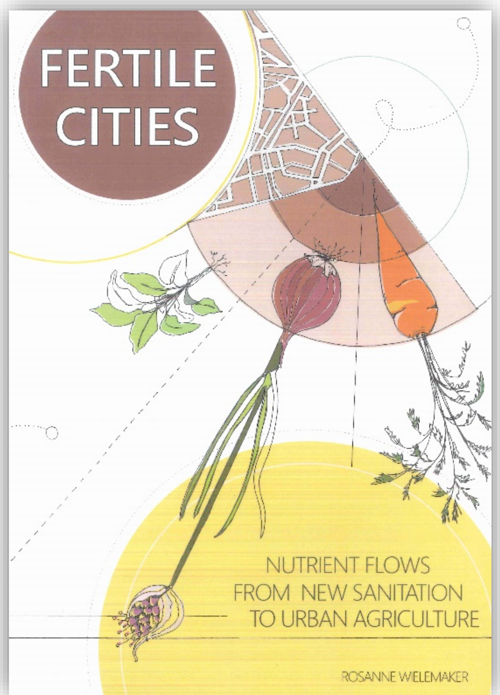
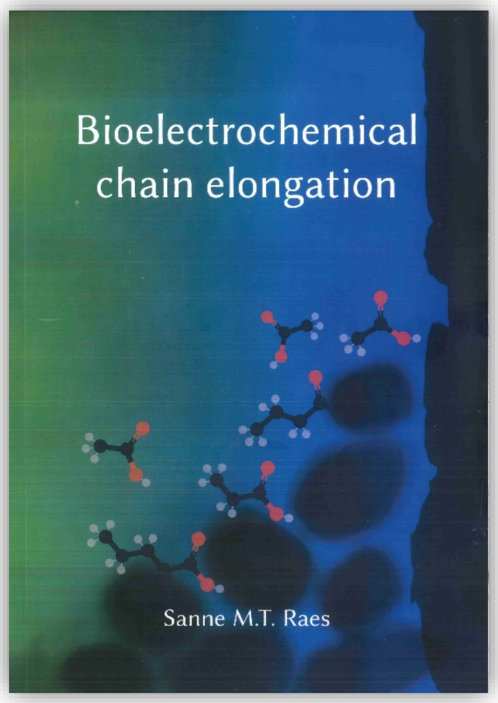
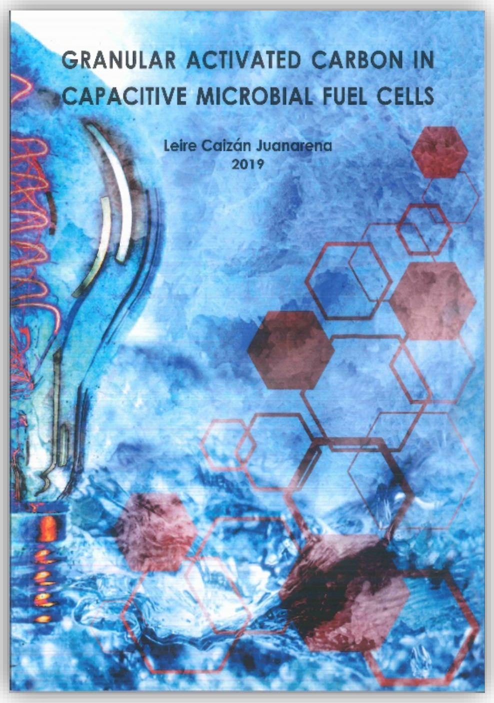


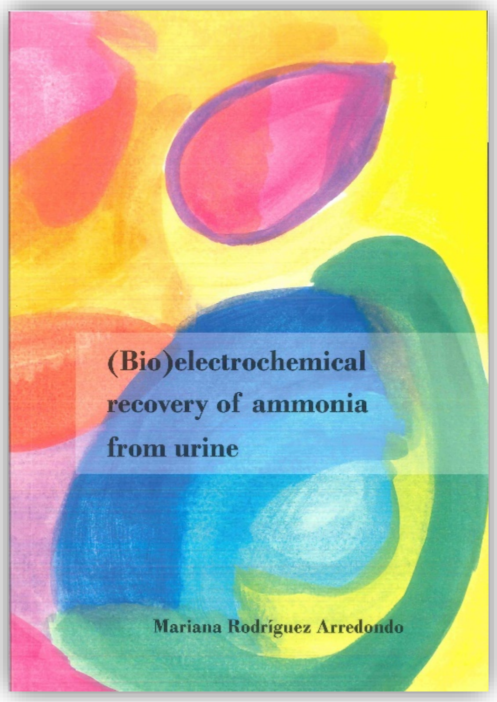


Environmental Technology 2020

Metropolitan and Environmental Solutions







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 2019. Education and research results are presented in terms of the 'output numbers' such as the number of MSc and PhD students, a list of the courses and educational programmes ETE participated in, concise information on each of our running research projects, and our list of 2019 publications.

The Environmental Technology Group

The ETE group is chaired by Huub Rijnaarts, Professor in Environment and Water Technology since September 2009. Prof. Cees Buisman holds since 2003 the chair in Biological Recovery and Reuse Technology. Cees and Huub form together the strategic leadership of the group. In addition we also have the special chairs of professors Prof. Dr. Ir. Albert Janssen (Biological Gas Treatment) and Prof. Dr.Ir. Bert van der Wal (Electrochemical Water Treatment), a special associate professor Dr. Ir Arjen van Nieuwenhuijzen, 18 members of scientific staff (from which 3 lecturers), 8 Laboratory and technology supporting co-workers, 7 postdocs, 68 PhD students, and 85 graduating MSc and 9 BSc students. We hope to announce in 2020 two more special professors.

Mission

The mission of the ETE group is to create unique breakthrough natural technologies for establishing new systems for recovery and reuse for both water and resources. A strong biotechnological component is combined with physics, chemistry and also social sciences. Concepts such as bio-crystallization, bioavailability, bio-retention and bio-electrochemistry generate technologies for producing products such as recyclable matters, reusable water and renewable energy. In our vision, we belief that new technologies come into society through entrepreneurial companies, and therefore we have strong cooperation with industrial technology companies and stimulate technology spin offs. 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 and industrial systems help to reduce Human Footprints and safeguard a sustained supply of water, energy and other resources for the growing world population. 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.

Awards/Grants

- Annemiek ter Heijne was awarded the prestigious NWO Vidi grant.
- Arnoud de Wilt, former PhD resecher at ETE has won the Jaap van der Graaf prize. Azie Sabri was also nominated for this prize.
- Yang Lei won the Marcel Mulder prize.
- Yang Lei won the Chinese Government Award for Outstanding Self-Financed Students Abroad.

Research

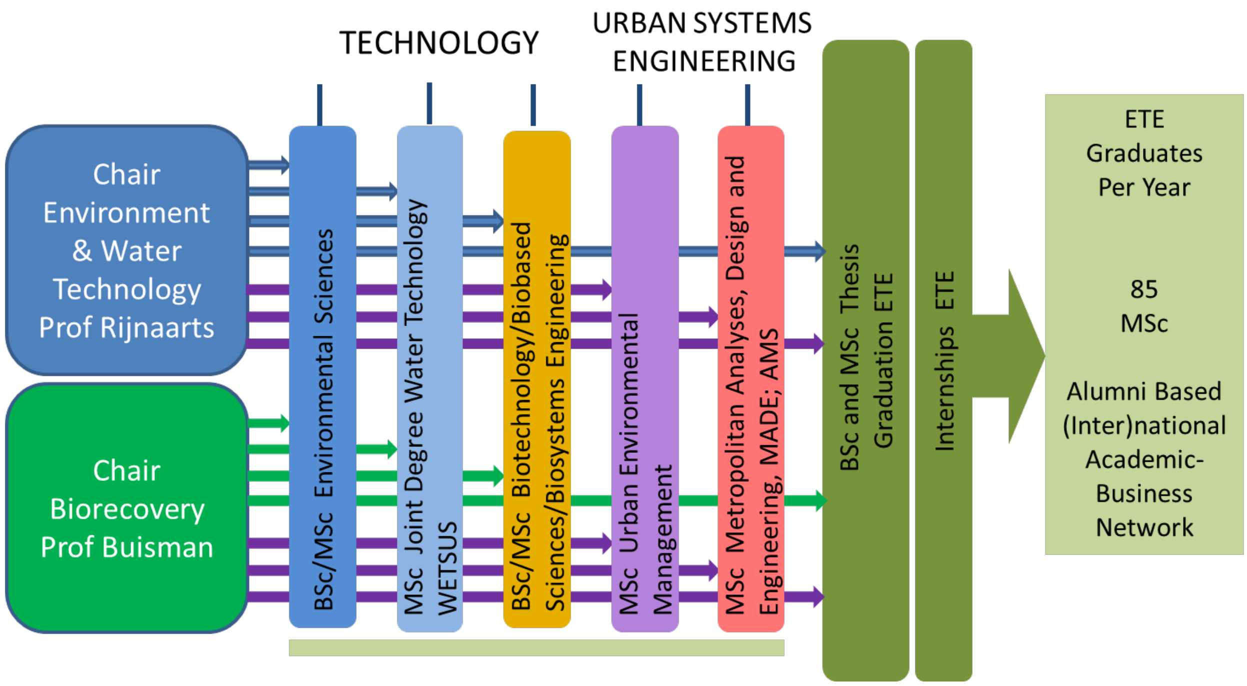
Our research program is characterized as follows:

⇒ **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.

⇒ **Reusable Water**: Technology focus is on bio-removal of micro pollutants and pathogens and the qualities of 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.

Education of ETE: Three environmental technology and two urban systems engineering programs delivering 85 MSc 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. Cees J.N. Buisman and Prof.dr.ir. Huub H.M. Rijnaarts
(Chairman ETE group)

Environmental Technology
Wageningen University
Bornse Weilanden 9
6708 WG Wageningen
The Netherlands

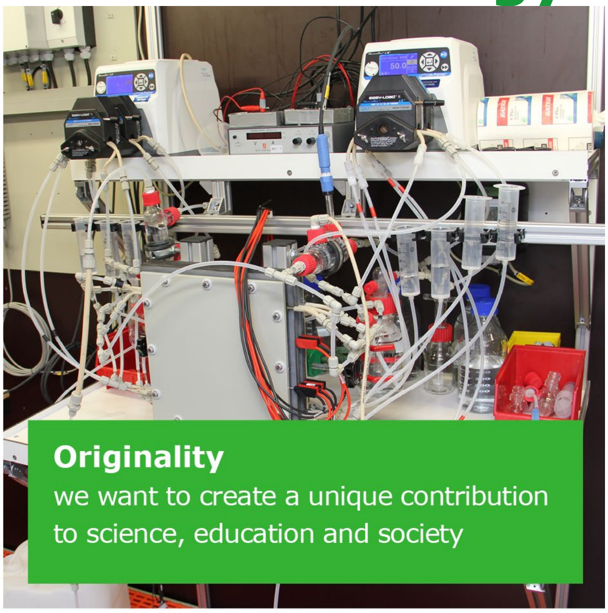
tel. +31 317 483339
email: Office.ETE@wur.nl
www.wur.nl/ete

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

Integrity
we stand for our principles and follow our vision and mission



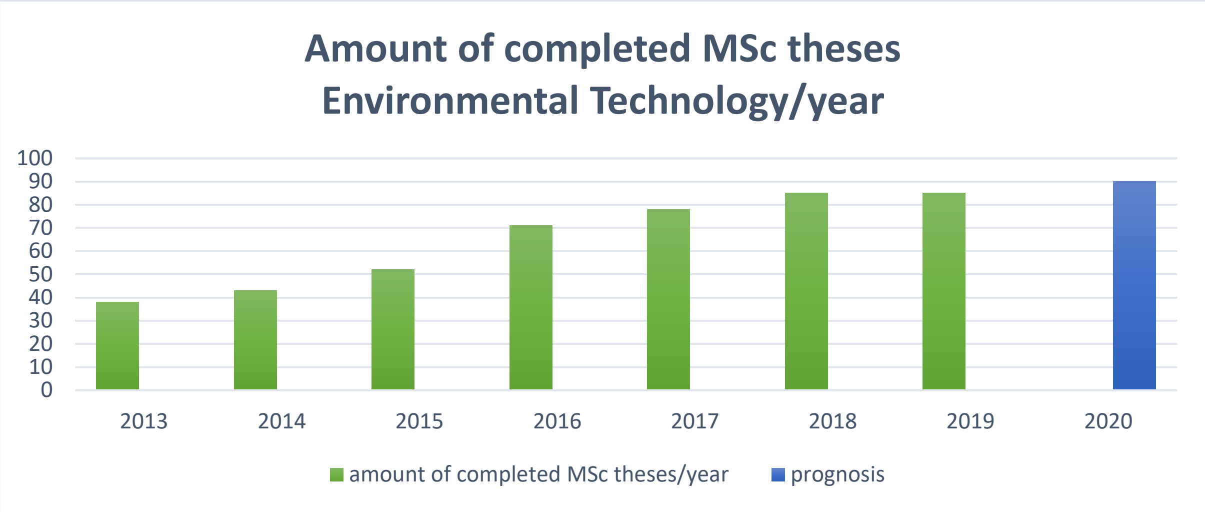
Originality
we want to create a unique contribution to science, education and society

Togetherness
we want everyone in our group to be an active participant

Personal Involvement
we show interest professionally and privately in colleagues and students

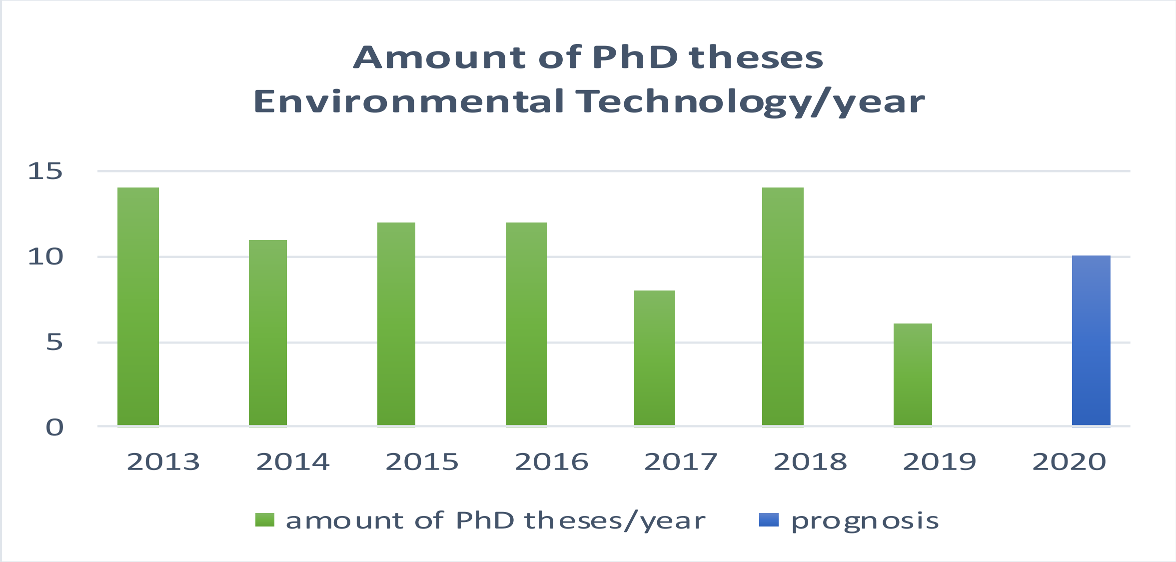
Output ETE 2019

In 2019, 85 MSc student completed a thesis. In the coming years we expect an increase, based on the expected increase on the total number of students, both in the master water technology in Leeuwarden, as well as at Wageningen University.

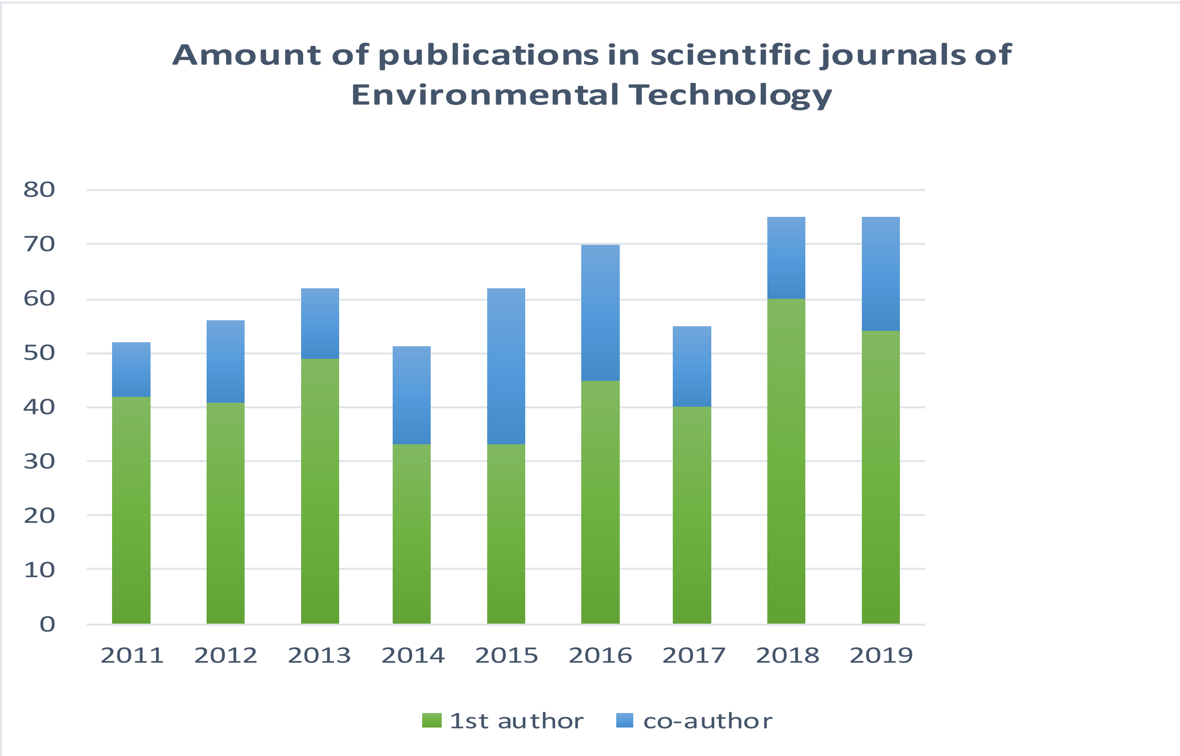


In 2019 we had 6 PhD defences. By the beginning of 2020 67 PhD students were working on their PhD research and did not yet graduate.

PhD Theses Environmental Technology 2019		
Name	**Promotor(s)**	**Title**
Caizán Juanarena, Leire	Buisman	Granular activated carbon in capacitive microbial fuel cells
Galvis Castaño, Alberto	Gijzen	Integrated pollution prevention and control for the municipal water cycle in a river basin context: validation of the three-step strategic approach
Lei, Yang	Buisman	Electrochemical phosphorus removal and recovery
Raes, Sanne M.T	Buisman	Bioelectrochemical chain elongation
Rodríguez Arredondo, Mariana	Buisman	(Bio)electrochemical recovery of ammonia from urine
Wielemaker, Rosanne	Zeeman/ Oenema	Fertile cities : Nutrient flows from new sanitation to urban agriculture



The complete Publication List of Environmental Technology 2019 can be found at the end of this brochure.



Education

Environment and Water 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 social aspects by co-operating with Environmental Policy and Economy, related groups.

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 (BMW)

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)

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 now 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 2020
ETE10806	Introduction Environmental Technology	• Excursion to soil remediation locations
ETE21306	Water Treatment	• Water treatment plant Amersfoort
ETE22806	Principles of Urban Environmental Management	• NIOO Wageningen • AVR Duiven
ETE23803	Environmental Process Engineering	
ETE24304	Treatment of (Micro)Pollutants in Soil and Water Systems	
ETE24804	Fundamentals of Environmental Technology	•
ETE 25306	Basics of Urban Environmental Technology	• Wastewater treatment plant • Solid Waste Management company
ETE25812	Environmental Project studies	
ETE30306	Biological Processes for Resource recovery	
ETE30806	Physical and Chemical Processes for Water Treatment and Reuse	
ETE32306	Renewable Energy: Sources, Technology & Applications	
ETE32806	Managing Urban Environmental Infrastructure	• Green Village Delft • Infrastructural sites
ETE33806	Planning and Design of Urban Space	• Virtual excursion Culemborg – EVA Lanxmeer: • Nieuwegein Centrum West
ETE34306	Energy, Water and Waste Cycles in the Built Environment	• Schoonschip Amsterdam • De Ceuvel Amsterdam

ETE34806	Resource Quality in the Circular Economy	• Circular water systems in the Western part of the Netherlands
ETE50401/ ETE50406	Capita Selecta Environmental Technology	
ETE50803/ ETE50806	Capita Selecta Urban Environmental Technology and 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
ETE70424/ ETE70439 Internship Environmental Technology	ETE70824/ETE70839 Internship Urban Sytems Engineering
ETE80418/ETE80439 Thesis Environmental Technology	ETE81824/ETE81839 Thesis Urban Sytems Engineering

PhD courses (WIMEK-SENSE)
Masterclass Biobased innovation
Masterclass Modelling Urban Environmental Systems

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 next door 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 12 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 disposal, nitrogen and compressed air and ventilation. Some units we can control the temperature between 15-35 ^oC . 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 the near future Modutech will have the unique possibility to work under fully anoxic conditions in select 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. 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. A pipeline from the town of Bennekom directs wastewater (1 m^3/hour) to Modutech for research, which can 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. The diversity and quantity of equipment support almost any experimental setup and allow clients to run several experiments simultaneously.

Laboratory facilities @ ETE

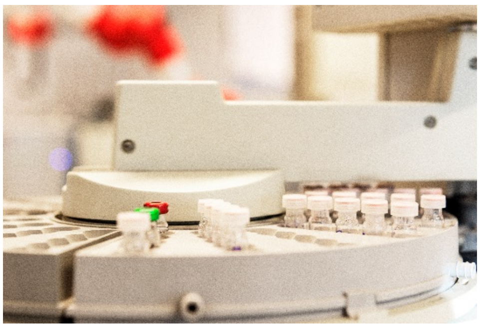
MODUTECH is supported by a well-equipped analytical research environment with an analytical staff of 5 persons (3.9 fte). They have broad practical knowledge in research and take care of the lab organisation, equipment and support in teaching and guiding the students and researchers in their practical period. Furthermore they take care of the practical input during the practical periods in the ETE educational program. The lab provides the researchers with basic laboratory equipment and a set of route analysis methods (e.g. biogas analysis, VFA & MCFA analysis, PAH analysis, TPH analysis, ICP metal analysis). In addition to the routine setups we 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.

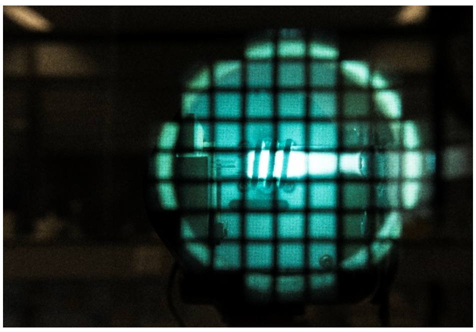
Environmental Technology makes use of concepts and mechanisms from different scientific disciplines also making microbiological facilities important. An anaerobic hood, laminar flow cabinet and microscopes offer us the possibility to make use of these topics in our studies. Of course we also have collaborations with colleague university group which gives us access to more specialised research techniques.

Overview of available measuring techniques in the ETE analytical labs.

Principle	Equipment	Detections method	To analyze
Chromatography	GC	FID	VFA & MCFA
			SC Alcohols
			TPH
			BTEX
		ECD	Chlorinated compounds
		HWD	O_2, N_2, CH_4, CO_2, CO, H_2
		IontrapMS	general
	LC	RI	sugars
		UV-Fluorescence	PAHs
		DAD-iontrapMS	u-pollutants (medicines, pesticides, hormones)
	IC	Conductivity	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, NH_4^+
		UV	AsO_4^{3-}/AsO_3^{3-}
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
Crystallography	XRD	Angle diffraction	Minerals

In 2015 the lab team has started working on improving instrumental lab efficiency by screening the need of specific analytical instruments. The outcome is a plan to upgrade the current analytical systems to be able to combine current analytical possibilities with future analytical needs keeping in mind user friendliness. In 2016 we aim to make a start with replacing some old systems which will be offered to partners interested.

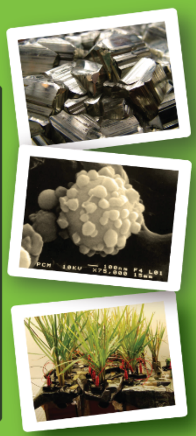




Environmental Technology

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

dr. Renata van der Weijden

E-mail:
Renata.vanderweijden@wur.nl

Tel: 0317-483851

dr.ir. Annemiek ter Heijne

E-mail:
Annemiek.terheijne@wur.nl

Tel: 0317-483447

dr.ir. Miriam van Eekert

E-mail:
Miriam.vaneekert@wur.nl

Tel: 0317 483360

prof.dr.ir. Albert Janssen

E-mail:
Albert.Janssen@wur.nl

Tel: 0317-483339

dr.ir. David Strik

E-mail:
David.Strik@wur.nl

Tel: 0317-483447

Dr.ir. Hardy Temmink

E-mail:
Hardy.Temmink@wur.nl

Tel: 0317-484805

Reusable Water and Urban Systems Engineering

dr. Katarzyna Kujawa

E-mail:
Katarzyna.Kujawa@wur.nl

Tel: 0316-485404

dr.ir. Alette Langenhoff

E-mail:
Alette.Langenhoff@wur.nl

Tel: 0317-480254

dr. Nora Sutton

E-mail:
Nora.Sutton@wur.nl

Tel: 0317 48 32 28

dr.ir. Harry Bruning

E-mail:
Harry.Bruning@wur.nl

Tel: 0317-483798

prof.dr.ir. Bert van der Wal

E-mail:
Bert.vanderwal@wur.nl

Tel: +316 20355523

Dr.ir. Tim Grotenhuis

E-mail:
Tim.Grotenhuis@wur.nl

Tel: 0317-482561

Biorecovery and Urban System Engineering

dr.ir. Jan Weijma

E-mail: Jan.Weijma@wur.nl

Tel: 0317-483851

dr. Phillip Kuntke

E-mail: Phillip.Kuntke@wur.nl

Tel: 0317-483339

Reusable Water and Urban System Engineering

dr. Hans Cappon

E-mail: Hans.Cappon@wur.nl

Tel: 0118-48 92 16

dr. Wei-Shan Chen

E-mail: Wei-shan.chen@wur.nl

Tel: 0317-486941

dr.ir. Jouke Dykstra

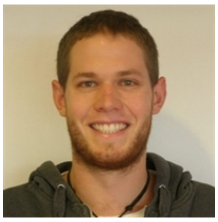
E-mail: Jouke.Dykstra@wur.nl

Tel: 0317-488110

dr. Dainis Sudmalis

E-mail: Dainis.Sudmalis@wur.nl

Tel: 0317-483339



dr. Joeri Willet

E-mail: Joeri.Willet@wur.nl

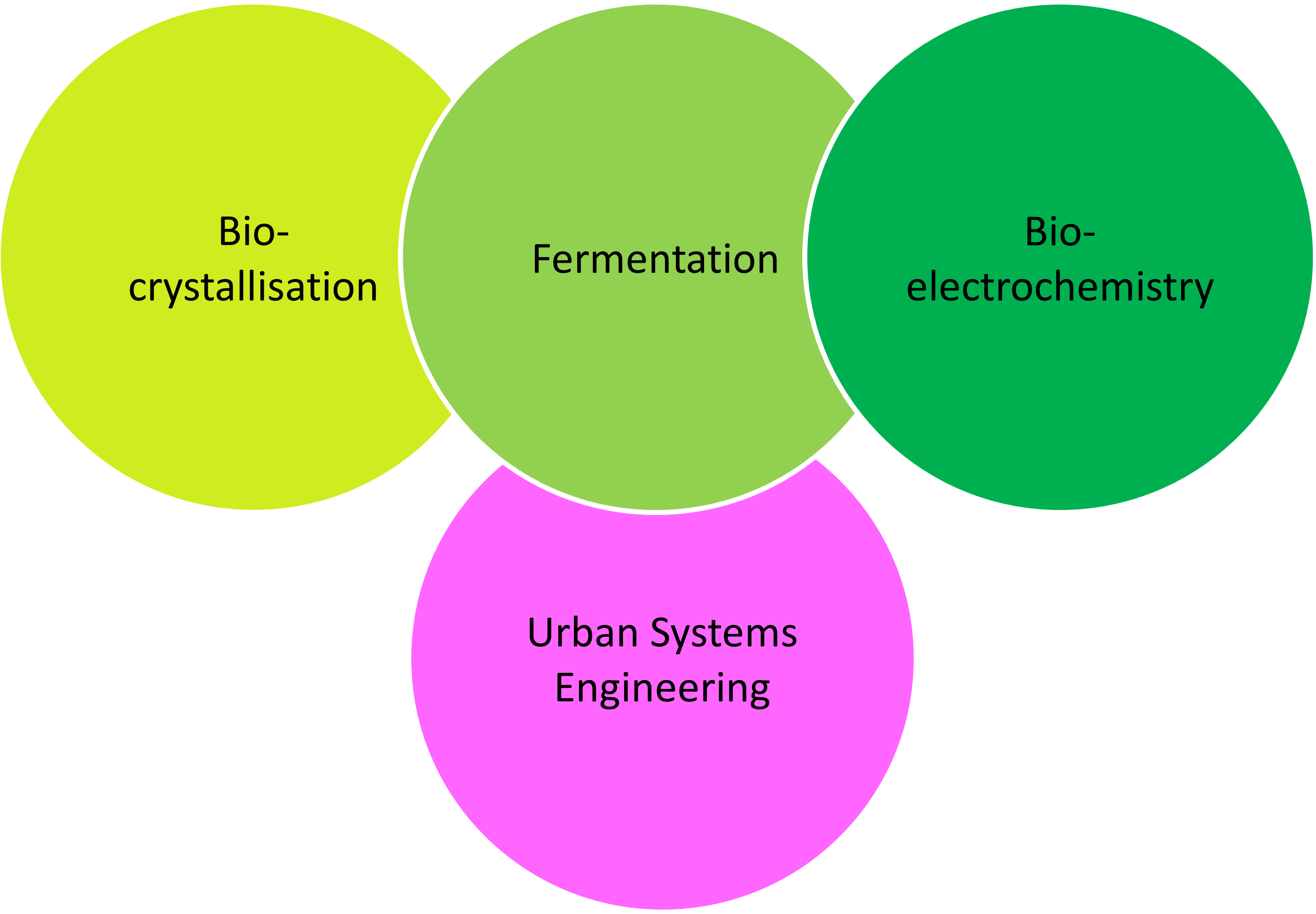
Tel: 0317-483339

dr. Shahab Shariat Torbaghan

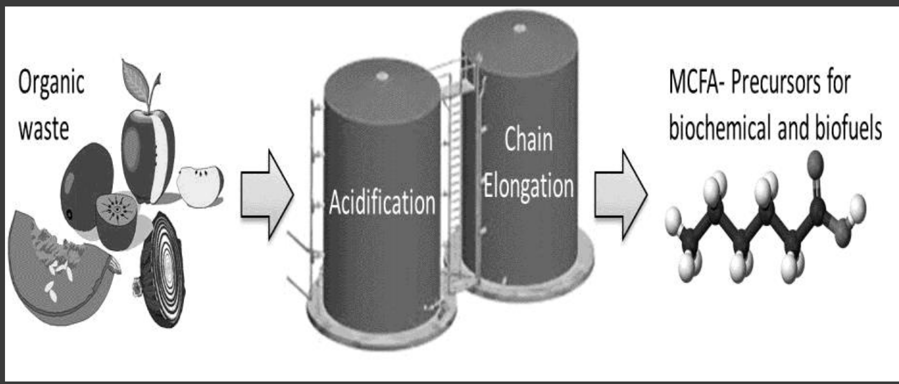
E-mail: Shahab.Torbaghan@wur.nl

Tel: 0317-483339

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.

Controlling Properties of Sulfur Particles Formed in Biological Desulfurization

Aug 2016 – May 2021

Researcher
Annemerel Mol

Supervisors
Dr. Renata van der Weijden
Dr. ir. Jan Klok

Promotor
Prof. dr. ir. Cees Buisman

Environmental Technology

Motivation

Biogas, natural gas and other fuel gasses may contain corrosive components such as H_2S, which has detrimental effects on the environment when combusted. Consequently, it is required to remove H_2S from gas before it can be used. Hence, a biotechnological desulfurization process was developed at Wageningen University, which uses natron-alkaline sulfide oxidizing bacteria to convert the H2S to harmless and re-usable elemental sulfur (Fig. 1).

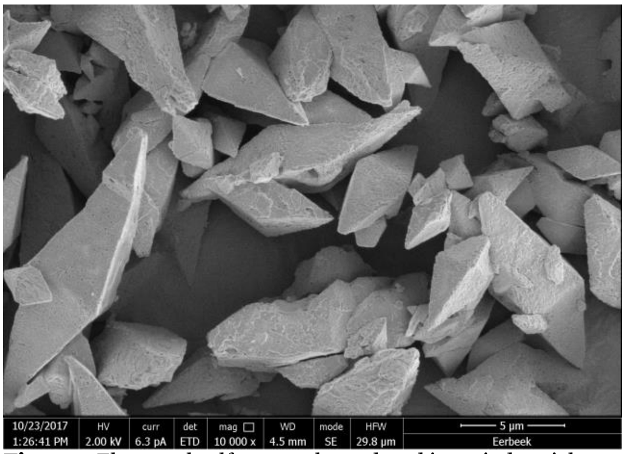


Figure 1 Elemental sulfur crystals produced in an industrial biotechnological desulfurization reactor

The biological process is an alternative to chemo-physical processes which are commonly applied in industry. Advantages of the biological process are (i) no consumption of chelating chemicals, (ii) operation at atmospheric pressure and ambient temperature, (iii) high removal efficiency with a sulfide-free waste stream and (iv) beneficial use of the biologically produced sulfur. The elemental sulfur can be re-used in various industries as raw material or as fertilizer or fungicide in agriculture.

Technological challenge

In the process, H_2S is absorbed into a mild alkaline liquid and dissociated (Eq.1). Subsequently, the dissolved HS^- is oxidized to elemental sulfur in a bioreactor (Eq.2). The produced OH^- regenerates the buffer by the production of CO_3^{2-} (Eq. 3).

$$H_2S\,(l) + CO_3^{2-} \rightleftarrows HS^- + HCO_3^- \quad (1)$$

$$HS^- + ½O_2 \rightarrow ⅛S_8^0 + OH^- \quad (2)$$

$$HCO_3^- + OH^- \rightleftarrows H2O + CO_3^{2-} \quad (3)$$

Knowledge on how to control the properties (like size and morphology) of the produced sulfur particles is crucial for stable process operation and the future of this technology.

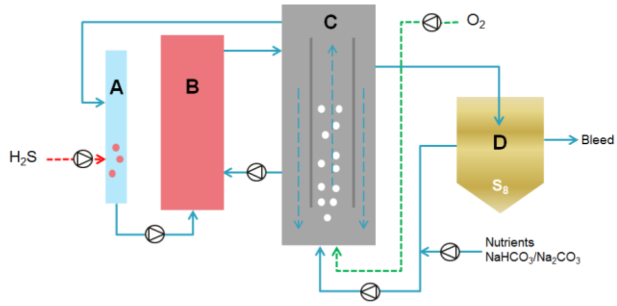


Figure 2 Example of reactor line-up in the laboratory

The optimization of sulfur particle growth and recovery is studied by operating biological lab-scale reactors (Fig. 2) and performing batch crystallization experiments. The technological challenges are to:

- Develop a crystallization model that describes elemental sulfur particle formation and growth under the mentioned process conditions.
- Translate the crystallization model to practical control strategies for the properties of sulfur particles formed in biological desulfurization.

CV Researcher

Name: Annemerel Rozemarijn Mol
Graduated: Wageningen University, Biotechnology (2016)
Hobbies: Volleyball, organizing parties
E-mail: annemerel.mol@wur.nl
Website: www.paqell.com

Paqell.

WAGENINGEN UNIVERSITY & RESEARCH

Increasing sustainability of biological gas desulfurization

Okt 2016 - 2020

Researcher	Supervisors	Promotor
Rieks de Rink	Dr. ir. Jan Klok Dr. Ir. Annemiek ter Heijne	Prof. dr. ir. Cees Buisman

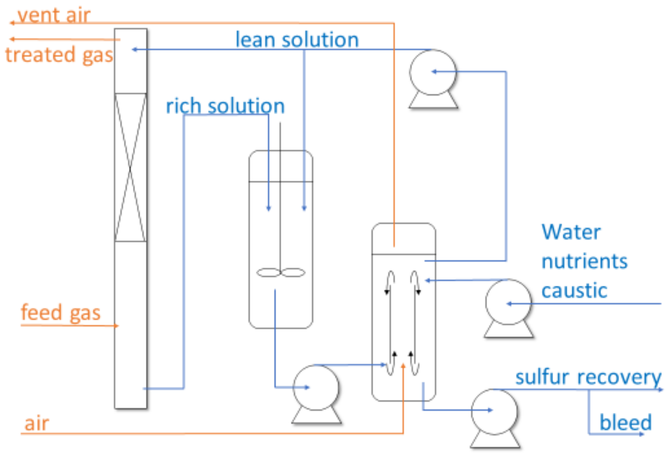
Motivation

H_2S is a toxic, odorous and corrosive gas, which contributes to air pollution, acid rain and smog. The biotechnological desulfurization technology is a sustainable alternative compared to commonly used physio-chemical process to desulfurize gas streams. It uses natron-alkaline conditions to remove H_2S from the gas stream and sulfide oxidizing bacteria (SOB) to convert the H_2S to elemental sulfur (S^0). This research focusses on increasing the sustainability of the process by supressing the formation of the unwanted by-products sulfate and thiosulfate as these require caustic addition and produce a bleed stream.

Technological Principle

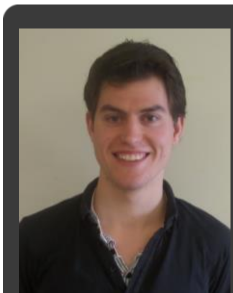
First, H_2S containing gas is counter-currently contacted with a mildly alkaline bicarbonate solution (lean solution) in an absorber column where the H_2S is dissolved into the solution and reacts with CO_3^{2-} to sulfide (HS^-):
$H_2S\,(aq) + CO_3^{2-} \rightarrow HS^- + HCO_3^-$

Subsequently, SOB convert the sulfide to sulfur with the controlled addition of air in a bioreactor:
$HS^- + \frac{1}{2}\,O_2 + HCO_3^- \rightarrow S^0 + H_2O + CO_3^{2-}$



The regenerated solution is recycled to the top of the absorber again. Sulfide can also be oxidized to either sulfate (biologically) or thiosulfate (chemically):
$HS^- + 2O_2 \rightarrow SO_4^{2-} + H^+$
$HS^- + O_2 \rightarrow \frac{1}{2}\,S_2O_3^{2-} + \frac{1}{2}\,H_2O$

In both reactions CO_3^{2-}, which is used in the absorber, is not regenerated and as a consequence caustic (NaOH) addition to the bioreactor solution is needed. Moreover, (thio)sulfate needs to be removed from the system via a bleed (waste) stream. Both caustic consumption and bleed stream formation contribute to operating costs of the process and impair its sustainability. In order to optimize the biodesulfurization process and make it more sustainable, by-product formation should be minimized by maximizing the selectivity for sulfur formation. A new process line-up was proposed, using an anaerobic bioreactor in between the absorber and the aerobic bioreactor (see figure). This should lead to a higher process efficiency because both sulfate and thiosulfate productions will be lower.



CV Researcher: Rieks de Rink
Graduated: Wageningen University, Biotechnology (2015)
Hobbies: Cycling, mountainbiking
e-mail: Rieks.derink@paqell.com
tel: 0622665471
website: www.paqell.com

Extremophilic bioreduction of elemental sulfur for recovery of valuable metals

May 2017 - 2021

Researcher	Supervisor	Promotor
Adrian Hidalgo Ulloa	Dr. ir. Jan Weijma	Prof. dr. ir. Cees Buisman

Motivation

Metallurgical streams are commonly treated using chemical or physical methods to recover the metal species of interest. These processes often result in a poor quality and voluminous sludge that requires further treatment prior to disposal. Additionally, pure metal precipitates are often difficult to obtain as all the metals precipitate jointly. To increase the mineral recovery and lower costs, this project aims to develop a thermoacidophilic sulfur reduction process to selectively recover metals.

Technological challenge

Hydrogen sulfide reacts with divalent chalcophile metals commonly present in metallurgical streams. The product of such reaction is a metal sulfide which solubility is greatly influenced by pH (eq. 1). The pH dependent solubility allows selective mineral recovery, yielding higher metal recovery efficiencies compared to conventional methods.

$$H_2S_{(g)} + Me^{2+}_{(aq)} \rightarrow MeS_{(s)} + 2H^+_{(aq)} \qquad \text{(eq. 1)}$$

Sulphate bioreduction is a well-studied route for hydrogen sulphide production. However current sulphate reduction technologies are not compatible with conditions often found in the metallurgical streams (extremely low pH and high temperature), making this technology expensive and less attractive for industries.
Elemental sulphur is commonly found in thermoacidophilic environments such as volcanic areas and thermal waters. Therefore microbial sulphur reduction metabolism is prone to occur.

Elemental sulfur reduction under thermoacidophilic conditions is a less studied pathway which could potentially optimize the sulfidogenesis process, making it alluring for the metallurgical industry. By reducing elemental sulfur instead of sulfate, a 4-fold reduction in the electron donor consumption can be achieved (eq. 2-3); thus, substantially reducing the Capex and Opex of the sulfidogenesis process.

$$S^0 + 2H^+ + 2e^- \rightarrow H_2S \qquad \text{(eq. 2)}$$

$$SO_4^{2-} + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O \qquad \text{(eq. 3)}$$

Here at ETE, we have recently achieved thermoacidophilic sulfidogenesis opening the door to a development of an innovative process in which metal sulfides can be formed under metallurgical water conditions.
The technological challenge of this project lies in the development of a single step elemental sulfur reducing process under thermoacidophilic conditions towards the selective metal recovery (figure 1).

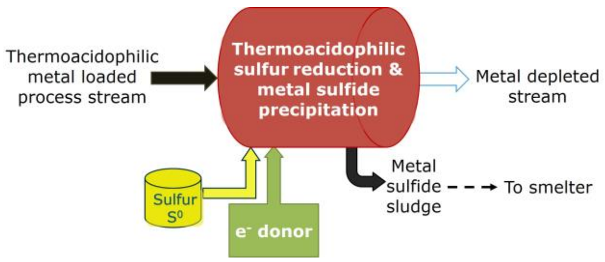


Figure 1. Elemental sulfur reduction process pursued.

CV Researcher;	Adrian Hidalgo Ulloa
Graduated;	Wageningen University. Process Technology (2016)
Hobbies;	MTB, water sports, football.
e-mail;	adrian.hidalgoulloa@wur.nl
tel;	0317-483997
website;	www.ete.wur.nl

Selenium Bio-recovery (Removal) from Wastewater

Nov 2017 - 2021

Researcher	Supervisor	Promotor
Bingnan Song	Dr. Renata van der Weijden Dr. ir. Jan Weijma	Prof. dr. ir. Cees Buisman

Motivation

Although selenium (Se) is a an essential micronutrient for animals and humans, it becomes toxic at slightly higher intake levels than metabolically needed. Recovery (removal) of Se from wastewater provide a solution for both securing the Se supply and decreasing Se pollution. To achieve this, bio-crystallization is attractive in terms of sustainability, cost and is suitable for treating dilute and variable Se-laden wastewaters. The objective of this project is to find an optimal operation method to remove/recover Se in wastewater down to 5 ppb.

Technological challenge

1. The large volume of wastewater makes it hard to design an efficient process to reach the strict discharging limits of Se-laden wastewater, especially at low temperature.
2. The Se products in a bio-system are usually attached to biomass or suspended in the effluent, challenging the solid-liquid separation process and thus leading to higher operational.

Thus, the aims of this project are:

1. To remove 0.42mg Se/L to less than 5ug Se/L at 5-15°C

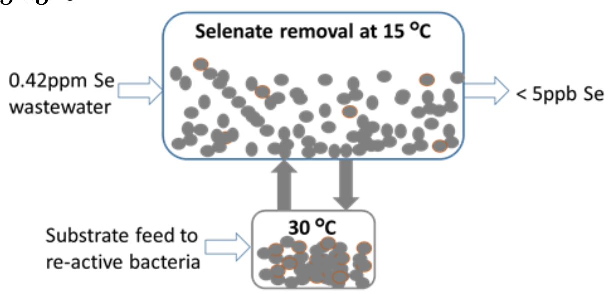


Figure 1. A two-reactor system to remove selenate at 5-15°C

2.To obtain recoverable Se particles from concentrated selenate waste streams at high bioconversion rates.

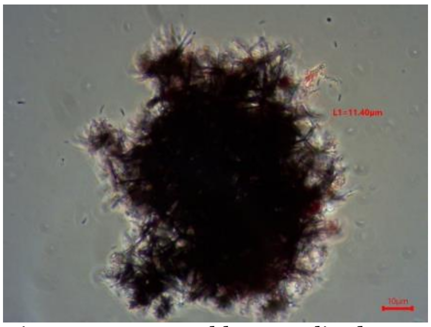


Figure 2. Recoverable crystalized Se particles from the continuous bio-reactor

Adding a minute amount (mg/L) of Sulphur or Sulphate might help the kinetics of selenate reduction process by providing HS- to react with the bio-produced selenite to SeS2, which can be further bio-reduced to larger-sized crystal elemental selenium.

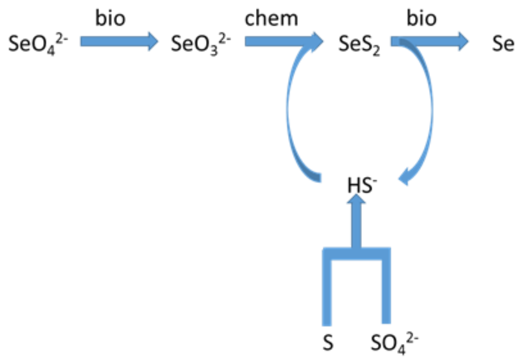


Figure 3. Possible principle of bio crystallization

CV Researcher;	Bingnan Song
Graduated;	Wageningen University, Environmental Technology (2017)
Hobbies;	Reading, swimming, travelling
e-mail;	Bingnan.song@wur.nl
tel;	0317-484611

Recovery of phosphorus from animal manure

Sep 2018 - 2022

Researcher	Supervisor	Promotor
Chris Schott	Dr. Ricardo Cunha Dr. Renata v. d. Weijden	Prof. dr. ir. Cees Buisman

Motivation

Phosphorus (P) is essential for life on earth due to its various functions in growth and energy mechanisms of fauna and flora. However, the natural reserves of P are diminishing in quality and quantity. To ensure future food security, P needs to be recovered from waste streams.
In The Netherlands, 71 million kg of P are annually generated mainly as cattle and pig manure. To prevent run off and consequent eutrophication, the agricultural applicability of animal manure is limited. Therefore, its surplus is incinerated or transported at high economic and environmental costs to other countries.
This project aims to design a sustainable biotechnological process which enables the recovery of phosphorus as concentrated calcium phosphate granules (Figure 1) from thin manure. The separation of nutrients allows more nutrient specific and predictable crop fertilization than spreading raw animal manure. This approach increases the value of animal manure and stimulates circular agriculture.

Technological challenge

In animal manure, P is barely abundant as soluble PO43- and the concentration of solids and organic matter is high. Therefore, calcium phosphate granulation is not occurring by simply adding calcium as previously demonstrated for black water treatment.

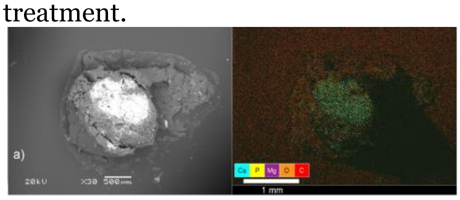
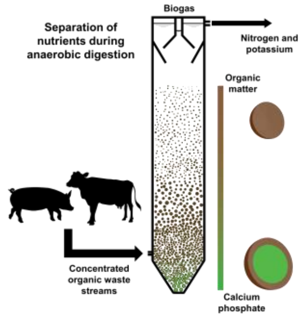


Fig 1. Scanning electron microscope (SEM, left) and electron dispersive x-ray (EDX, right) image of a calcium phosphate granule with an inorganic core consisting of calcium phosphate (EDX green) [4].

Releasing P into solution requires an understanding of how P occurs in animal manure. The phase in which P is present in cow and pig manure as well as various pre treatments to release P into solution will be investigated so that in the main reactor calcium phosphate may granulate.
After enabling calcium phosphate granulation, the collection from the reactor requires optimization. The recovered products need to be suitable for direct use in agriculture or for processing in the fertilizer industry.



Research goals

- Characterizing cow and pig manure and specifically the P speciation
- Stimulating calcium phosphate granulation by increasing the ionic activity of PO_4^{3-}
- Optimizing bioreactor design for recovery of calcium phosphate granules
- Characterizing the products based on their composition, fertilizing performance and applicability

CV Researcher;	Chris Schott
Graduated;	Wageningen University, Water Technology (2018)
Hobbies;	Football, table tennis, boardgames and motorbiking
e-mail;	Chris.Schott@wetsus.nl
tel;	+31 (0)58 284 3000
website;	www.wetsus.nl

Cyanophycin from Urine

Mar 2016 - 2020

Researcher	Supervisors	Promotor
Sebastian Canizales Gomez	Dr. ir. Marcel Janssen Dr. ir. Hardy Temmink	Prof. dr. ir. Rene Wijffels

Motivation

In a world with an increasing population and consequently high demand of resources, new approaches to close material and nutrient cycles are needed. In this perspective microalgae and cyanobacteria present new possibilities.

Humane urine is a nutrient source containing 70% of the phosphorous and 40% of the nitrogen load in household wastewater. The microalgae Chlorella sorokiniana was successfully grown on urine and it was proposed to use the algae biomass as a fertilizer (Tuantet et al., 2014). However, Chlorella's nutrient requirements does not match the urine's high phosphorous to nitrogen ratio and due to its rigid cell wall it is difficult to extract energy or functional components from it. Also Cyanobacteria could be used for urine treatment, with the advantage that under certain stress conditions (e.g. phosphorous limitation) some species of cyanobacteria can accumulate a nitrogen rich polypeptide called cyanophycin.

The aim of this project is to grow cyanobacteria on urine and in this manner combine urine treatment with recovery of cyanophycin as a valuable product, to be used in the bio-plastic and pharmaceutical industry.

Technological challenge

Cyanobacteria accumulate nitrogen when they face stress conditions (P and/or light limitations). This nitrogen is stored in cyanophycin granules (CG).

Under certain conditions cyanobacteria vegetative cells develop a resting cell stage called akinete in which cellular structure, composition and morphology change (Figure 1).

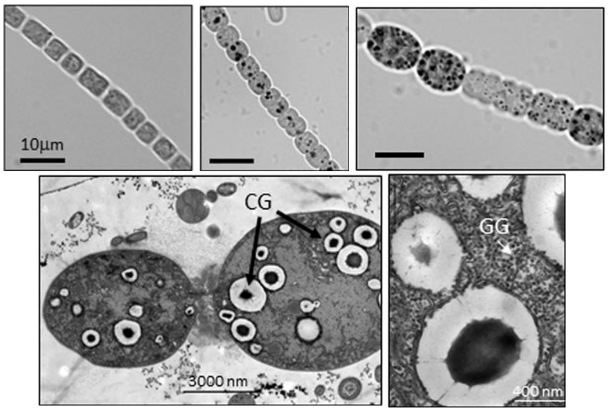


Figure 1. Akinetes development and CG. (Sukenik et al., 2015)

In the transition from vegetative cell to akinete cyanophycin accumulation is increased as well as the cell volume and the cell wall is thickened (Sukenik et al., 2015).

The technological challenge is to find conditions that trigger the production of cyanophycin in flat panel photobioreactors with several cultures of cyanobacteria, and to identify the optimal conditions to maximize cyanophycine cell content. This should be combined with efficient nutrient removal from urine.

CV Researcher;	Sebastian Canizales Gomez
Graduated;	Wageningen University, Environmental Technology (2016)
Hobbies;	Traveling, Guitar Playing, Scuba Diving, Coding
e-mail;	sebastian.canizalesgomez@wur.nl
tel;	0582-843018
website;	https://www.wur.nl/en/project/Cyanophycin-from-

Chain elongation from biomass streams– Production of longer fatty acids

February 2017 - 2021

Researcher	Supervisor	Promotor
Carlos Contreras Davila	Dr. ir. David Strik	Prof. dr. ir. Cees Buisman

Motivation

Sustainable and cost effective biochemical/biofuel production is a key factor for the reduction of anthropogenic climate change as well as for the future development of a bio-based economy. The carboxylate platform is a novel biotechnological approach which provides the ability to convert complex organic wastes into valuable and energy-dense chemicals such as medium chain fatty acids (MCFA). Caproic acid (C6) is the common product in chain elongation reactors. However, production of the longer MCFA caprylic acid (C8), which in theory can be achieved under more selective conditions, will broaden the product spectrum of the carboxylate platform and the potential impact on replacing fossil based chemicals with biobased chemicals.

Technological principle

During the first steps of anaerobic digestion, organic matter is biologically transformed into volatile fatty acids (VFA), alcohols, hydrogen and carbon dioxide. By a process called biological chain elongation, these VFA can be further transformed into MCFA which after a separation step can be electrochemically upgraded to produce fuels and chemicals.

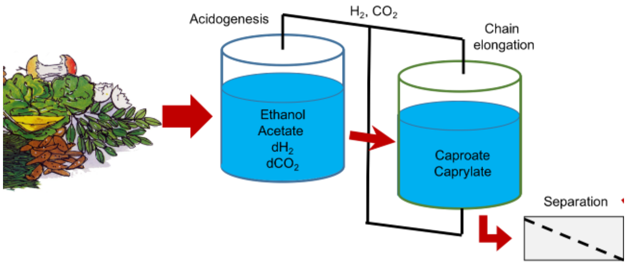


Fig. 1 Envisioned biorefinery

Research challenges

- Determine steering conditions on formation of longer MCFA.
- Using real waste streams for chain elongation.
- Evaluate a two-stage system for chain elongation using organic wastes.
- Identify key microorganisms in MCFA production.

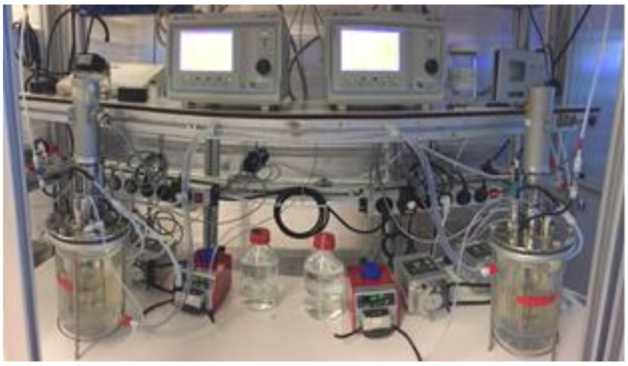


Fig. 2 Chain elongation reactors set-up

Fig. 3 Full-scale chain elongation plant (under construction)

CV Researcher;	Carlos Contreras Davila
Graduated;	Institute for Scientific and Technological Research of San Luis Potosi, Environmental Sciences (2015)
Hobbies;	Football, guitar
e-mail;	carlos.contrerasdavila@wur.nl
tel;	
website;	www.ete.wur.nl

Pre-defined co-cultures to incorporate microbial electrosynthesis in the syngas fermentation platform

Dec 2019 - 2023

Researcher	Supervisor	Promotor
Marten Gelderloos	Dr ir. D.P.B.T.B. Strik Dr D.Z. Sousa (MIB)	Prof. Dr A.J.M. Stams (MIB)

Motivation

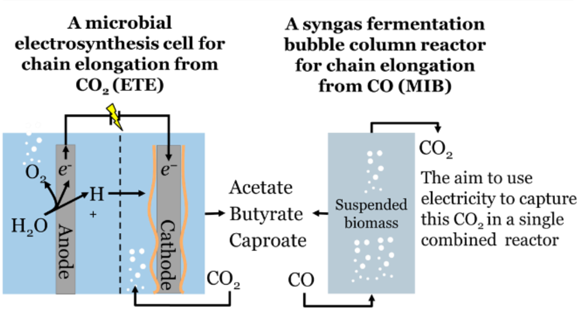
Syngas is a gaseous mixture of CO, H_2 and CO_2, which can be generated by the gasification of biomass. Syngas fermentation (SGF) has received increased attention as a route to use syngas to produce liquid fuels (full-scale stage) or biochemicals (development stage). However, during CO fermentation about two-thirds of the carbon is emitted as CO_2. The complete fixation of CO_2 into products is possible, but requires extra reducing power, e.g. by supplementing H_2 or electricity.

Technological challenge

In SGF the main source of energy and carbon is CO, while in microbial electrosynthesis (MES) protons and electrons released with electrical energy from H_2O and CO_2 serve as energy and carbon source respectively.
The aim of this project is to design and characterize pre-defined microbial co-cultures fed with CO and electricity for zero CO2-emission syngas fermentation for the production of medium chain fatty acids (MFCAs).

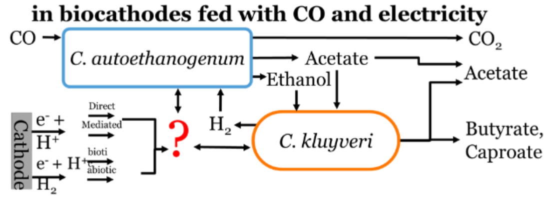
The technological challenge is to adapt proof-of-principle reactor systems this combined purpose. This will enable us to study the microbial consortia, enrich and isolate usable microbes, and make pre-defined co-cultures to further investigate the important interactions and ultimately develop MCFA producing microbial co-cultures with minimal complexity capable of feeding on syngas and electricity.
To optimally answer these questions this project is a collaboration between ETE and the Microbial Physiology group at the Laboratory of Microbiology

A simplified comparison MES and SGF for MFCA production

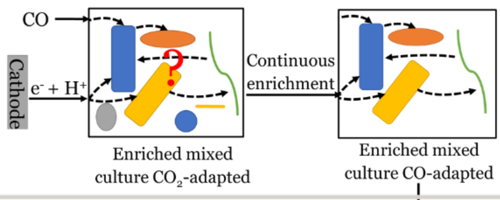


Project approaches

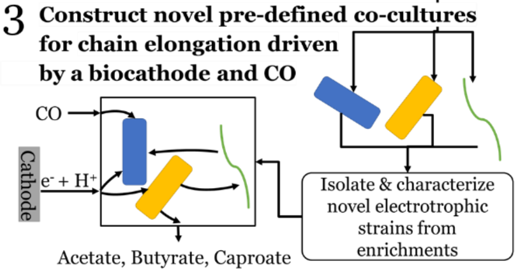
1 Test MCFA-producing defined co-cultures in biocathodes fed with CO and electricity



2 Test MCFA-producing open mixed-cultures in biocathodes fed with CO and electricity



3 Construct novel pre-defined co-cultures for chain elongation driven by a biocathode and CO



CV Researcher;	Marten Gelderloos
Graduated;	Wageningen University, Biotechnology (2019)
Hobbies;	Rugby, my motercycle, camping, DIY-ing
e-mail;	Marten.Gelderloos@wur.nl
tel;	06-23989631

WAGENINGEN UNIVERSITY & RESEARCH

Nutrient and energy recovery from black water through hyper-thermophilic anaerobic digestion

October 2017-2021

Researcher
Merijn Moerland, MSc

Supervisor
Dr. ir. Miriam van Eekert

(Co-)Promotors
Prof. dr. Ir. Cees Buisman

Motivation

Global demands for fertilizer production are increasing due to exponential population growth. Domestic wastewater is a nutrient-rich source, but in conventional treatment processes nutrients from this source are recovered to a low extend or not even at all (<50% phosphorus and <5% nitrate). In Run4Life[1], an EU-funded project, a decentralised approach for segregating different domestic wastewater streams is applied for efficient nutrient recovery. In segregated waste water collection, black water (BW), containing the urine and faeces fraction, is collected separate from rain- and bathroom water (grey water) and kitchen waste (KW). This segregated collection of wastewater has the advantage of obtaining BW with high concentrations of nutrients and organic matter, and thus energy. On the other hand, also the main pathogen fraction is present in BW, along with micro-pollutants. The aim of the research is to design a single step anaerobic digestion process for the recovery of safe (pathogen free) fertilizers along with energy production through biogas.

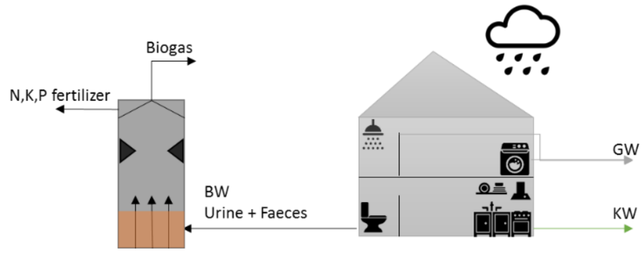


Figure 1 Schematic overview of the concept

[1] Recovery and Utilisation of Nutrients for Low Impact Fertiliser

Process description

In order to remove pathogens, the process will be performed at 70 °C (hyper-thermophilic) in an upflow anaerobic sludge blanket reactor (UASB). At this temperature most pathogens are thought to be inactivated and methane production is still possible. However, the hyper-thermophilic anaerobic digestion process has not been applied on concentrated BW before. The first goal is to select the inoculum which is best capable of adapting to the hyper-thermophilic conditions. Then the optimal reactor conditions, kinetic parameters and efficient nutrient recovery methods will be determined and finally the process will be applied on a treatment facility for decentralised segregated wastewater in Sneek. Methods for the recovery of nitrogen and phosphate at 70 °C also need to be developed.

Figure 2 UASB in Sneek where source separated BW is treated in a decentralized approach

Research challenges

- Assess the possibility of hyper-thermophilic treatment of BW and select inoculum
- Determination of reactor conditions for a stable process (pH, HRT, SRT, etc.)
- Obtain hygienic fertilizer by sufficient pathogen removal
- Recover nutrients and energy from black water at high temperatures

CV Researcher; Merijn Moerland
Graduated; Wageningen University and Research
Biotechnology (2017)
Hobbies; Sports and music
e-mail; merijn.moerland@wur.nl
tel; 06-37011905
website; www.ete.wur.nl

Improving Agricultural Soils by Organic Residues

April 2018 – April 2022

Researcher:	Supervisor:	Promotor:
Yujia Luo	Dr. ir. Annemiek ter Heijne Prof. dr. Martijn Bezemer	Prof. dr. ir. Cees Buisman

Motivation

It is general accepted that organic residues like compost and digestate have great potential to improve physical, chemical and biological status of soil. Different treatments for instance composting and digestion of organic waste will result in organic residues with different chemical and microbial compositions. Here, chemical composition means chemical structure of humic-like substances in organic residues; microbial composition means microbial activity, abundance and diversity. The effect of organic residues with different chemical and microbial compositions on soil matrix is very complex and surrounded by riddles, especially the relationship with soil microbial characteristics and crop growth. In this project, environmental technology specialists and soil ecologists are going to cooperate and shed light on this complex context.

Hypothesis and research question

Our hypothesis is that the influence on soils and crop growth depends on chemical and microbial composition of organic residues rather than their C, N, and P concentrations alone. Our investigation intends to answer the following questions:

1) What is the relationship between the molecular C composition of added organic residues and soil microbial community composition?
2) How do organic residue associated microbial communities influence soil microbial community composition?
3) How do organic residue induced changes in soil microbial communities affect crop growth? And through what mechanisms?
4) Can we select organic residues to promote or reduce specific groups of crop beneficial or detrimental soil microorganisms?

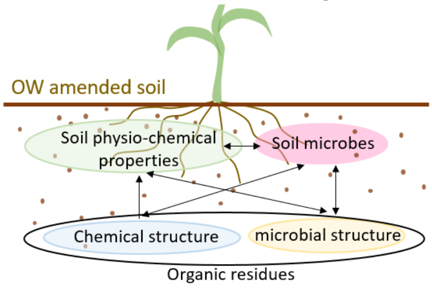


Figure 1. Above- and belowground interactions

Technical Challenge

- Processes involved in the soil matrix are complex and always inter-related;
- Relate intrinsic properties of organic residues to their effects on soil microbial characteristics;
- Identify/isolate/enrich specific groups of crop beneficial or detrimental soil microorganisms;
- Relate the changes in soil characteristic to crop growth, and study the mechanisms

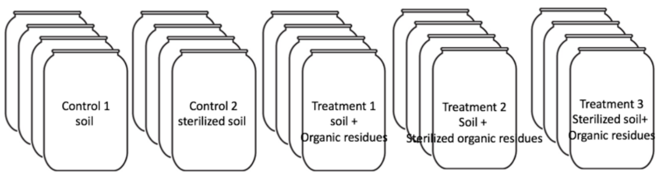


Figure 2. Soil incubation experiments with addition of different organic residues in glass jars. Pot experiments will also be conducted afterwards

Researcher: Yujia Luo
Graduated: Wageningen University (2016)
Hobbies: Cooking, reading, running
E-mail: Yujia.luo@wur.nl
Tel: 0647684005
Website: https://www.wetsus.nl/soil

Organic residues engineering to increase organic matter in agricultural soils

Oct 2018 - 2022

Researcher	Supervisor	Promotor
Vania Scarlet Chavez Rico	dr. ir. M. van Eekert, dr. P. Bodelier, and dr. V. Sechi	Prof. dr. ir. Cees Buisman

Motivation

In the European Union, 970 Tg of soil is lost annually [1]. Despite the policy interventions, such as the "Common Agricultural Policy" and "Soil Thematic Strategy", soil erosion rates are 1.4 higher than soil formation rates [1][2]. One of the most important driving factors of soil erosion is organic matter decline [3]. Ironically, only about one third of the total bio-waste is used to replenish the organic carbon losses [3]. By using organic residues engineering, we could use these residues to produce organic amendments (OA) to improve specific soil functions according the requirements of each specific case.

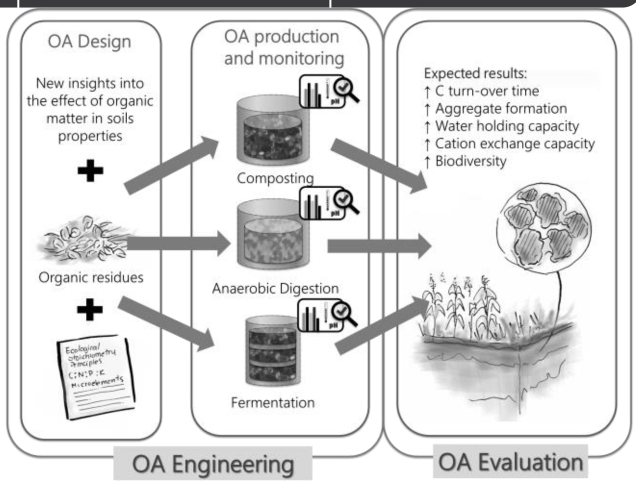


Fig.1 Graphical abstract.
Changes in engineered organic amendments (OAs) will be evaluated by monitoring specific soil properties.

Technological challenge

New insights on OA engineering are required to increase its efficacy, efficiency and effectivity. For example, different technologies are used to produce OAs. Each technology yields OAs with different chemistry. It is unknown to what extent OA chemistry is modulated by these technologies and what effects these OA have on soil properties. The main technological challenges will be to:

1. Assess the influence of engineered OAs on soil properties.
2. Identify potential improvements for the design of OAs.
3. Modify operational parameters or/and system configurations to produce the designed OAs.
4. Identify strategies that involve engineered OAs to steer specific groups of microorganisms. This will be done by applying ecological stoichiometry principles towards the production of compounds leading to stable organic matter formation.

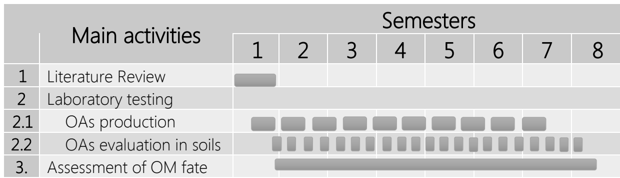


Fig 2. General Schedule

[1] Panagos, P., & Borrelli, P. (2017). Soil erosion in Europe: Current status, challenges and future developments | EU Science Hub. Retrieved January 15, 2019
[2] Verheijen, F. G. A., Jones, R. J. A., Rickson, R. J., & Smith, C. J. (2009). Tolerable versus actual soil erosion rates in Europe. Earth- Science Reviews, (94), 23–38.
[3] Middleton, N., & Thomas, D. S. G. (1997). World Atlas of Desertification. United Nations Environment Programme (UNEP) - University of Sheffield, UK (Vol. 2).

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 665874

CV Researcher; Vania Scarlet Chavez Rico
Graduated; Ghent University, Master in Environmental Sanitation (2018)
Hobbies; Reading, painting and drawing
e-mail; vania.chavezrico@wur.nl
tel; 0657208079
website;

Sustainable heat production using biological wood oxidation

Feb 2017 - 2021

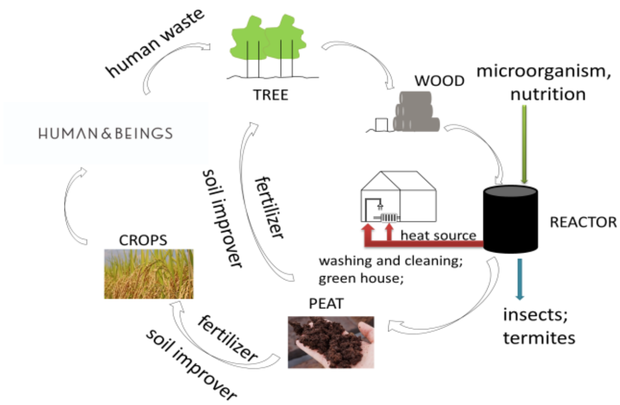
Researcher	Supervisor	Promotor
Shiyang Fan	Dr. ir. Annemiek ter Heijne	Prof. dr. ir. Cees Buisman

Motivation

Heating is one of the main energy consuming processes in countries with moderate temperatures. Heat is mostly produced from fossil fuels such as natural gas and fuel oil. A sustainable alternative energy source is biomass. However, combustion of biomass results in harmful emissions to the environment, such as emission of SO_2, CO, NO_x, fine particles and Polycyclic Aromatic Hydrocarbons (PAHs). Moreover, the remaining ashes cannot be reused. Biological wood oxidation has been proposed as a new technology for heat production at temperatures around 40-55 °C.

Wood oxidation, or aerobic wood oxidation, is a process in which wood is composted by microorganisms in the presence of oxygen. In this process, sustainable heat is produced. Compared to wood combustion, only CO_2 and H_2O are released to the atmosphere (see the following equation). Besides, the residue from this process is peat instead of ash. Peat soil is rich in organic matters and can be used as fertilizer.

$$CH_{1.5}O_{0.7} + 1.03O_2 \rightarrow CO_2 + 0.734H_2O + Heat$$



Technological challenge

The central challenge is to increase the rate of biological wood degradation. This rate is determined by, for example, types of microorganisms, types of wood, and wood size. Other factors, such as the nutrient supply (i.e. N, P, K), moisture content, temperature and aeration will also influence heat production.

Besides, the assessment of heat production from wood oxidation is unknown.

Sterile

Non sterile

The main challenges are:

(1) To optimize the temperature, moisture content, aeration strategy, and nutrient supply
(2) To study the heat production for different types of woods, different wood sizes
(3) To study the suitability of the wood residues as soil improver
(4) To operate a scale-up reactor for heat recovery from wood
(5) To assess the application of heat production from wood oxidation to urban heating system

Key words: wood oxidation; heat production; urban heating system

CV Researcher;	Shiyang Fan
Graduated;	Beijing Forestry University, Environmental Science and Technology (2016)
Hobbies;	Cycling, traveling, music
E-mail;	shiyang.fan@wur.nl
Tel;	06-45594860

Combining *Chemo*- and *Bio*-Electro - Catalytic Synthesis of Chemicals

Mar 2015 - 2019

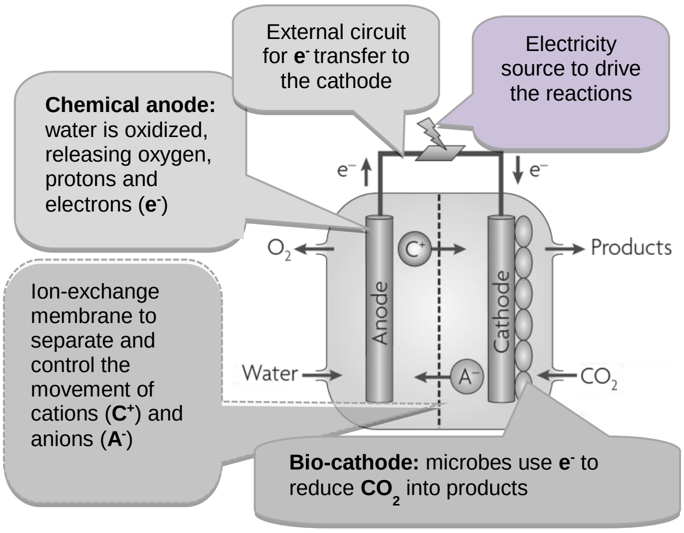
Researcher	Supervisor	Promotor
Konstantina Roxani Chatzipanagiotou	Dr. ir. David Strik	Prof. dr. ir. Cees Buisman Prof. dr. Harry Bitter, BCT

Motivation

CO2 is the primary contributor to global warming. The conversion of waste CO2 into valuable products has been proposed by many researchers. A novel mechanism is microbial electro-synthesis (MES), in which electrochemically active microbes use renewable electricity to convert CO2 in organic molecules. MES is considered more efficient and sustainable than photosynthetic bio-fuel production.

Technological challenge

The MES cell consists of an anode and cathode, separated by a membrane, as shown here.



Although promising, MES still faces challenges that limit its application. Three main challenges will be addressed as part of this research project:

- The e- transfer from the electrode to the microbes is limiting.
- The product spectrum of MES is limited.
- Product separation is inefficient due to high solubility, low product concentration, product inhibition, bio-degradation or toxicity.

Methodology

In order to address these limitations, we will evaluate electrodes modified with electro-catalysts as bio-cathodes for MES cells, thus combining electro-catalysis and MES. The set-up that will be constructed to evaluate the concept is shown below (depicted to operate with a bio-anode and chemical cathode).

The challenge is to investigate and develop different electro-catalytic bio-cathodes, resulting in improved operation of the MES process. The project will be performed in collaboration with the Biobased Chemistry and Technology (BCT) group of WUR.

CV Researcher; Konstantina Roxani Chatzipanagiotou
Graduated; Wageningen University, MSc. Environmental Technology (2014)
Hobbies; Dancing, reading, swimming
e-mail; roxani.chatzipanagiotou@wur.nl
tel; +31 (0) 622 161 990
website; www.wur.nl/ete ; www.wur.nl/bct

Capacitive bio-anodes for electricity production in Microbial Fuel Cells

Environmental Technology

Aug 2015 – 2019

Researcher	Supervisors	Promotor
ir. C. Borsje	Dr. ir. A. ter Heijne Dr. ir. T.H.J.A Sleutels	Prof. dr. ir. C.J.N. Buisman

Motivation

Wastewater treatment is an essential part of the society. The organic material in wastewater can be recovered as electricity with Microbial Fuel Cells (MFCs), while the wastewater is treated simultaneously. The dissolved organic material in wastewater is directly converted to electricity via oxidation by electroactive bacteria growing on the bioanode (Figure 2, top left). Industrial application is hampered by clogging, pH gradients and slow, expensive cathodes compared to the anode, limiting scale up and power densities. A new development: the capacitive MFC, can in principle solve these challenges. Bacteria grow on the surface of a porous structure. Electrons from the oxidation are stored in the porous structure. The combination forms a capacitive bioanode, shown in Figure 1 as a porous activated carbon granule.

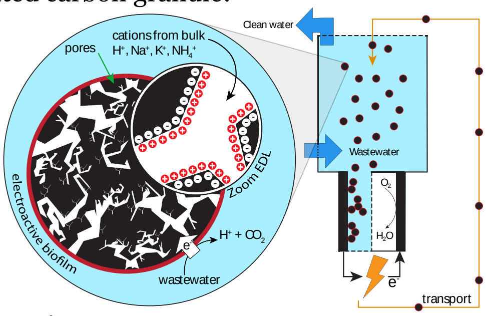


Figure 1

Technological challenge

The capacitance allows decoupling of the wastewater treatment and the electricity production, which allows both steps to be optimized separately. In the larger anode volume, the bioanode granules, which provide high capacitance and growth surface per volume of reactor, are charged. The charged granules move to a smaller discharge cell, where the electricity is produced, which reduces the costs per volume. See Figure 1 for a schematic representation. The aim this research project is to develop the capacitive bioanode Microbial Fuel Cell concept towards application, by:

- Discharge characteristics of granular (bio)anodes
- Designing a moving bed reactor
- Optimization of operational parameters
- Pilot scale application with real wastewater.

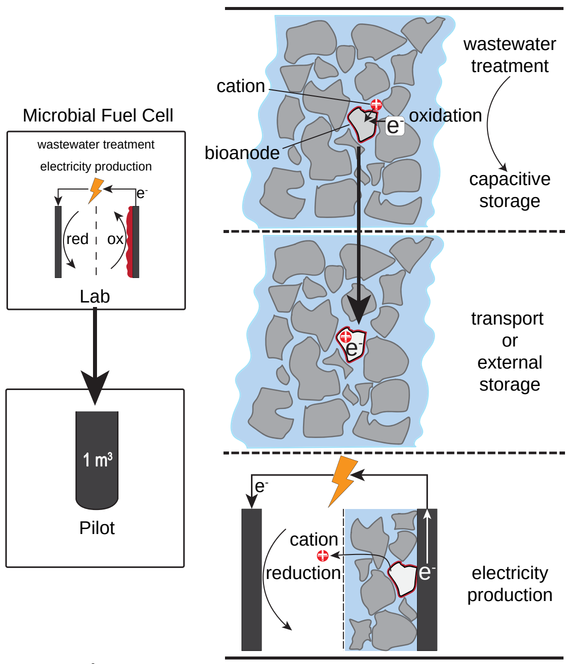


Figure 2

CV Researcher;	Casper Borsje
Graduated;	Wageningen University, Environmental Technology (2015)
Hobbies;	Photography, reading and nature
e-mail;	casper.borsje@wur.nl
tel;	058-2843016

Sub-department of
Environmental Technology

Bioelectrochemical Systems for Ammonia Recovery from Wastewater

Sept 2017 - 2021

Researcher
MSc. Steffen Georg

Supervisors
Dr. Philipp Kuntke
Dr. ir. Annemiek ter Heijne

Promotor
Prof. dr. ir. Cees Buisman

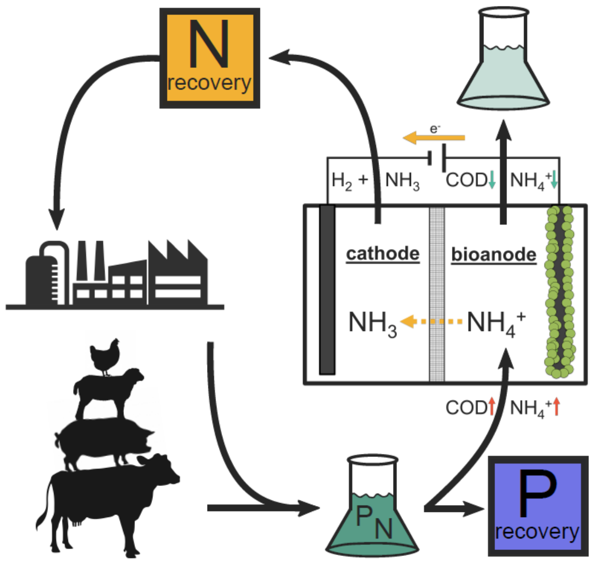


Figure 1: Nutrient removal and recovery cycle.

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)

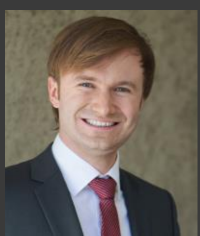
Technology

- 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.



CV Researcher: Steffen Georg
Graduated: Technical University of Munich, Biochemistry (2017)
Hobbies: Squash, music, travel
e-mail: steffen.georg@wetsus.nl
tel: +31 (0) 58 2843 188
website: www.wetsus.nl/research/research-themes/resource-recovery

wetsus

WAGENINGEN UNIVERSITY & RESEARCH

Plant microbial fuel cell: Mechanistic characterization

March 2018-2022

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

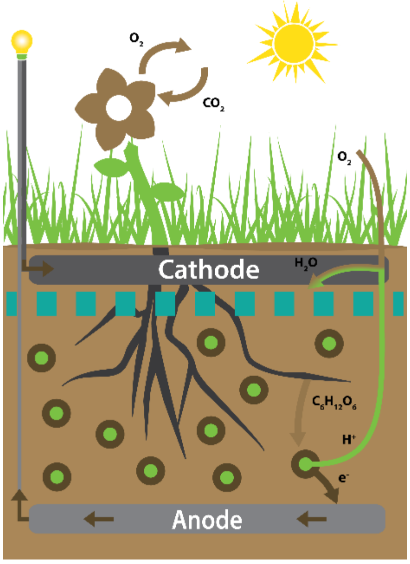
Motivation

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

CV Researcher;	Pim de Jager
Graduated;	Wageningen University, Environmental Technology (2013)
Hobbies;	Sports, outdoor
e-mail;	pim.dejager@wur.nl
tel;	0317-483228
website;	-

Fouling and Process Design in reverse electrodialysis: a case study with real waters

Nov 2018 - 2022

Researcher	Supervisors	Promotors
Bárbara Vital	Dr. M. Saakes Dr. ir. T. Sleutels Dr. ir. A. ter Heijne	Prof. dr. ir. Cees Buisman Dr. ir. Bert Hamelers

Motivation

To include renewable energy in the energy matrix can be a challenge for many societies. Blue energy is a promising energy source that uses the controlled mixing of the salinity gradient between river and sea water to produce electrical energy. Reverse Electrodialysis (RED) is a process that allows to harvest this energy. It uses a series of alternating anion (AEM) and cation (CEM) exchange membranes to direct ions and the membrane stack voltage is converted into an electrical current by the means of a redox reaction. This principle is represented in Figure 1. The by-product of the process is only brackish water, so it does not generate any harmful substances to the environment. The estimated salinity gradient power available globally is estimated to be between 1.4 and 2.6 TW [1].

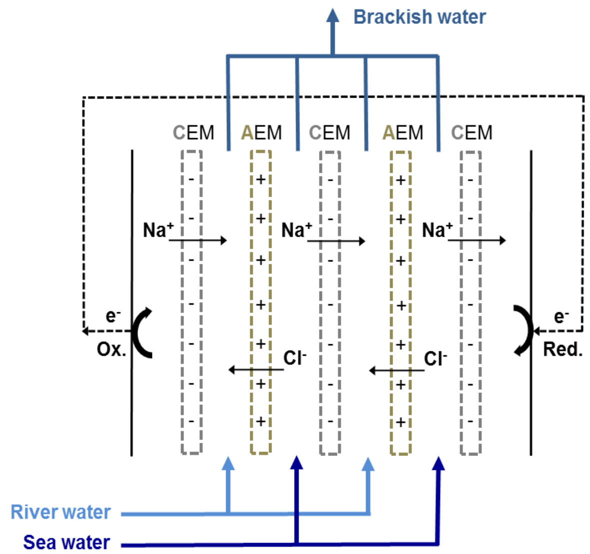


Fig 1. Simplified principle of RED

Technological challenge

Fouling of the ion exchange membranes is known as one of the most severe problems within RED applications, since it decreases the overall power output that can be harvested. Fouling can be present in diverse ways, like organic, inorganic, biofouling and scaling, as seen on Figure 2. It is believed that for a good performance of the process, a feed water pre-treatment is necessary to inhibit fouling.

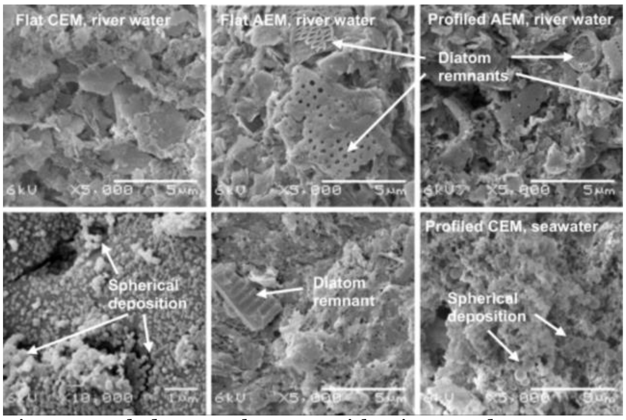


Fig 2. Fouled membranes with river and sea water, different types of AEMs and CEMs. Adapted from [2]

Research goals

- Identify the effect of individual foulants present in natural waters (river and sea) on RED performance,
- Identify how the foulants interact with different membranes (CEM and AEM) and how this impacts the RED process,
- Propose and test pre-treatment combinations and membrane cleaning for fouling control.

[1] Post (2009), Blue Energy: electricity production from salinity gradients by reverse electrodialysis
[2] Vermaas et al, (2013) Water Research 47 (3), 1289-1298

CV Researcher; Bárbara Vital
Graduated; International Master of Science in Environmental Technology and Engineering – IMETE (2016)
Hobbies; Volleyball, hiking, cycling
e-mail; barbara.vital@wur.nl
tel; 058 – 284 30 00

Novel methods for electrochemical capture and conversion of CO_2

Sept. 2018 - 2022

Researcher	Supervisor	Promotor
Qingdian Shu	Dr. ir. Bert Hamelers Dr. Michele Tedesco	Prof. dr. ir. Cees Buisman

Motivation

Climate change is one of the most critical global challenges. Increasing atmospheric CO2 concentration brought by anthropogenic emissions is the primary driver of climate change. Capturing CO2 from emission points and even directly from air provides a potential solution to mitigate the amount of CO2 emissions and reduce the atmospheric CO2 concentration. Anion exchange resin (AER), a polymeric material with amine-functionalized groups usually used in water desalination process, has been proven to be a promising solid amine sorbent for CO2 capture.

Technological challenge

CO2 capture using ion exchange AERs involves adsorption and desorption steps. CO2 from CO2-rich stream can be adsorbed so that the outlet becomes CO2-lean stream, and pure CO2 can be produced during desorption. The adsorption process is due to the reaction between fixed amine groups on the resins and CO2. Since the reaction can be reversed at around 100 °C, conventional desorption process is by heating up the resins. Nevertheless, the regeneration of AERs using a high temperature restricts the application of this material owing to the high energy cost and likely degradation of resins.

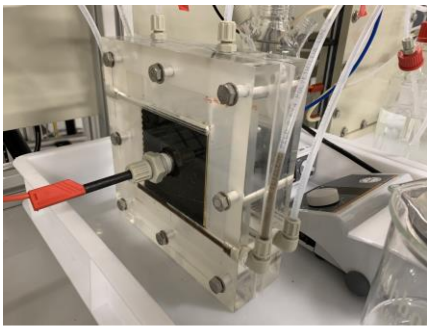
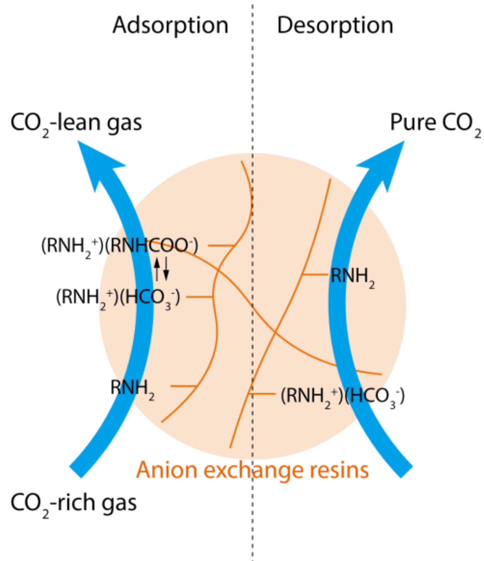


Figure 1. Electrochemical cell used in this study.



In this work, we propose a novel method to combine the conventional adsorption step with a more efficient electrochemical desorption step (Figure 1). The major challenge is to discover operation conditions that give high CO_2 capture performance at low energy consumption.

Research goals

- Developing a novel system for CO_2 capture based on ion exchange resins
- Investigating the CO_2 capture performance and energy consumption of the system under different current density, CO_2 partial pressure, and initial concentration of the regeneration solution
- Studying the performance of the system with different sorbents
- Developing a mathematical model of the system describing the kinetics and transport of various components

CV Researcher; Qingdian Shu
Graduated; Wetsus Academy, Water Technology (2018)

Hobbies; Ping pong, cooking, and Rubik's cube
e-mail; Qingdian.shu@wetsus.nl
tel; 0627430016
website; https://www.wetsus.nl/sustainable-carbon-cycle

Bioelectrochemical chain elongation of CO2 to caproate: *electrification of biotechnology*

Environmental Technology

Sep 2018 - 2022

Researcher	Supervisor	Promotors
Sanne de Smit, MSc.	Dr. ir. David Strik	Prof. dr. ir. Cees Buisman Prof. dr. Harry Bitter, BCT

Motivation

The world population is growing and the amount of arable land becomes scarce. Therefore, solutions are needed for a more efficient use of the available land and water for the production of biochemicals. Capturing CO2 and utilization of waste streams to (re)produce chemicals in electricity driven microbial electrosynthesis represents an effective solution to circularly utilize waste-resources from our society.

The current process yields can be further improved for practical application of the process. And also the working mechanisms of this process remain to be further revealed. The main focus of this research is to investigate the role of the biofilm and the changes therein in the optimization of the electron flux between the cathode and the biofilm. By better understanding of these fluxes we can develop new ways to steer the bioelectrochemical processes.

Technological challenge

Bioelectrochemical chain elongation (BCE) is a promising technique to produce caproate from CO2 or evenly organic waste streams. Caproate is a platform chemical that can be used as animal feed additive, plant growth promotor or for the production of biodegradable plastics or fuels.
In BCE, water is oxidized to release electrons which take-up renewable electrical energy. The highly energetic electrons are supplied to the biofilm where a CO_2 elongating biofilm grows.

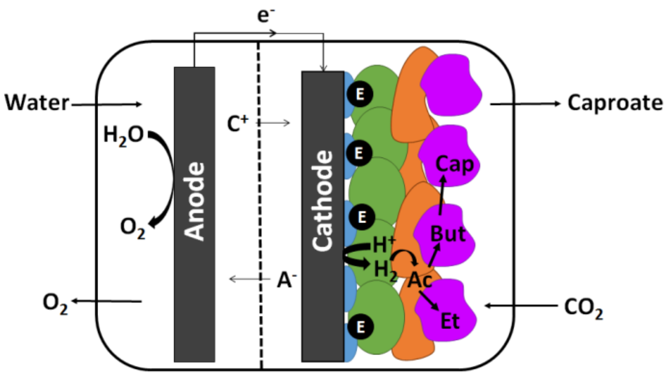


Fig 1. *Schematic overview of a bioelectrochemical chain elongation system.*

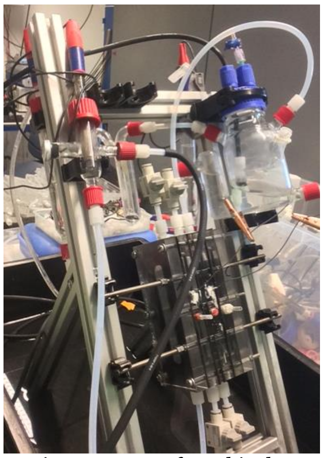


Fig 2. *Laboratorium setup of a bioelectrochemical chain elongation system.*

Research challenges

- Gain insights about the biofilm composition and the role of different microbial groups in the chain elongation process
- Study the electrode surface and the changes therein during development of the biofilm
- The project is performed in collaboration with the Biobased Chemistry and Technology (BCT) group of WUR.

CV Researcher;	Sanne de Smit
Graduated;	Wageningen University, Biotechnology (2018)
Hobbies;	Gardening, crocheting, ice skating
e-mail;	sanne.desmit@wur.nl
tel;	06-12119465
website;	www.ete.wur.nl

Wimek Research Institute

CHAINCRAFT BIOBASED INNOVATORS

WAGENINGEN UNIVERSITY & RESEARCH

Bio electrochemical degradation of thiols (organo sulphur compounds)

Biorecovery
Environmental Technology

Aug 2018 - 2022

Researcher	Supervisor	Promotor
Margo Elzinga	Dr. ir. Annemiek ter Heijne Dr. ir. Jan Klok	Prof. dr. ir. Cees Buisman

Motivation

The treatment of thiols has been challenging for the petrol industry over the past decades. The combustion of natural gas containing thiols (organo sulphur compounds) forms SO2, resulting in adverse health effects, the formation of acid rain and dry acid deposition. Conventional treatment methods focus on the oxidation of thiols. However, this treatment strategies are not widely applied due to low efficiencies and high installation and operational costs. Bio electrochemical systems (BES) have proven themselves capable of treating complex organic materials at high rates and deep treatment of organic pollutants. BES may potentially be used as new removal strategy for the reduction of thiols.

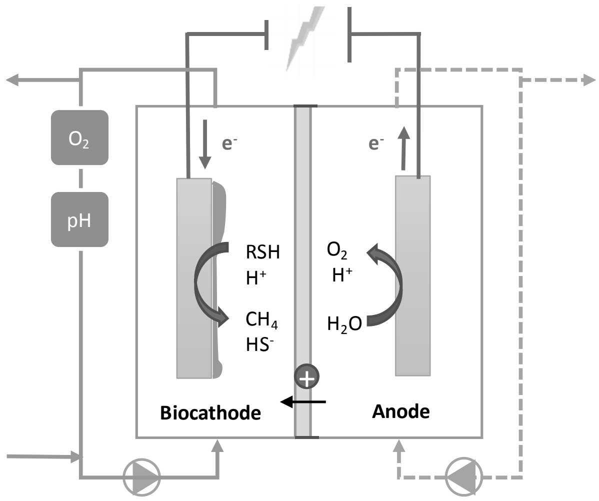
Technological challenge

Bio electrochemical systems are characterized by the separation of oxidation and reduction reactions at the anode and cathode. In these systems at least one of the reactions is bio catalyzed. Electrons flow through an external circuit from the anode to the cathode and reaction rates can be stimulated by changing the electrode potential or current density.

Microorganisms can donate electrons to the anode or utilize electrons from the cathode to perform otherwise thermodynamically unfavorable reactions.

Preliminary studies showed that thiols were successfully reduced to sulfide and methane when a small electric current was supplied. During these tests, arbitrarily operating parameters were chosen. To secure a robust technology various aspects need to be evaluated. Currently the involved reaction mechanisms are unknown. The need for co-substrates, the microorganisms involved, pH and toxicity limits have to be studied. A balance between fast reaction rates and energy efficiency needs to be obtained.

In this study, we will explore the possibility of stimulating anaerobic biodegradation of thiols in BES and its potential to form a safe, low cost and sustainable technology.



CV Researcher; Margo Elzinga
Graduated; Wageningen University, University of Twente, University of Groningen, Water Technology (2017)
Hobbies; Gardening, climbing, reading nonscientific literature
e-mail; margo.elzinga@wur.nl
tel; 06-57653904

Paqell.

WAGENINGEN UNIVERSITY & RESEARCH

Optimization and upscaling of electrochemical ammonia recovery

Environmental Technology

Sept 2018 - 2022

Researcher	Supervisor	Promotor
Mariana Rodrigues	Dr. Philipp Kuntke Dr. Annemiek ter Heijne	Prof. dr. ir. Cees Buisman

Motivation

The intensive use of fertilizers in EU regions is degrading sensitive water bodies. When these nutrients make their way into rivers, they considerably disturb aquatic ecosystems. Recycling the reactive nitrogen could reduce the energy needed to both produce fertilizers and dispose of nutrients, cutting greenhouse gas emissions on both ends of their production chain.

Electrochemical systems (ES) can be the new solution for this nitrogen issue, as they are capable to both remove and recover nitrogen. Earlier results using ES to treat urine showed an effluent with a lowered TAN (total ammonia nitrogen) concentration and a product with potential use as a fertilizer (ammonium sulphate).

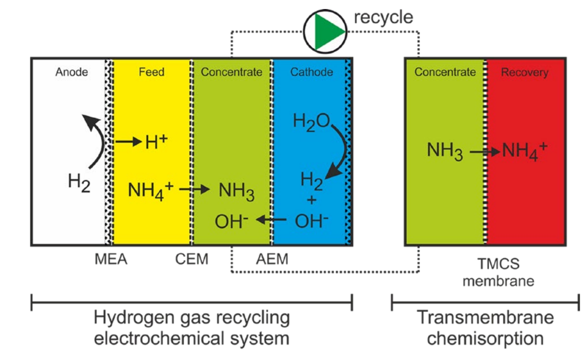


Fig 1. Scheme of the up-scaled electrochemical system for TAN recovery.[1]

Figure 1 illustrates a hydrogen gas recycling electrochemical system (HRES) including 4 compartments (anode, feed, concentrate and catholyte) for ammonia recovery. At the anode occurs the oxidation of H_2 instead of water oxidation. The formed electrons move through an external circuit towards the cathode, where the reduction of water occurs.

The current supplied to the system drives the hydroxides formed at the cathode, across the AEM to the concentrate. Likewise, ammonium ions (NH_4^+) protonated in the feed, move through the CEM to the concentrate. As a result, ammonium is deprotonated to ammonia ($NH_4^+ + OH^- \rightarrow NH_3$). The formed NH_3 can be recovered using a gas permeable hydrophobic membrane, such as transmembrane chemisorption (TMCS).

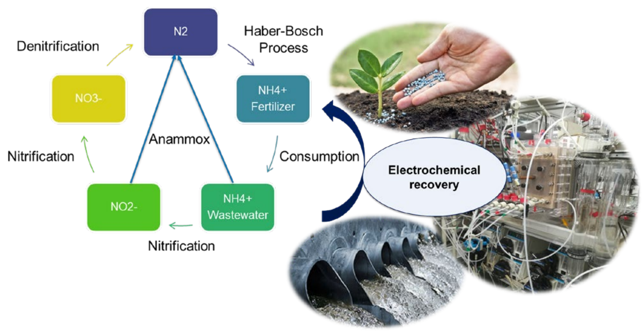


Fig 2. Electrochemical recovery, a new alternative in the Nitrogen cycle.

Technological challenge

This project aims to improve and **scale-up** an electrochemical system for TAN recovery using different **real wastewater streams** (source separated urine, digester effluent, etc.) in a **multiple stacked cell system**.

The process will be optimized to a simple and compact system, capable to treat a significant volume of influent and to achieve high TAN recovery at low energy input.

CV Researcher;	Mariana Rodrigues
Graduated;	Engineering Faculty of Porto University
Hobbies;	Travelling, painting, play football
e-mail;	mariana.rodrigues@wetsus.nl
tel;	0582843188
website;	http://newbies.eu/

Optimization of BES by unravelling the storing mechanisms of electro-active bacteria

Environmental Technology

Nov 2019 - 2023

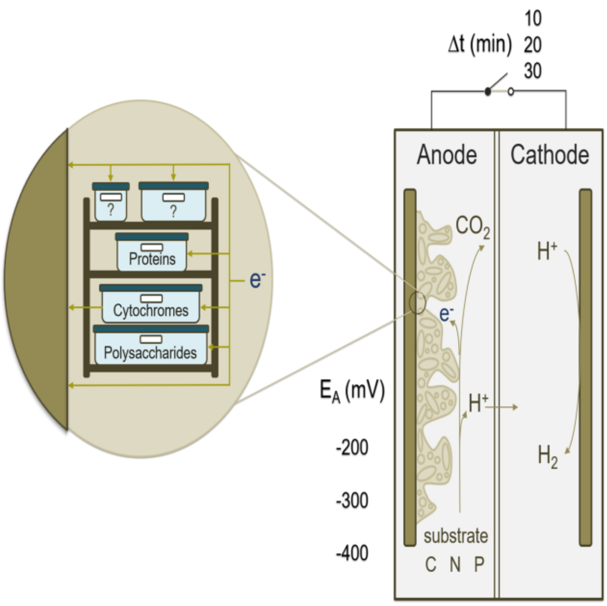
Researcher
João Pereira

Supervisor
Dr. ir. Tom Sleutels
Dr. ir. Bert Hamelers

Promotor
Dr. ir. Annemiek ter Heijne

Motivation

Bio-electrochemical systems (BESs) have been referred as a new technology for chemicals productions, bioremediation and power generation. The role of electro-active microorganisms in these systems is crucial. However, their performance in terms of current output is not competitive for practical application. Recently, higher currents have been reported for electro-active bacteria (EAB) controlled under intermittent polarization. Using this regime, biofilm morphology also differed from the structure typically observed under continuous polarization. However, the underlying mechanisms are still to be unraveled. In this project we propose the study of charge storage capabilities of electro-active bacteria by integrating several techniques to understand biofilm growth kinetics and biochemical composition. These results will provide valuable information to control and optimize biofilms performances in BES.



Technological challenge

The main challenge will be the integration of different quantification and characterization methods to assess the biofilm development on the anode. Due to the limited number of in-situ techniques available to track biofilm growth kinetics and chemical composition, the integration of several optical and electrochemical approaches is essential to a better understanding of biofilm behavior and a more detailed biofilm analysis (Figure 1). By studying the effect of operational conditions on the biofilm development, a final inherent challenge will be the creation of knowledge to control biofilm growth kinetics towards better performances in BES.

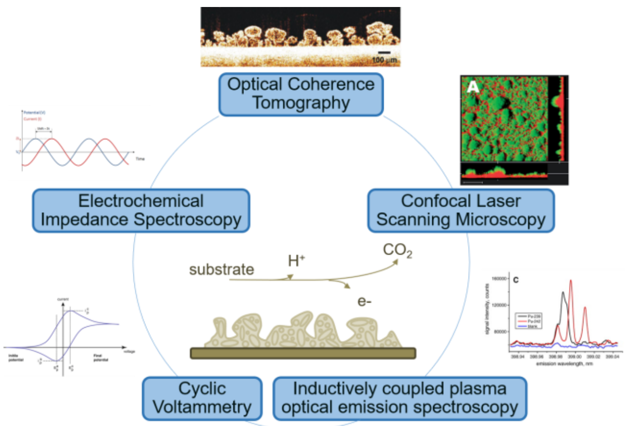


Fig 1. Examples of techniques to evaluate biofilm growth in BES: optical techniques (Optical Coherence Tomography and Confocal Laser Scanning Microscopy), electrochemical analysis (Electrochemical Impedance Spectrosocopy, Cyclic Voltametry) and chemical methods (Inductively Coupled Plasma Optical Emission Spectroscopy).

CV Researcher; João Pereira

Graduated; Faculty of Engineering of University of Porto, Bioengineering (2018)

e-mail; joaopedro.fontespereira@wur.nl

tel; (+351) 917333946

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 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).

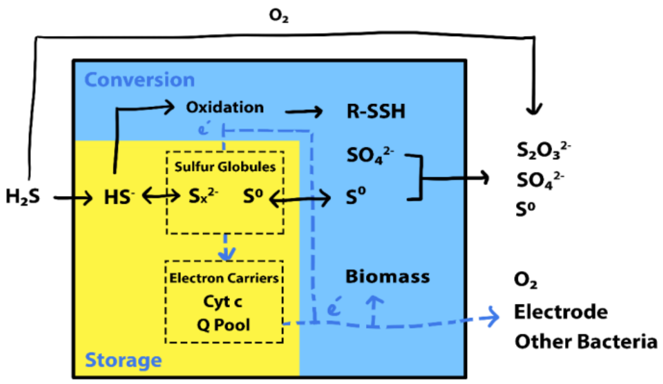


Figure 1 A simplified overview of the postulated mechanics of sulfide conversion and storage yellow field), and electron transfer (blue striped lines).

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).

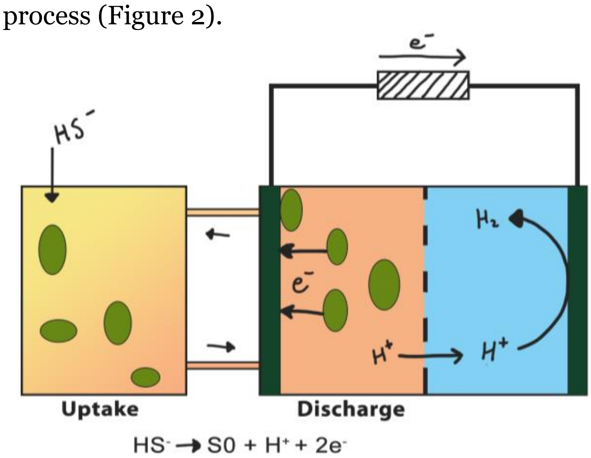


Figure 2 A simplified sketch of a sulfide removal SOB fuel cell.

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.

CV Researcher;	Rikke Linssen
Graduated;	Wageningen University and Research (2020) Biotechnology – Process Engineering
Hobbies;	Music (violin), hiking, drawing, games
E-mail;	Rikke.linssen@wur.nl

WAGENINGEN UNIVERSITY & RESEARCH

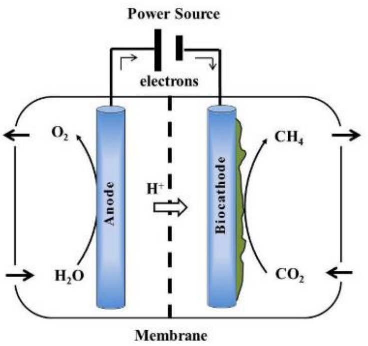
July 2020 - 2024

Power-to-methane in a Bioelectrochemical System

Researcher	Supervisors	Promotors
Ana Micaela Lavender	Dr. ir. Johannes B. M. Klok Ir. Dandan Liu	Dr. ir. Annemiek ter Heijne Dr. ir. Cees Buisman

Motivation

Interest in electricity storage technologies is on the rise with the increasing implementation of renewable energy into the electricity market and consequential fluctuations between electricity supply and demand.
Power-to-methane in a bioelectrochemical system (BES) is a novel electricity storage concept inspired by research on methane producing BES, with the intent of recovering methane from electrical energy. Methane can then be stored or transported through existing natural gas pipeline infrastructure. The energy efficiency of the system quantifies the methane recovery as of electrical power input and is calculated as the product between current-to-methane efficiency and voltage efficiency. With this said, the higher the energy efficiency the less energy is lost between conversions and the more efficiently electricity is stored.

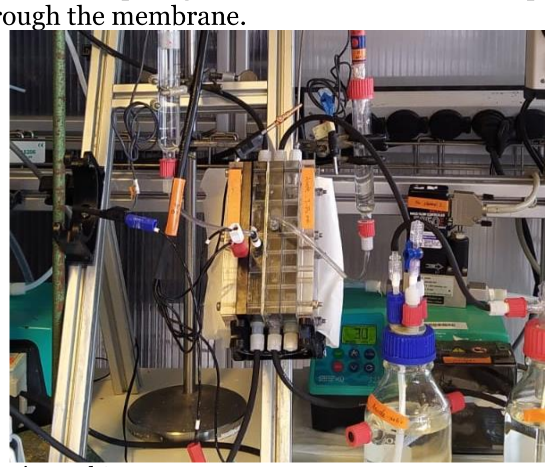


Methane-producing BES: CO_2 is converted to methane by mixed culture microorganisms at the cathode side while at the anode water oxidation provides the protons and electrons necessary for reduction of CO_2.

Technological challenges

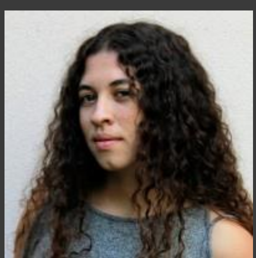
So far the energy efficiency of methane-producing BES is below 25%, low in comparison to currently implemented electricity storage technologies.

In this context, the main challenge is to increase the energy efficiency while at the same time ensuring a highly productive system. This meaning without compromising methane production rates.
Current-to-methane efficiency is highest when no other reactions occur besides methane production and voltage efficiency is highest the lowest the losses within the BES. These losses can be associated to cathode overpotential, anode overpotential, ion movement, pH gradients and other transports through the membrane.



Experimental Set-up.

With this said the main goals are:
(1) To develop a biocathode at minimum overpotential;
(2) To design a state-of-the-art (highly productive) methane-producing BES;
(3) To study the influence of intermittent electricity supply (characteristic of electricity storage applications) in the state-of-the-art system;
(4) To evaluate the most valuable CO_2 containing waste streams;
(5) To understand the applicability of the state-of-the-art system as an electricity storage technology based on all above.

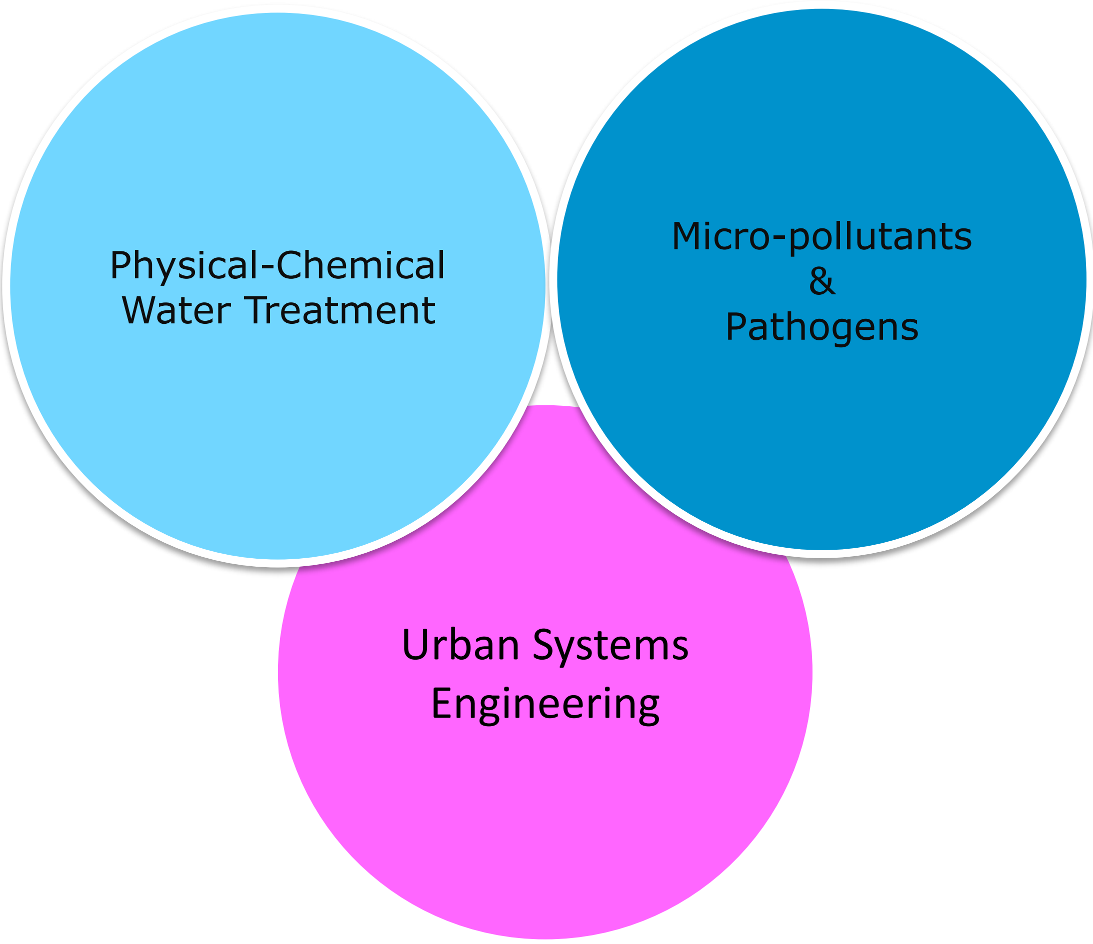


CV

Researcher:	Ana Micaela Brandão Ferreira Lavender
Graduated:	Wageningen University & Research, Environmental Sciences (2020)
Hobbies:	Sports & travelling
E-mail:	ana.brandaoferreiralavender@wur.nl
Tel:	+351 961 051 753

Environmental Technology

Reusable Water



Reusable Water

Water treatment technologies have the objective to safely discharge municipal and industrial wastewater to surface water, and to reduce the risks associated with polluted surface and groundwater.
Directly related challenges are fresh water scarcity, a lack of nutrients (e.g. the phosphorus crisis), climate change, degradation and erosion of soils and the necessity for a more bio-based economy to reduce our dependency on fossil fuels.
This explains why wastewater is more and more considered as a valuable resource for reusable water, energy, chemicals, nutrients and complex organic matter. To make this possible, domestic and industrial water loops will be further closed, become interconnected, and new treatment technologies and concepts (together with the USE group) need to be developed that combine treatment and recovery of these resources.

Micro-pollutants and pathogens

In closed water loops, environmental and health related risks by the accumulation of recalcitrant, toxic organic micropollutants (e.g. medicines, hormones, antibiotics, pesticides, POPs, consumer product chemicals, and industrial chemicals), pathogens and antibiotic resistance genes (ARGs) should be avoided.
Biological technologies are studied, possibly combined with physical-chemical technologies, to remove micro-pollutants, pathogens and antibiotic resistance genes from wastewater, surface water and groundwater to make water fit for applications such as irrigation water, industrial process water, (secondary) household water, and as a source for drinking water production.

For historical groundwater, we co-develop with municipalities and industrial site owners, nature based solutions where natural attenuation processes (bioconversion, sorption) are combined with other applications such as green infrastructure groundwater cleaning, Aquifer Thermal Energy Storage, and sediment recovery, cleaning and reuse.

Physical-chemical water treatment

Saline water provides an immense source for fresh process water and drinking water. Innovative electrochemical techniques including capacitive de-ionisation, electro-dialysis and combinations of these are studied to reduce costs and energy demand for fresh water production and for selective removal and recovery of salts and ionic species from wastewater and natural waters. Polymers and mineral colloidal particles hamper desalination or electrochemical technologies, especially in industrial (salt)water applications, such as oil/gas and thermal energy produced water, process water in the food and beverage industry, or drinking water productions from DOC rich groundwater. Polymer removal is therefore studied in our program. The recovery of waste water organics as methane or bio-flocculants, via (an)aerobic sludge or biofilm based reactor technology, are studied together with the Biorecovery tea

Improving the removal efficiency of constructed wetlands

Nov 2019 - 2021

Researcher	Supervisors
Thomas Wagner	Dr. Alette Langenhoff Prof. dr. ir. Huub Rijnaarts

The research project

From October 2015 – October 2019, I did my PhD-research in ETE, in the NWO-TTW Water Nexus research program. Water Nexus aimed to lower the industrial fresh water footprint by reusing industrial saline wastewater. I studied the use of constructed wetlands (CWs) as a pre-treatment for cooling tower water before subsequent desalination and reuse of the cooling tower water in the cooling tower itself.

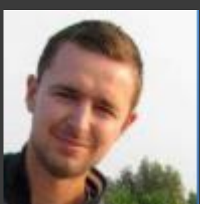
During my research, I showed that CWs are able to remove conditioning chemicals from cooling tower water in lab-scale removal experiments and pilot-scale constructed wetlands that are located outdoors next to the laboratories of ETE (Fig. 1) (Wagner et al., 2020). In addition, I showed that the CW removal efficiency can be hindered by factors, such as the climate.

Currently, I'm doing a postdoc in which I continue working on CWs. The focus will be on improving the CW treatment-efficiency for various waste waters, using lab-scale and pilot-scale CWs. I am able to supervise MSc. students that can study different topics:

- The influence of different **operational strategies** on the removal efficiency of the pilot-scale constructed wetlands. These operational strategies might include:
  - A different hydraulic retention time
  - The addition of fungi
  - The addition of adsorbing substrate
- Elucidation of specific **removal mechanisms** for different chemicals, such as plant uptake.

Figure 1. Pilot-scale constructed wetlands next to the laboratories of ETE.

Figure 2. The removal of the vegetation from the pilot-scale constructed wetlands in summer.



CV Researcher;	Thomas Wagner
PhD;	WUR, Environmental Technology & UvA
Hobbies;	Soccer, fishing, cooking
e-mail;	Thomas.wagner@wur.nl
tel;	0317-483997

Environmental Technology

Technology integration for removal of organic pollutants from saline water

April 2016 - 2020

Researcher	Supervisor	Promotor
Pradip Saha	dr.ir. H (Harry) Bruning	prof.dr.ir. HHM (Huub) Rijnaarts

Motivation

Two third of the fresh water produced in Netherlands is used by industry and ends up as wastewater, often rich in inorganic salts and containing a complex mixture of organic compounds. The presence of salts limits biological treatment.

Within the Water Nexus project, a new treatment scenario is proposed based on a wetland for removal of organics, combined with electrochemical oxidation (EO) and membrane treatment for recalcitrant compounds and plant-microbial desalination cells (PMDC) for desalination.

This project focusses on the integration of EO within this concept.

In the EO process, electrons are transferred from organic compound to the electrode using electrical energy. In this process, in-situ generated strong oxidizing species can degrade a wide variety of compounds. EO does not need the input of chemicals and can run at normal temperature and pressure. Moreover, this robust technology has the ability to withstand the variation of incoming wastewater quality and quantity.

However, still, the EO process is not a standalone alternative for wastewater treatment due to high costs, and toxic by-product formation. Hence, optimization and integration of EO with other technologies is required. Integration of EO process with a membrane process concentrating the organics is suitable when organic chemical are present at a very low concentration where EO is not feasible due to mass transfer limitation. Moreover, the EO of chloride containing wastewater generates perchlorate (ClO4-) and

active chlorine, which reacts with an organic compound forming highly toxic Absorbable Organic Halide compounds (AOX). In this case, using Plant-microbial Desalination Cell (PMDC) before the EO process is useful.

Technological challenge

The challenge of this research is to optimization of the EO process in saline water in order to reduce the cost and by-product formation, and to develop case specific technology integration scenarios including membranes and PMDC for application of Zhe EO

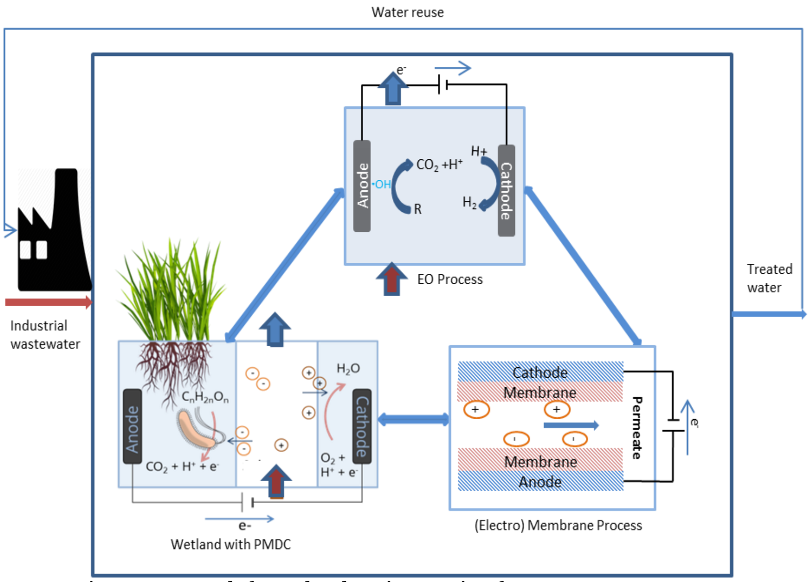


Figure: Approach for technology integration for wastewater treatment

CV Researcher: Pradip Saha

Graduated: Wageningen University, Environmental Technology (2016); SUST(Bangladesh), Chemical engineering and polymer Science (2013)

Hobbies: Cricket, Music, Traveling

e-mail: Pradip.saha@wur.nl; Pradip-cep@sust.edu

Website: www.wur.nl/ete

STW Enabling new technology

WATER NEXUS

WAGENINGEN UNIVERSITY & RESEARCH

Capacitive Deionization with Membranes for Selective Ion Removal

Jan. 2016 - 2020

Researcher	Supervisor	Promotor
Tania Mubita	Dr. ir. Slawomir Porada	Prof. dr. ir. Bert van der Wal

Motivation

Membrane capacitive deionization (MCDI) has been introduced to improve the performance of conventional capacitive deionization system. The MCDI technology depends critically on the ability of the ion exchange membranes (IEMs) to exclude ions carrying the same charge as the electrode charge while simultaneously allowing the transport of oppositely charged ions.
Although the MCDI technology has the potential to specifically remove ions from water, research on this topic has remained unexplored.

For industrial applications, and from an academic perspective there is need to develop ion selective membranes which allow the removal of certain ions from multi-ion systems. For instance: i) to remove nitrates from a mixed solution of chloride and nitrate ions, Fig.1, to avoid health effects on humans, ii) to reduce sodium concentration in irrigation water, which affects the optimal growth of most crop plants, and iii) to recover valuable ions, such as lithium, or unwanted ions, such as arsenic.

Research challenge

IEMs allow the concentration and separation of ionic species. However, they exhibit very low performance when the selective uptake of ions is the aim, e.g., the removal of ions with the same charge and valence.

Endowing the IEMs with selective properties or modifying them for imparting selectivity between specific ions often leads to various associated problems, such as high electrical resistance, and loss of mechanical strength.

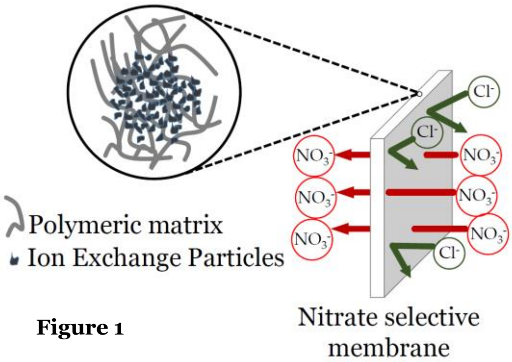


Figure 1

We intend to fabricate and tailor membrane functionalities in order to improve their physical-chemical properties and enhance the selectivity by evaluating different fabrication routes, Fig. 2. Our final aim is to use these ion selective membranes for the removal of ions using MCDI technology.

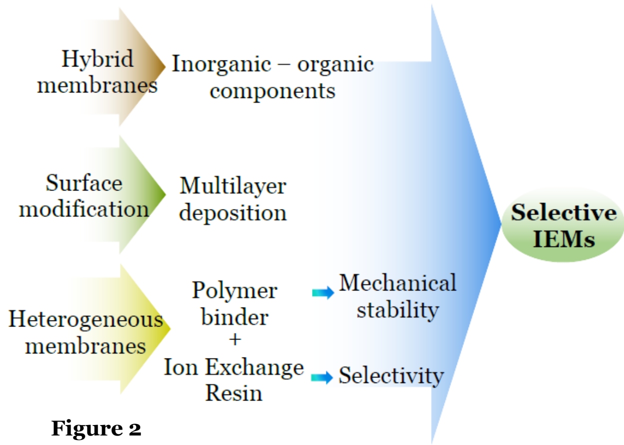


Figure 2

CV Researcher	Tania Mubita
Graduated:	Wageningen University, Water Technology (joint degree), 2015
Hobbies:	Running, reading
e-mail:	Tania.Mubita@wur.nl
tel.:	058-2843016

Anaerobic conversion of proteins under acidifying and methanogenic conditions

2016 - 2020

Researcher	Supervisor	Promotor
Duong Thu Hang	Dr.ir. Hardy Temmink, Dr.ir. Miriam van Eekert, Dr.ir. Tran Thi Viet Nga.	Prof. dr. ir. Grietje Zeeman

Motivation

Wastewaters and wastes generated by the food industry typically contain high concentrations of biodegradable organic materials such as carbohydrates, lipids and appreciable quantities of proteins.

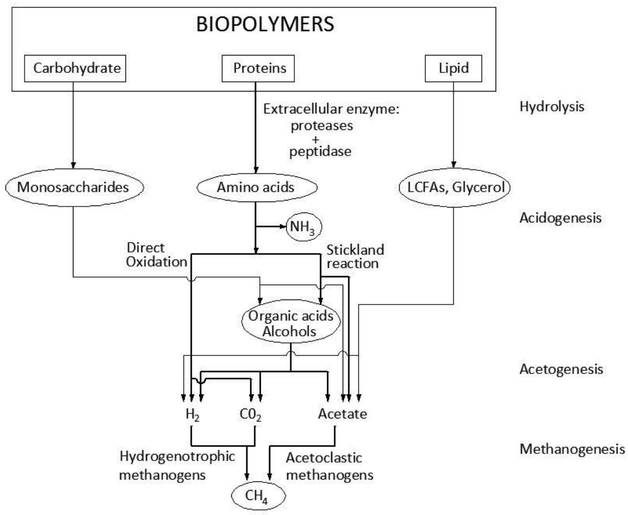
Anaerobic digestion has been widely used for the treatment of wastewater since it combines pollution control and energy recovery (as biogas). The tropical climate in Vietnam especially favors anaerobic treatment, which makes this project very relevant for sustainable development in Vietnam and other high temperature developing countries in general.

Technological challenge

Serious problems in the anaerobic treatment of wastewaters containing proteins are reported, resulting in low organic removal rates, low methane production, foaming, sludge flotation, a deteriorating effluent quality and biomass washout. Nevertheless, anaerobic degradation of proteins only has been investigated in a few studies, and in particular the effect of the presence of other biopolymers such as carbohydrates and lipids on protein hydrolysis is largely unknown. More knowledge can give directions on how to solve the problems associated with insufficient protein degradation. Moreover, research will give more insight in the necessary design for optimal treatment of protein containing wastewaters.

The objective of this study is to investigate anaerobic conversion of proteins under acidifying and methanogenic conditions at mesophilic temperatures (30-35°C) and the interactions that occur with carbohydrate degradation pathways and bacteria. We aim to provide deeper insight into the hydrolysis rate of proteins, the formation and activity of the proteolytic enzymes and the biochemical reaction pathways involved in the transformation of proteins in the presence and absence of carbohydrates. Also, the composition of the microbial community in relation to the protein degradation in anaerobic reactors will be assessed.

The results of the research will be used to propose and test technical solutions to overcome difficulties in anaerobic treatment of rich protein wastewaters.



CV Researcher: Duong Thu Hang
Graduated: Ghent University (Belgium), MSc Environmental Sanitation (2009)
e-mail: thuhang.duong@wur.nl, hangdt@nuce.edu.vn
tel: 0084 936 486 399
website: www.wur.nl, vnwater.org

Decentralized electrochemical synthesis of green oxidants

Jan 2019 – Jan 2023

Researcher	Supervisors	Promotor
Vincent van Vught	Dr. ir. Harry Bruning Dr. ir. Norbert Kuipers (WFBR) Roel Bisselink MSc (WFBR)	Prof. dr. ir. Huub Rijnaarts

Motivation

Oxidants are bulk chemicals in industrial, environmental, and domestic applications. One of the most common is hydrogen peroxide (H2O2), since its residues are environmentally benign. At least 4.3 million tonnes of H2O2 was produced in 2015 [1]. H2O2 is used to remove organic pollutants in waste water and soil, to bleach paper and textile, to disinfect food, or to drive chemical processes. Since electricity is likely becoming the main industrial energy carrier, electrosynthesis of H2O2 is an emerging alternative to the Riedl-Pfleiderer chemical synthesis process, which requires organic chemicals, hydrogen gas, catalyst, and high amounts of pressure and heat [2]. Transport, handling, and storage are also hazardous.

This can be avoided if the H2O2 is generated locally and in-situ. Small scale electrochemical synthesis at ambient conditions removes the need for transportation, and reduces the consumption of chemicals.

Technological challenge

An electrolysis cell capable of this synthesis has been developed at WFBR (figure 1). At ambient temperature it can produce non-saline H2O2 solutions with an input of oxygen (or air), water, and electricity. The device combines complex physical and chemical interactions in different phases. Also, its yield and electric performance cannot be measured up to industrial benchmarks. The knowledge gap between theory and practice is impeding the development of the system. Additionally, the system has unexplored potential to produce alternative oxidants.

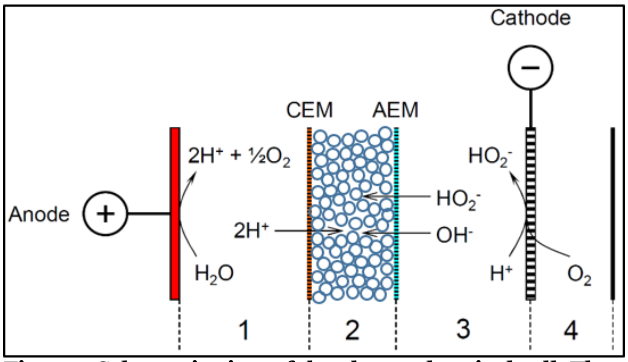


Figure 1 Schematic view of the electrochemical cell. The cell consists of an acidic anolyte compartment (1), a central H_2O_2-rich channel of neutral pH packed with a porous ion exchange matrix (2), a basic catholyte (3), and a gas compartment (4).

Method

This project is aiming to characterize the most significant physical and chemical mechanisms in the cell, and the methodology will comprise a mathematical model and a lab scale reactor. It will use the synergy between theory and application to support innovative design of an optimized system.

Outcomes

- A mathematical model which is used as a tool for innovation in electrochemistry.
- Characterization of the internal physics and chemistry in the electrolysis cell.
- Progress towards viable H2O2 electrosynthesis.
- Proof of principle for synthesis of alternative oxidants.

1. Hydrogen peroxide. 2016 6 November 2016 [cited 2019 6 February]; Web library for industrial chemicals, production, and applications.]. Available from: http://www.essentialchemicalindustry.org/chemicals/hydrogen-peroxide.html.
2. Campos-Martin, J. M., Blanco-Brieva, G., & Fierro, J. L. (2006). Hydrogen peroxide synthesis: an outlook beyond the anthraquinone process. Angewandte Chemie International Edition, 45(42), 6962-6984.

CV Researcher; Vincent van Vught
Graduated; Wageningen University, MES Environmental Technology (2018)
Hobbies; Photography, outdoor sports, gardening
e-mail; vincent.vanvught@wur.nl
tel; 06 21373161
website; -

Selective Electrodialysis for Food Industry

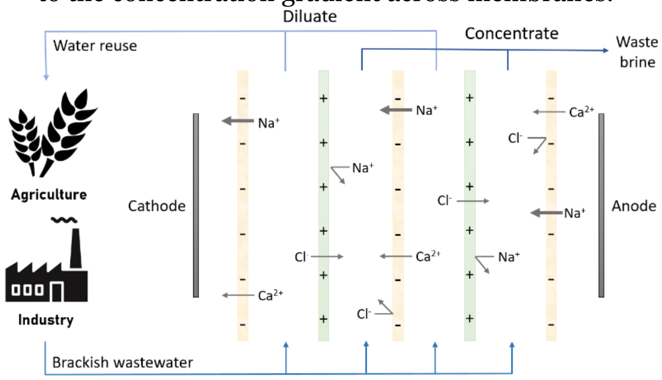
Reusable Water
Environmental Technology

Jul 2019 - 2023

Researcher	Supervisors	Promotor
Selin Özkul	Dr. ir. Jouke Dykstra Dr. ir. Harry Bruning Dr. ir. Norbert Kuipers (WFBR) MSc Roel Bisselink (WFBR)	Prof. dr. ir. Huub Rijnaarts

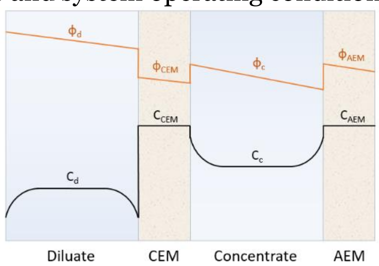
Motivation

In many sectors, there is an increasing interest to desalinate and re-use water due to the rising demand for limited freshwater resources. However, continuous use of water in closed cycle systems can result in accumulation of specific ions in the recirculating water. Especially in agricultural sector, accumulation of sodium ions (Na+) in the irrigation water negatively affects the soil permeability and limits crop growth, thus makes the water unusable in agricultural systems. In order to increase the potential for water re-use, it is important to develop desalination technologies that selectively remove specific ions from the solution.
Electrodialysis (ED) is an electrically driven membrane desalination technology, which has high potential to selectively remove specific ions from the solution. An ED cell consists of two electrodes and alternatingly placed ion exchange membranes between them. When electrodes are electrically charged, the salt concentration increases in each alternate cell due to the arrangement of membranes. Mass transport in an ED cell is the result of electro-migration due to electrical forces, and diffusion due to the concentration gradient across membranes.



Technological challenge

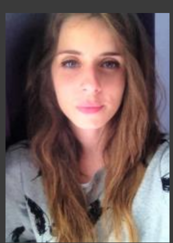
Mass transport determines ion removal rate, quality of the desalinated water and ion selectivity of the ED process. In order to selectively remove undesired ions and recover valuable ones in the solution, ion transport mechanisms should be studied in detail. Several factors can be controlled in the ED system to influence the concentration gradients, thus the ion transport. The technological challenge is to modify these factors in a way to achieve specific ion removal considering membrane characteristics, individual ion properties and system operating conditions.



Methodology

In this project, we aim to study ion-transport controlling parameters to develop ion selective ED technology. For this purpose;

- A theoretical model describing ion transport through ion-selective membranes will be developed for multi-ionic solutions.
- Laboratory experiments will be performed in order to validate and improve the developed model.
- Ion selectivity of the ED process will be enhanced by influencing the concentration gradient between the diluate and concentrate compartments.
- Industrial applications of the developed selective ED process in food industry will be evaluated.



CV Researcher; Selin Özkul
Graduated; Middle East Technical University (Turkey), Environmental Engineering (2019)
Hobbies; Yoga, snowboarding
e-mail; selin.ozkul@wur.nl
Tel; 0317-484993
Website; -

WAGENINGEN UNIVERSITY & RESEARCH

Biopolymer based membranes for (waste) water filtration.

Reusable Water
Environmental Technology

March 2017 - 2021

Researcher	Supervisor	Promotor
Emanuel Dinis	Dr.ir. Hardy Temmink Dr.ir. Antoine Kemperman	Prof. dr. ir. Huub Rijnaarts Prof.dr.ir. Rob Lammertink

Motivation

The use of micro- and ultrafiltration membranes in membrane bioreactors (MBRs) allows complete retention of biomass and wastewater particle separation during (biological) waste water treatment. However, the treatment costs are high because the membranes are expensive and suffer from fouling. In aerobic MBRs, generally a gel layer is formed on the surface of the membrane (van den Brink et al., 2013). This is caused by gelation of extracellular polymeric substances (EPS) such as polysaccharides and proteins, which are excreted by microorganisms. It is generally accepted that this gel layer dictates the filtration process, i.e. determines the retention of compounds and the permeability.

Technological challenge

The objective of this project it to create a gel layer of anaerobic EPS on a porous support as a cheap alternative for expensive membranes. This is accompanied by several challenges and research questions:

- Can a suitable gel layer be formed from anaerobic EPS, what is the composition and structure of this gel layer and what is the effect of environmental conditions such as temperature and cation concentrations?
- Under which operational conditions and with what type of porous carrier material is the performance of this layer optimal with respect to solids retention and permeability?
- How can a gel layer be formed in-situ and what is its long-term stability?

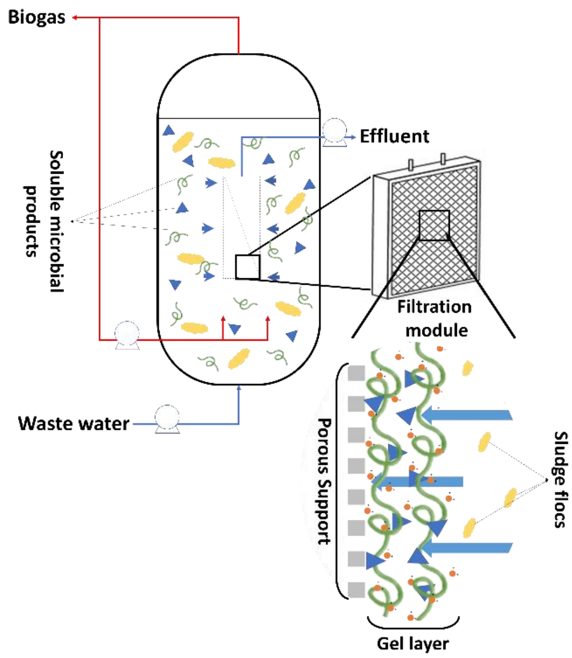


Fig. 1 – Illustration of a gel membrane in an anaerobic bioreactor

Reference

Van den Brink, P., et al. "Potential of mechanical cleaning of membranes from a membrane bioreactor." *Journal of membrane science* 429 (2013): 259-267.

CV Researcher; Emanuel Dinis
Graduated; Universidade da Beira Interior - Covilhã, Portugal (2012)
Hobbies; Backpaking, Weekend Tourist, Startups
e-mail; Emanuel.Dinis@wetsus.nl
tel; 00351-969944896

wetsus
UNIVERSITY OF TWENTE.
WAGENINGEN UNIVERSITY & RESEARCH

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

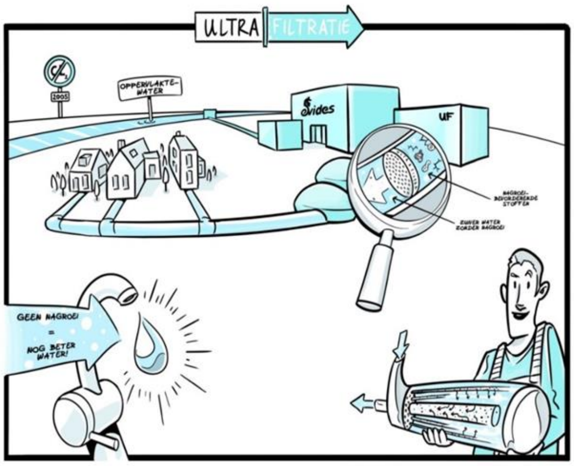
Distribution of potable water without any residual disinfectant eliminates DBP (disinfectant-byproduct formation) and maximizes consumer satisfaction in terms of taste and odor. However, biological stability, i.e. unobjectionable levels of microbial and invertebrate organisms, is to be maintained in 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.



CV Researcher: Rinnert Schurer

Graduated: Rijksuniversiteit Groningen, Chemical Engineering (1994)

Hobbies: Yacht sailing, traveling

e-mail: R.Schurer@evides.nl

tel: 0620861687

website: www.evides.nl

Chemically modified carbon electrodes for electrochemical separation processes

Oct 2018 - 2022

Researcher	Supervisors	Promotor
Antony Cyril Arulrajan	Dr. ir. Jouke E. Dykstra Dr. Slawomir Porada	Prof. dr. ir. Albert van der Wal

Motivation

Water, being the most essential need for all living creatures, becomes scarce as consumption rapidly increases every year. To overcome the scarcity of potable water, technologies to desalinate and to purify ground water, surface water and sea water can be developed and employed. Electrochemical methods can be used to remove ions and charged molecules from water.

Capacitive Deionization (CDI)
CDI is an electrochemical method for ion removal using porous electrodes. These electrodes adsorb ions from water, resulting in a desalinated stream. Later, the electrodes are regenerated, and the ions are released, resulting in a concentrated stream. Traditionally, CDI uses a cell design with one porous carbon electrode that adsorbs and releases the cations (cathode), and another electrode that adsorbs and releases the anions (anode).

Technological challenge

Since carbons do not have a natural preference for the adsorption of either anions or cations, the ion adsorption is solely based on the potential applied. This results in a reduced ion removal efficiency due to phenomena such as co-ion adsorption.
To overcome this, following strategies can be employed.

- *Selective ion adsorption* by the electrodes can be increased.
- *Selective ion transport* across the electrodes can be achieved through *ion-selective membranes.*
- The effect of faradaic and non-faradaic processes on (selective) ion adsorption, and on potential pH changes during operation, should be understood to increase the performance and stability of the electrodes and membranes.

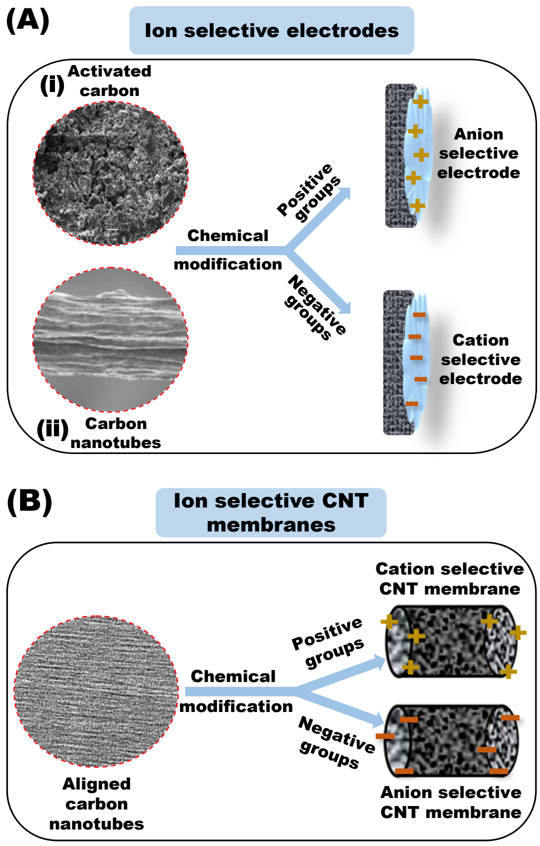


Fig.1: (A) Preparation of ion selective carbon electrodes from (i) activated carbon (AC) and (ii) carbon nanotubes (CNTs). (B) Chemical modification of aligned carbon nanotubes (CNTs) to prepare an ion-selective membrane.

CV Researcher;	Antony Cyril Arulrajan
Graduation;	Wageningen University and Research, Environmental Technology (2022)
Hobbies;	Photography, Badminton, Traveling.
e-mail;	antonycyril.arulrajan@wur.nl
Tel;	+31582843190
Website;	www.wetsus.nl

Fouling prevention through biological activated carbon and ultrafiltration

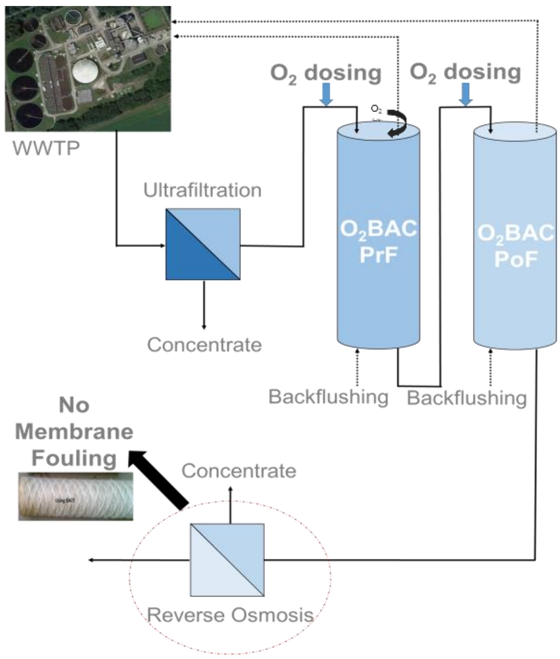
Environmental Technology

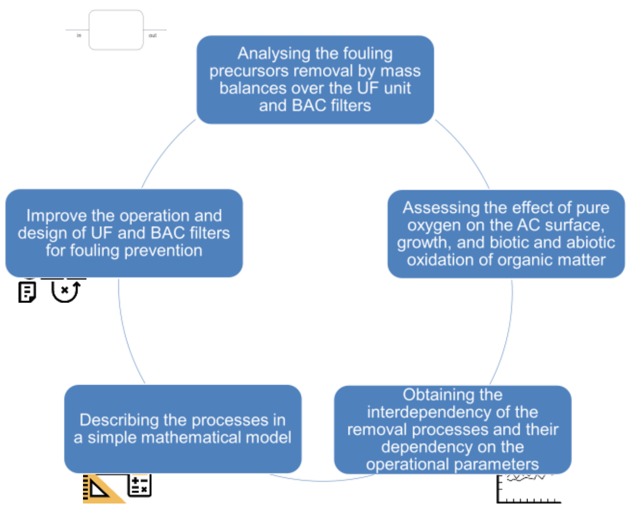
Oct 2019 - 2023

Researcher	Supervisor	(Co-)Promotor
Sara Ribeiro Pinela	Dr. ir. R. J. W. Meulepas Dr. M. C. Gagliano	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.

CV Researcher; Sara Ribeiro Pinela
Graduated; University of Minho, Integrated Master in Biological Engineering (2016)
Hobbies; Swimming, Writing, Reading
e-mail; sara.pinela@wetsus.nl
tel; +31 (0)58-2843000
website;

wetsus

WAGENINGEN UNIVERSITY & RESEARCH

Biostimulation of aromatic hydrocarbon mixture degradation in a former gaswork site

Environmental Technology

April 2019 - 2023

Researcher	Supervisor	Promotor
Dilan Camille Aydin	Dr. ir. Tim Grotenhuis Dr. Ivonne Nijenhuis	Prof. Dr. ir Huub Rijnaarts

Motivation

Since the start of the industrial revolution a wide variety of organic chemicals has been released into the environment through anthropogenic activity. One of major concerns affecting the groundwater quality and aquifer ecosystem health is contamination with aromatic hydrocarbons because of their relatively high water solubility, toxicity, and carcinogenicity.

As an efficient and eco-friendly treatment method, in situ bioremediation of contaminated soils and groundwater by naturally occurring microorganisms or by bioaugmentation of adapted microorganisms is possible. Therefore, the aim of this study is to develop a new approach for the biostimulation of aromatic hydrocarbon degradation that could also be applied to many different polluted sites.

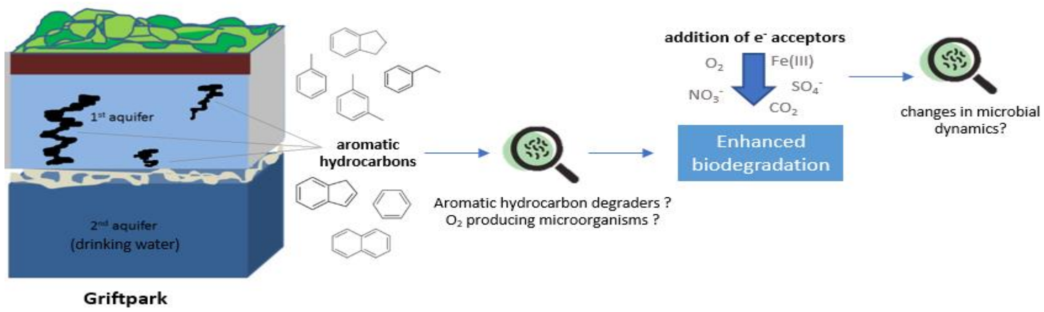
Technological challenge

In the presence of oxygen, aromatic hydrocarbons can be rapidly degraded. However, groundwater and soil environments are mostly **anoxic.** Therefore, it is necessary to artificially improve the degradation activity of indigenous microorganisms for an efficient remediation approach.

Engineered bioremediation is usually applied to speed up the biodegradation process by addition of nutrients, **electron acceptors**, bioaugmentation or other stimulants. In this project, our target area is Griftpark (Utrecht) which used to be a manufactured gas plant site. The soil and the groundwater is currently contaminated with high concentrations of BTEX, indene, indane and naphthalene.

In this project:

- The effect of different electron acceptors on the biodegradation of a **hydrocarbon mixture** present in Griftpark will be tested.
- Changes in **microbiome dynamics** within different redox conditions will be studied by use of molecular techniques.
- The presence of **O2 producing microorganisms** in Griftpark will be investigated hereby the formed O2 can be used by the microorganism for aerobic catabolic pathways in an anoxic environment, suggesting an ecophysiological niche space of substantial appeal for bioremediation.



CV Researcher;	Dilan Camille Aydin
Graduated;	Middle East Technical University (Ankara, Turkey) (2018)
Hobbies;	Video editing, travelling, cooking
e-mail;	dilan.aydin@wur.nl
tel;	0317-483997
website;	www.wur.nl/ete

Universiteit Utrecht
Deltares Enabling Delta Life
Gemeente Utrecht
WAGENINGEN UNIVERSITY & RESEARCH

Selective sorption and stimulated biodegradation for sustainable use of large-scale industrial sites

Reusable Water
Environmental Technology

Jan 2020 - 2022

Researcher
Marjet Oosterkamp

Supervisor
Dr. ir. Tim Grotenhuis

Co-supervisors
Prof. dr. ir. Huub Rijnaarts
Prof. dr. ir. Rob Comans

Motivation

Industrial waste and spillage is taken care of to the best of experience and knowledge. However, toxic compounds from industries, such as chlorobenzenes, aromatic sulfonic acids and benzene, can be present in soil and groundwater at industrial sites. Especially when groundwater flows directly into surface water, this can allow pollutants to spread over large areas.

One of the difficulties of treating a variety of contaminants is the complexity of obtaining optimal conditions to allow degradation of all of the different types of pollutants. For example conversion of chlorobenzenes and aromatic sulfonic acids can occur in presence of an electron donor such as yeast extract, lactate or acetate [1, 2]. Benzene conversion requires an electron acceptor, such as oxygen, nitrate, iron(III) or sulfate [3]. Chlorobenzenes and aromatic sulfonic acids can also be degraded in the presence of an electron acceptor [4, 5]. Furthermore, bacteria that are mediating the conversion of these pollutants, are necessary. In order to thrive, these bacteria require sufficient bioavailability of the pollutants, which should not be in a too high concentration or toxic level. The concentration of contaminants can possibly be controlled by sorbents. In this project such challenges will be addressed and optimal degradation of a mixture of chlorobenzenes, aromatic sulfonic acids and benzene will be studied.

Technological challenge

By coupling geochemical, (micro)biological and molecular biological data, a Source-Path-Receptor interception plan will be composed for remediation of contaminated large-scale industrial sites (Figure 1). In this project the aim is to deliver the proof-of-principle of this interception plan. Batch tests in serum flasks will be used to focus on biodegradation of chlorobenzenes, aromatic sulfonic acids and benzenes. Furthermore, bioreactors will be designed for continuous experiments studying mixtures of pollutants as well as environmental conditions that will be defined based on the batch tests.

Main principles

- Stimulation of pollutant biodegradation by different environmental conditions.
- Controlling level and localization of pollutant biodegradation by sorbents.
- Creating a suitable habitat for bacteria involved in the bioconversion of environmental pollutants.

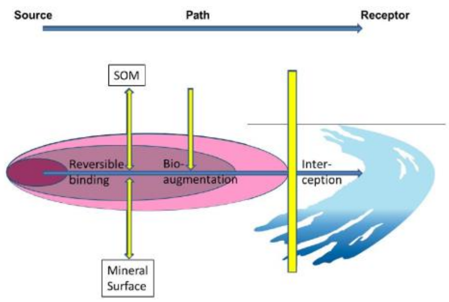


Figure 1. Source-Path-Receptor interception plan.

References

1. Nelson, J.L., et al., Environ Sci Technol, 2011. **45**(16): p. 6806-6813.
2. Liang, X., et al., Environ Sci Technol, 2013. **47**(5): p. 2378-2385.
3. Vogt, C., et al., Microb Biotechnol, 2011. **4**(6): p. 710-724.
4. Nishino, S.F., et al., Appl Environ Microbiol, 1992. **58**(5): p. 1719.
5. Thurnheer, T., et al., Biodegradation, 1990. **1**(1): p. 55-64.

CV Researcher; Marjet Oosterkamp
Graduated; PhD Wageningen University, Laboratory of Microbiology (2013)
Hobbies; Hiking, pilates/body sculpt a.o.
e-mail; Marjet.Oosterkamp@wur.nl
tel; +31 680129805
website; www.wur.nl/ete

DSM

WAGENINGEN UNIVERSITY & RESEARCH

Improving microbiological urban surface water quality with nature-based technologies

Reusable Water
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.

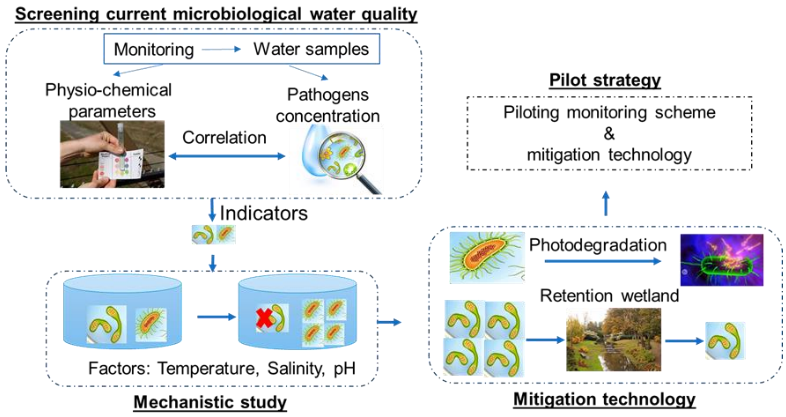


Fig 1 Research approach

CV Researcher;	Sha Gao
Graduated;	Xi'an Jiaotong University, Environmental Engineering (2019)
Hobbies;	Hiking, Travelling, Cooking
e-mail;	Sha.gao@wur.nl
tel;	0616403465
website;	www. ete. wur. nl

China Scholarship Council

WAGENINGEN UNIVERSITY & RESEARCH

Reusable Water

Environmental Technology

Understanding the fate of antibiotic resistance genes from swine manure

Feb 2019 - 2023

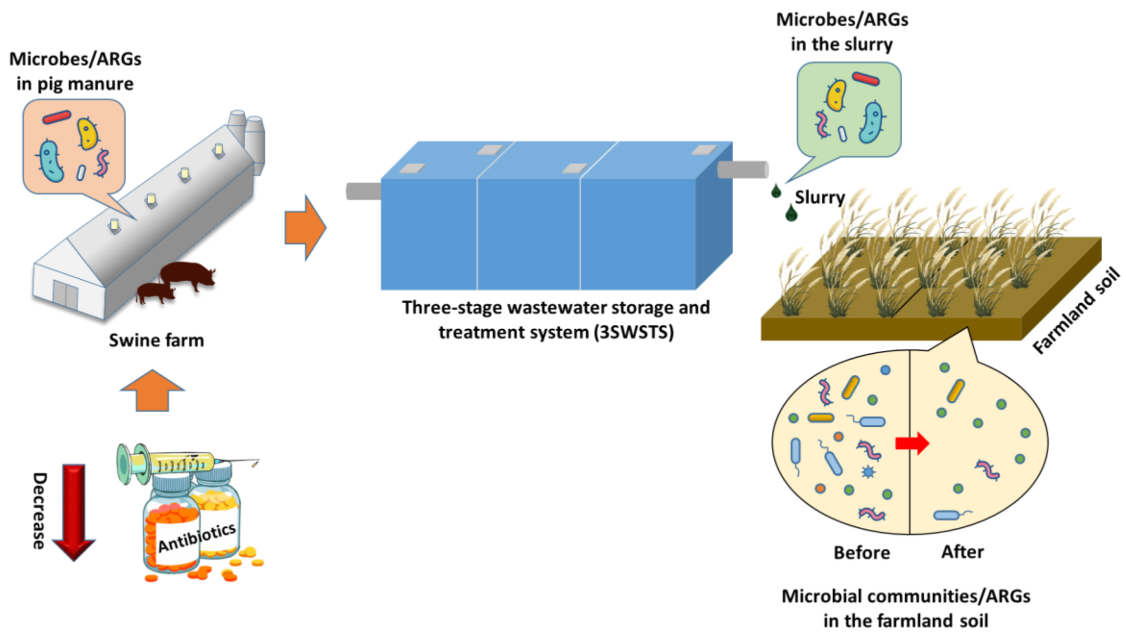
Researcher	Supervisor	Promotor
Yi Wang	Dr. ir. Nora B. Sutton	Prof. dr. ir. Huub Rijnaarts Prof. dr. ir. Hongmin Dong

Motivation

In China, increased use of sub-therapeutic antibiotics on pigs made the microbial populations present in swine manure and wastewaters become reservoirs of antibiotic resistance (AR) genes (ARGs) and posing unknown threats to health of livestock and humans. We aim to measure AR and ARGs in manure and wastewater from Chinese swine farms and in the novel three-stage storage and treatment system which often applied in Northern China. We will investigate the ARGs dissemination mechanism among microbial populations in this system and in soil environments. Finally, the effect of reduced antibiotic use planned in China will be included in this study.

Research Topics

1. The changes of antibiotic resistance (AR) during the antibiotic banning policy execution period.
2. Compare AR between China and the Netherlands
3. The ARGs removal efficiency of the novel 3-stage wastewater storage and treatment systems.
4. The distribution of ARGs and related microbe communities in the 3-stage wastewater storage and treatment system.
5. The dissemination of ARGs from swine farm to the farmland soil environment after apply slurry onto the soil.



CV Researcher;	Yi Wang
Graduated;	Hebei Normal University, Hebei province, China (2016)
	Microbiology, Microfluidics
Hobbies;	Cycling, Photography
e-mail;	yi1.wang@wur.nl
tel;	
website;	www.wur.nl/ete

中国农业科学院 CHINESE ACADEMY OF AGRICULTURAL SCIENCES

WAGENINGEN UNIVERSITY & RESEARCH

Biodegradation of micropollutants in groundwater systems

Environmental Technology

Apr 2017 - 2021

Researcher	Supervisor	Promotor
Andrea Aldas Vargas	Dr. Nora B. Sutton	Prof. dr. ir. Huub Rijnaarts

Motivation

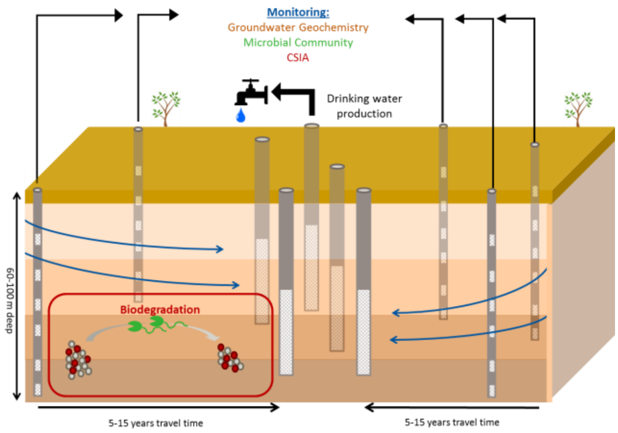
The increasing presence of organic micropollutants in different segments of the water cycle threatens future water resources. These micropollutants are currently being detected at low concentrations in groundwater and surface water used for drinking water intake. While current monitoring (chemical analyses) gives an indication of the presence of these micropollutants, little is known about the natural attenuation of micropollutants in water. This information is required to assess and mitigate the risks of contamination of drinking water resources. The aim of this research is to understand micropollutant fate and transformation in natural systems and develop tools to assess and stimulate microbial biodegradation activity.

Technical Challenge

This research project aims to improve the biodegradation of micropollutants by developing tools to determine biodegradation capacity of a number of key compounds. Micropollutants have very diverse chemical structures and are present at low concentrations. These factors make it is very difficult to determine degradation pathways and develop tools to assess natural attenuation. Also, there is a lack of information on biodegradation rates under environmental conditions. This information is required to improve models used to assess and predict the long term risks of contamination of drinking water intakes Finally, there are no technologies available to stimulate micropollutant biodegradation in natural systems.

Method

The project focuses on micropollutants that specifically threaten Dutch drinking water quality. Collaboration with drinking water companies provides a list of priority compounds for further research in lab experiments and a set of field locations for investigations. For both, biomolecular tools based on DNA analysis are used to assess the natural attenuation capacity. This is combined with advanced analytical tools to identify biodegradation using isotope fractionation. Results will be integrated to form guidelines for the prediction of natural attenuation using molecular tools.



CV Researcher; Andrea Aldas Vargas

Graduated; Wageningen University, MSc. Biotechnology (2017)

Universidad San Francisco de Quito, Engineer Biotechnology (2013)

Hobbies; Yoga, traveling.

e-mail; andrea.aldasvargas@wur.nl

tel; 0657174604

website: www.wur.nl/ete

WAGENINGEN UNIVERSITY & RESEARCH

Adsorption and biodegradation of organic micropollutants in activated carbon filters

Sub-department of Environmental Technology

Jun 2016 - 2021

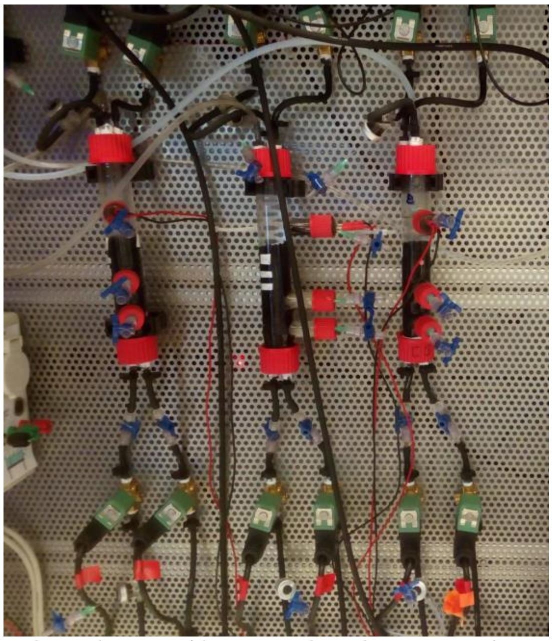
Researcher	Supervisor	Promotor
Laura Piai	Dr. ir. Alette Langenhoff	Prof. dr. ir. Bert van der Wal

Motivation

Organic micropollutants such as industrial chemicals, pesticides and pharmaceuticals are present in surface water and some are not removed by conventional drinking water treatment. Even though they are present at very low concentrations the effects to human health of chronic consumption of those compounds are not well stablished, and therefore additional treatment is needed to remove these compounds from water. Activated carbon (AC) is widely applied in water treatment as its adsorptive properties support the removal of organic compounds from aqueous media. However, the regeneration of the carbon after saturation of its adsorptive capacity is a costly and energy intense process.
The aim of this research is to understand the contribution of biodegradation to the removal of organic micropollutants in AC filters and how biodegradation can be stimulated to bio-regenerate the AC.

Technological challenge

- Biodegradability of organic micropollutants can vary and sometimes metabolites are less biodegradable than the parent compound. AC can promote biodegradation by increasing biomass concentration, increasing contact time between biomass and substrate and adsorbing inhibitory compounds.
- Adsorption and biodegradation are processes that usually occur in parallel in an activated carbon filter. Different strategies are applied to quantify the contribution of adsorption and biodegradation to the removal of micropollutants from water and how they affect each other.
- Operational parameters of an activated carbon filter influence their performance. Lab-scale filters are used to study how to optimize micropollutants removal in a continuous process.



Lab-scale GAC filters used in this research

CV Researcher;	Laura Piai
Graduated;	Wageningen University, Molecular Life Sciences (2012)
Hobbies;	Capoeira, hiking, travelling
e-mail;	laura.piai@wur.nl
tel;	0317-482020

Removal of organic micropollutants from wastewater using a hybrid technology

Reusable Water

Environmental Technology

Jan 2018 - 2022

Researcher	Supervisor	Promotor
Koen van Gijn	Dr. ir. Alette Langenhoff Dr. ir. Arnoud de Wilt	Prof. Dr. ir. Huub Rijnaarts

Motivation

Since the population, average age and life standards are rising all over the world, we produce and use more and more complex compounds that eventually end up in our water systems. The risks for our environment and health are hard to determine because of a long list of compounds and low prevalent concentrations. Still, the scale of the problem and the potential effects show that we should do something to reduce the discharge of organic micropollutants (OMPs) into the environment. Cooperating with the consultancy company Royal Haskoning DHV, our study aims to contribute by further developing a hybrid tertiary treatment technology that can remove OMPs from wastewater treatment plant (WWTP) effluent.

BO_3B technology

This hybrid technology (Figure 2) combines the efficiency of biological removal and the effectivity of ozonation to remove a broad range of OMPs, with limited energy demand. WWTP effluent is fed into the first reactor (bio), where dissolved organic carbon (DOC) is removed to reduce the required ozone dose in the second reactor (ozone). In the third reactor (bio), potentially toxic ozone transformation products are further mineralized by microorganisms.

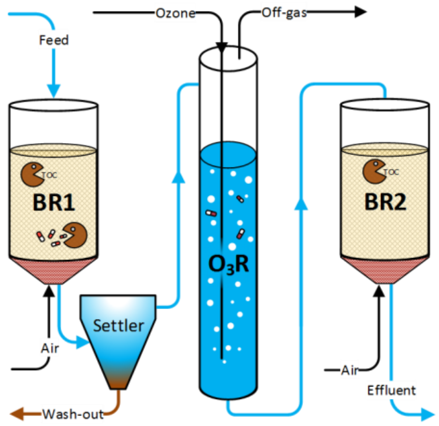
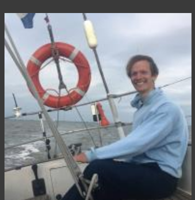


Figure 2 *Schematic overview of the BO_3B (bio ozone bio) lab reactor*

Research topics

We want to increase our understanding of the processes inside the reactors to finally improve and upscale this hybrid technology by studying:

- Interactions between different types of DOC and ozone and how this affects ozonation of OMPs
- Formation and further break down of transformation products using both chemical and toxicological analyses
- The stability of the technology: e.g. over time and for different types of effluents
- Optimizing the reactor configuration; create a design that can be implemented and operated easily as a tertiary treatment step behind conventional WWTPs
- Upscaling the technology; working towards a pilot scale plant



CV Researcher;	Koen van Gijn
Graduated;	Wageningen University, Environmental Technology (2017)
Hobbies;	Tennis, outdoors, bass guitar, cooking
e-mail;	Koen.vangijn@wur.nl
tel;	06-13234567

Royal HaskoningDHV
Enhancing Society Together

WAGENINGEN UNIVERSITY & RESEARCH

Vital Urban Filter: A Novel Solution for Safe and Productive Use of Wastewater

Reusable Water
Environmental Technology

Aug 2017 - 2021

Researcher	Supervisors	Promotor
Elackiya Sithamparanathan	Dr.ir. Katarzyna Kujawa Dr.ir. Nora Sutton	Prof. dr.ir. Huub Rijnaarts

Motivation

Rapid urbanization results in the generation of large volumes of wastewater, usually not paired with adequate treatment facilities. Together with the overexploitation of freshwater resources, the discharge of untreated wastewater puts a tremendous pressure on freshwater supply, especially in urban environments and downstream watersheds. Existing traditional treatment technologies may not be efficient enough to remove certain pollutants, such as micropollutants like PhACs (Pharmaceutically Active Compounds), pathogens and antibiotic resistance that all may become a serious threat in the future. Therefore, novel decentralised, more efficient and compact technologies have to be developed and adopted to treat urban wastewater efficiently.

Technological challenge

The envisioned Vital Urban Filter (VUF) is a filter based on the principle of conventional vertical flow constructed wetland (VFCWs) but with a smaller footprint due to the selection of highly efficient filter materials that can intensify biomass growth and thus degradation and sorption processes.

Figure 1: Potential Filter Materials for VUF

It is challenging to intensify biomass growth in VUF while avoiding clogging. Therefore, we investigate the use of different filter materials to achieve high biomass without much clogging. The filter materials we use need at the same time to support the growth of ornamental plants and enhance the quality of the effluent. It is also vital to ensure that the produced effluent and flowers are safe for use. Therefore, VUF system will be optimized to enhance the removal of pathogens and micropollutants along with the conventional pollutants. Nutrient conservation in VUF is also required to produce effluent suitable for irrigation as fertigation water.

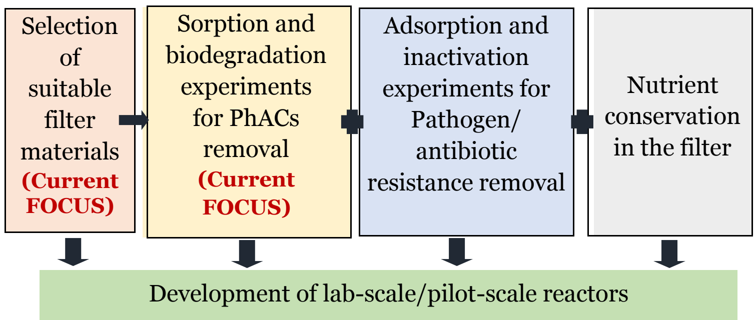


Figure 2: Scheme of the Overall Research Plan

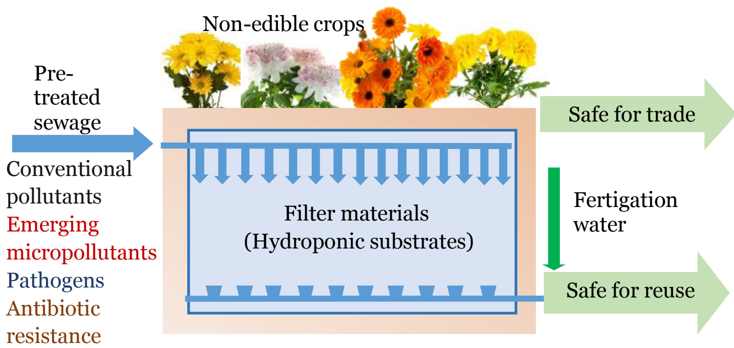


Figure 3: The envisioned VUF

CV Researcher; Elackiya Sithamparanathan

Graduated; Wageningen University, Environmental Technology (2016)

Hobbies; Cycling, Travelling, Listening to Music, Cooking

e-mail; elackiya.sithamparanathan@wur.nl

Tel; +31687316681

Website; -

LOTUS HR
Local Treatment of Urban Sewage and Streams for Healthy Reuse

WAGENINGEN UNIVERSITY & RESEARCH

Treatment of micropollutants contaminated wastewater effluent by constructed wetlands

Nov 2017 - 2021

Researcher	Supervisor	Promotor
Yu Lei	Dr. ir. Alette Langenhoff	Prof. dr. ir. Huub Rijnaarts

Motivation

The presence and fate of micropollutants and their transformation products in the aquatic environment has raised increasing concern in recent years due their potential hazard at low concentration (ng/L-μg/L). Conventional WWTPs don't remove micropollutants sufficiently from the wastewater. Constructed wetlands (CWs) are a promising alternative as a post-treatment technique to remove micropollutants from the effluent of WWTPs, possibly in combination with pre-treatment techniques (e.g. advanced oxidation processes or aeration).

The aim of this study is to optimize design parameters of CWs to enhance the removal efficiency of micropollutants, and explore the effect of pre-treatment processes (e.g. advanced oxidation processes or aeration) to CWs to enhance the overall treatment performance.

Technological challenges

- Sorption, plant uptake and phytodegradation, and biodegradation are main removal mechanisms for micropollutants in CWs. This study will optimize these removal mechanisms by identifying the optimal support matrixes, plant species and activated sludge to enhance micropollutant removal in CWs.
- CWs are a dynamic eco-system and changing one of the design parameters can influence the performance of a CW. After optimization of the individual removal mechanisms, we will study the overall removal of mcirosollutants in mesocosm-scale CWs in order to understand the interaction between these removal mechanisms.
- In order to further improve micropollutant removal in CWs, various pre-treatment processes will be studied, e.g. UV/H_2O_2, UV/TiO_2 or aeration. We will test possible combinations of AOPs or aeration as pre-treatments for CWs and as a complementary treatment process to remove micropollutants and their transformation products.
- Finally, the removal of micropollutants in pilot-scale CWs and full-scale CWs is crucial. We will study the fate of micropollutants and transformation products in an integrated pilot CW under real conditions with real wastewater effluent.

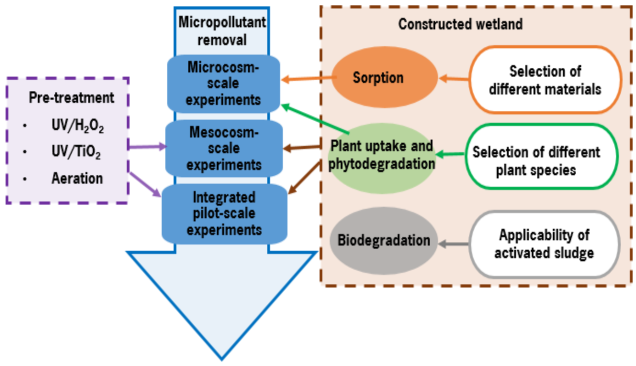


Figure 1. Scheme of this research

CV Researcher: Yu Lei

Graduated: Wageningen University, Environmental Technology (2017)

Hobbies: Squash, Running, Yoga

e-mail: yu.lei@wur.nl

Tel: 0317484611

Compounds of Emerging Concern removal by microalgae-based technology

Jan 2019 - 2023

Researcher	Supervisor	Promotor
Kaiyi Wu	Dr. ir. Tania V. Fernandes Dr. ir. Alette Langenhoff	Prof. dr. ir. Huub Rijnaarts

Motivation

Compounds of emerging concern (CEC) have become a new challenge for wastewater treatment, as conventional wastewater treatment plants are designed for the removal of macropollutants and not micropollutants, such as CEC. CEC are found at low concentrations (ng/L-µg/L), and negatively affect natural fresh water quality and aquatic ecosystems.

Microalgae-based technology has shown to remove nutrients and CEC from wastewater. The resulting microalgal biomass can be applied as biofuel or fertilizer to achieve a 'zero-waste' treatment system. The aim of this study is to evaluate the removal of CEC and its transformation products from municipal wastewater in a microalgae photo bioreactor (PBR).

Technological challenge

Microalgae-mediated bioremediation of CEC is gaining increasingly scientific interest, yet there are still many unknowns, such as the removal mechanisms due to limited tested compounds, and biotic and abiotic conditions. The research is divided into four work packages:

- Evaluate the removal performance of a selection of CEC and its transformation products in a microalgae PBR. Furthermore, identify which compounds are removed and how they affect algal growth in the PBR.
- Investigate the mechanisms (photolysis, oxidation, adsorption, bioaccumulation, intracellular and extracellular biodegradation, etc.) responsible for CEC removal
- Evaluate the effect of environmental and operational conditions on CEC removal and define the optimal design of a PBR.
- Test the CEC removal in a pilot scale PBR in a greenhouse at Dutch natural light conditions.

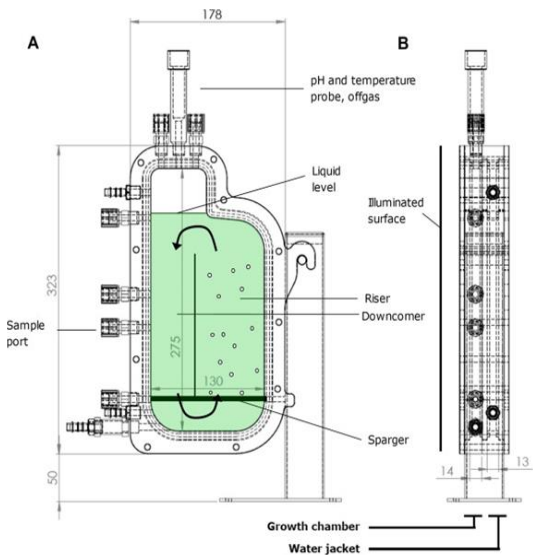


Fig. 1 Design of the lab-scale PBR

CV Researcher;	Kaiyi Wu
Graduated;	South China University of Technology, Environmental and Energy (2018)
Hobbies;	Singing, Cycling
e-mail;	k.wu@nioo.knaw.nl; kaiyi.wu@wur.nl
tel;	06-17643520
website;	https://nioo.knaw.nl/en/employees/kaiyi-wu

Optimizing Design and Operation of Sand Filtration for Removal of Micropollutants from Drinking Water

Oct 2018 - 2022

Researcher	Supervisor	Promotor
Jinsong Wang	Dr. ir. Nora Sutton	Prof. dr. ir. Bert van der Wal

Motivation

The micropollutants in the water cycle threatens the quality of surface water used for drinking water production. Thus, micropollutants removal should be actively managed at the drinking water treatment plant (DWTP) to protect public health. Add-on techniques such as (advanced) oxidation combined with activated carbon or membrane filtration have been installed for micropollutants removal. Nevertheless, these processes still suffer from toxic by-product formation and high investment and energy costs. This project aims at developing a novel and cost-effective sand filtration system for efficient micropollutants removal.

Technological challenge

As sand filter material has lower absorption capacity, the biodegradation is the main removal process (**Fig. 1**).

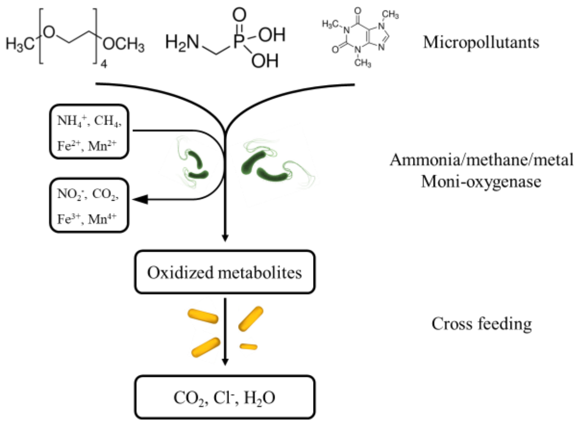


***Fig. 1** Biodegradation of micropollutants in sand filtration*

Previous research on sand filtrations found the potential of biological processes at DWTPs to remove a wide range of micropollutants (Zearley and Summers, 2012). However, several research topics (Fig. 2) remain unaddressed:

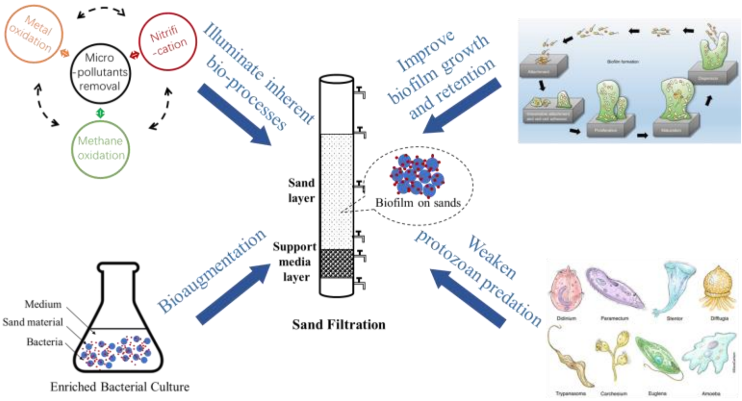


***Fig. 2** Strategies for improving micropollutants biodegradation in sand filtration*

1. The different contributions of micropollutant removal from inherent microbiological metabolisms will be studied in lab-scale sand filter.
2. The microbial adhesion and biofilm retention will be strengthened by optimized filter material and hydraulic condition.
3. Effective microbial culture will be enriched and inoculated into sand filtration to investigate the achievement of bioaugmentation.
4. We will research protozoa population in sand filter and reduce the negative effects of protozoan predation on introduced degrader bacteria.
5. We will validate the above findings from lab scale reactors in the field with pilot-scale filters.

CV Researcher;	Jinsong Wang
Graduated;	Chinese Academy of Sciences, Environmental Engineering (2018)
Hobbies;	Fitness, Travelling, Photography
e-mail;	jinsong.wang@wur.nl
tel;	0644123844
website;	www.ete.wur.nl

Dissolved Organic Matter Dosing To Enhance *In Situ* Micropollutants Biodegradation In Drinking Water Aquifers

Feb 2019 - 2023

Researcher
Rita H. R. Branco

Supervisor
Dr. Nora Sutton
Dr. ir. Roel Meulepas

Promotor
Prof. dr. ir. Huub Rijnaarts

Motivation

Almost two thirds of the drinking water in the Netherlands comes from groundwater. Recent studies have detected micropollutants such as pesticides and pharmaceuticals in Dutch groundwater, sometimes in concentrations close to or above the permitted level (0.1 µg/L for a single micropollutant).
Biodegradation of micropollutants can occur naturally in the environment and it can be influenced by the presence of dissolved organic matter (DOM). In groundwater, DOM is present at low concentrations and is very recalcitrant, which leads to low rates of this natural attenuation. However, previous research indicates that amendment with a labile DOM source can enhance the biodegradation of micropollutants.
Hence, the aim of this research is to study the effect of DOM dosing in order to develop an in situ micropollutants bioremediation technology in groundwater.

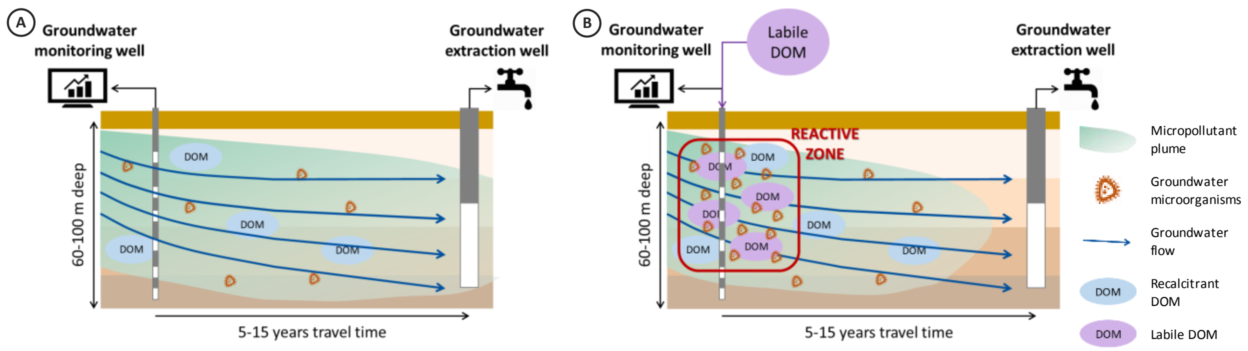
Technological challenge

When developing an *in situ* micropollutants technology some challenges need to be overcome.

The low concentrations of micropollutants (µg/L range or lower) can be hamper to biodegrade and DOM can be preferentially degraded over micropollutants. Furthermore, for micropollutants degradation to occur, favorable environmental conditions are required but groundwater conditions (e.g. low microorganism density, anaerobic environment and low temperature) do not support biological activity. Finally, the *in situ* treatment should not affect the quality of groundwater as it is used for drinking water production.

Research goals

This project is divided in 4 phases:
Phase 1 – Screening for biomass sources capable of degrading micropollutants and assess the effect of different DOM sources on micropollutant biodegradation
Phase 2 – Understand the kinetics and mechanisms of degradation at conditions mimicking the aquifer (column experiments)
Phase 3 – Develop a groundwater transport model that includes the biological degradation processes
Phase 4 – Perform a field demonstration of the developed *in situ* micropollutants bioremediation technology



Micropollutant attenuation in groundwater: A – Natural attenuation; B – DOM amended attenuation

CV Researcher; Rita Henriques Rebola Branco
Graduated; Universidade de Aveiro, MSc. Industrial and Environmental Biotechnology (2018)
Universidade de Aveiro, BSc. Biotechnology (2016)
Hobbies; Fitness, reading
e-mail; rita.branco@wetsus.nl / rita.henriquesrebolabranco@wur.nl
tel; 058-2843179
website; www.wur.nl/ete

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 665874

Biological treatment of organic micropollutants present in nanofiltration membrane concentrate

2020-2024

Researcher	Supervisor	Promotor
Fatma Al-Manji	Dr. ir. Hardy Temmink 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 (OMPs) in our surface water. OMPs originate from consumer products or from medicinal, agricultural or industrial activities. Although in wastewater they are present in very low concentrations (ng-ug/l), they have the potential to cause long-term harm to humans and the environment.

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

Partners in our project are studying the (multi-layered) nanofiltration membranes that can selectively remove OMPs. And the treatment of retentate of these nanofiltration membranes (NF) is the topic of our study.

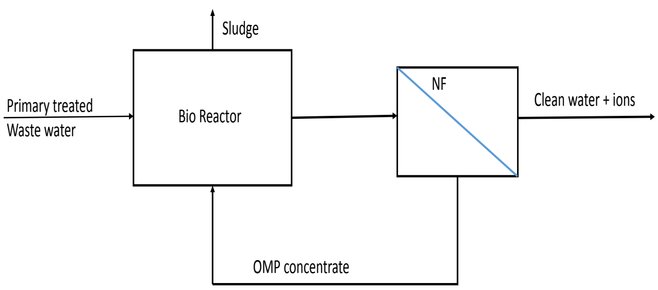


Figure 1 The proposed process, a combination of nanofiltration and biological treatment

Whereas OMP concentrations in MWTP effluents may be too low to initiate their biodegradation, this may be feasible at the elevated concentrations in the membrane concentrate. In addition, recycling of the OMPS to the MWTP's bioreactor increases the contact time between the microorganisms and OMPs further increasing the chances of OMP biodegradation.

This study focusses on biodegradation of the OMPs but also on the effect of recirculation of the OMPS on the primary (biological) functions of the MWTPs, i.e. oxidation of bulk organic pollutants, nitrogen and phosphorus removal and digestion of the waste sludge.

Technological challenge

- Perform several lab-scale experiments in reactors to identify removal mechanisms of OMPs in activated sludge reactors:
  - Biodegradation
  - Sorption
  - Adsorption
- Use different TOC/DOC concentrations in the reactors to identify the effect on the degradation of OMP
- Identify the effect of recirculation of the retentate in the reactors
- Perform bioassays to test the toxicity of parent OMPs and transformation compounds present in the reactor effluent.

CV Researcher;	Fatma Al-Manji
Graduated;	Wageningen University, Environmental Technology (2019)
Hobbies;	Painting, travelling & cooking
e-mail;	Fatma.almanji@wur.nl
tel;	0617261440
website;	www.ete.nl

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

Environmental Technology

Sep 2020 - 2024

Researcher	Supervisor	Promotor
Sebastian Castaño Osorio	Dr. ir. Maarten Biesheuvel Dr. ir. Jouke Dykstra Dr. ir. Evan Spruijt	Prof. dr. ir. Bert van der Wal

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.

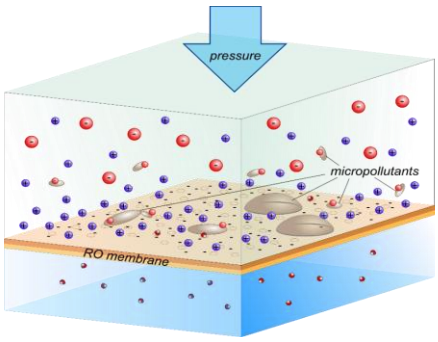


Fig 1 Schematic illustration of the processes at the high-pressure side of a membrane that retains micropollutants from surface water

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.

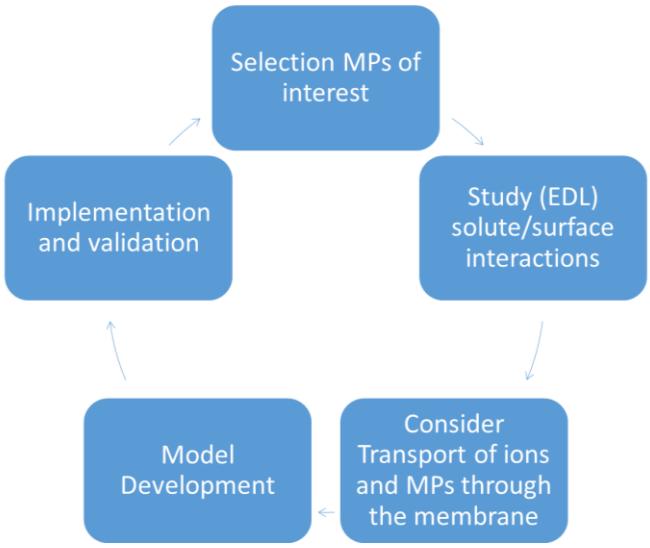


Fig 2 Methodological approached, (EDL) electrical double layer

CV Researcher;	Sebastian Castaño Osorio
Graduated;	Wageningen University, Water Technology (2020)
Hobbies;	Jogging, gym, listening to music, dancing, city trips
e-mail;	sebastian.castano@wetsus.nl
tel;	+31 (0)58 284 30 00

Urban Systems Engineering

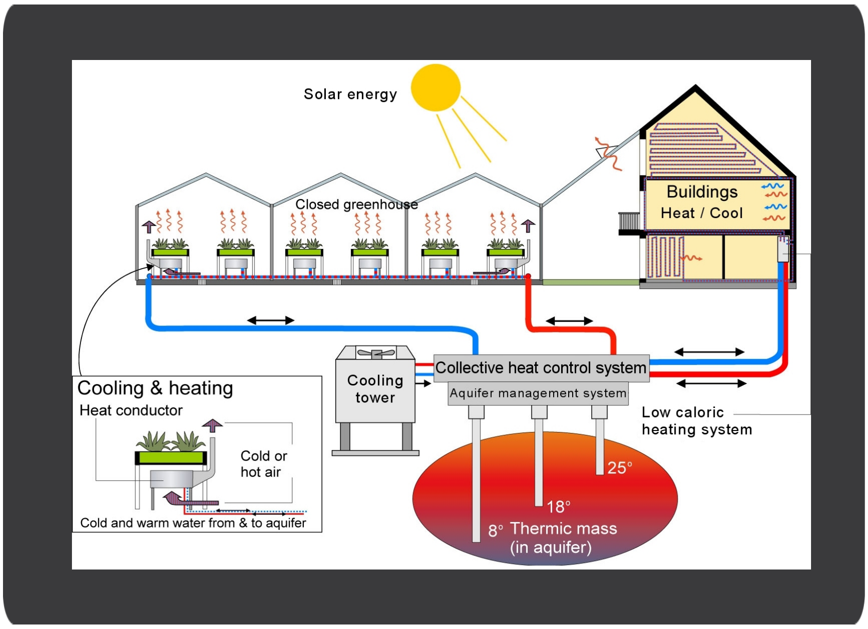
Biorecovery

Water Reuse

Nutrient and Carbon Cycles

Smart Urban Infrastructure

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.

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

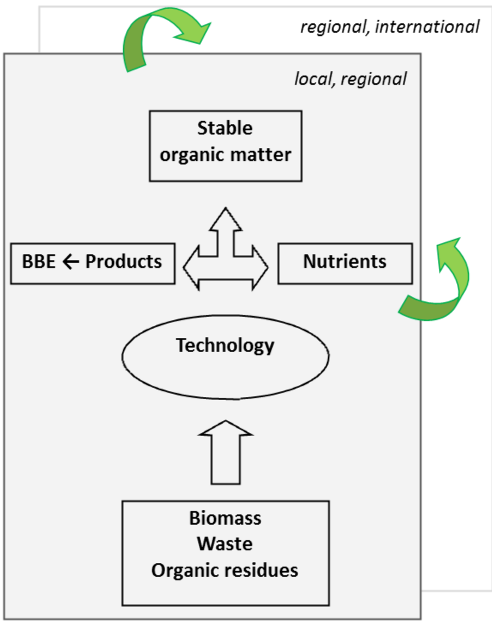
Nutrient cycling pyramid

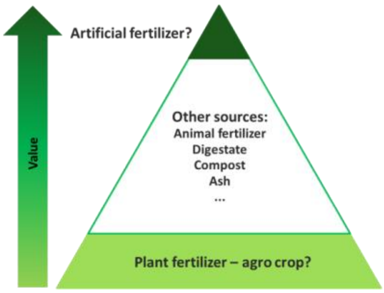
Dr. ir. J. Weijma
Dr. ir. Miriam van Eekert

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 initiatives in place for the recovery and reuse of nutrients from biomass and waste streams. Nutrients (N, P, K) are recovered in a variety of forms which may be more or less applicable for fertilization purposes.





Research challenge

The variety of waste streams used as input, recovery technologies and nutrient products (CNPK, others) make a comparative assessment for the optimal recycle strategy complex. Nutrient content, purities, additives may vary and as a result some strategies thought feasible from one criterion may not be suitable for other criteria. To enable structural analysis of nutrient recycling strategies we will develop a nutrient cycling pyramid for each nutrient source. The result will be a database containing a variety of nutrient "products" with their specific characteristics: e.g. origin, composition, purity and concentration of the produced nutrient scheme as well as amount of energy and additional costs related to production. In addition, the residual stream remaining after production of the nutrient will be taken into account as this is often overlooked. The attribution of weighing factor will enable us to assess the (ecological / economical / environmental / applicability / other?) value of each product and the application range. This can be used as a basis for closing of the nutrient cycles on different scales.
This project will align with the EU H2020 project Run4Life which aims to recover nutrients from different domestics sources on a pilot scale at four different locations and utilise those nutrients as fertilizers.

Dr.ir. Miriam van Eekert
e-mail: miriam.vaneekert@wur.nl
tel. 0317-483360

Dr.ir. Jan Weijma
e-mail: jan.weijma@wur.nl
tel. 0317-483851

Micronutrients: recycling to sustain life on Earth and Mars?

Dr. ir. J. Weijma
Dr. ir. Miriam van Eekert

Prof. dr. ir. Cees Buisman

Environmental Technology

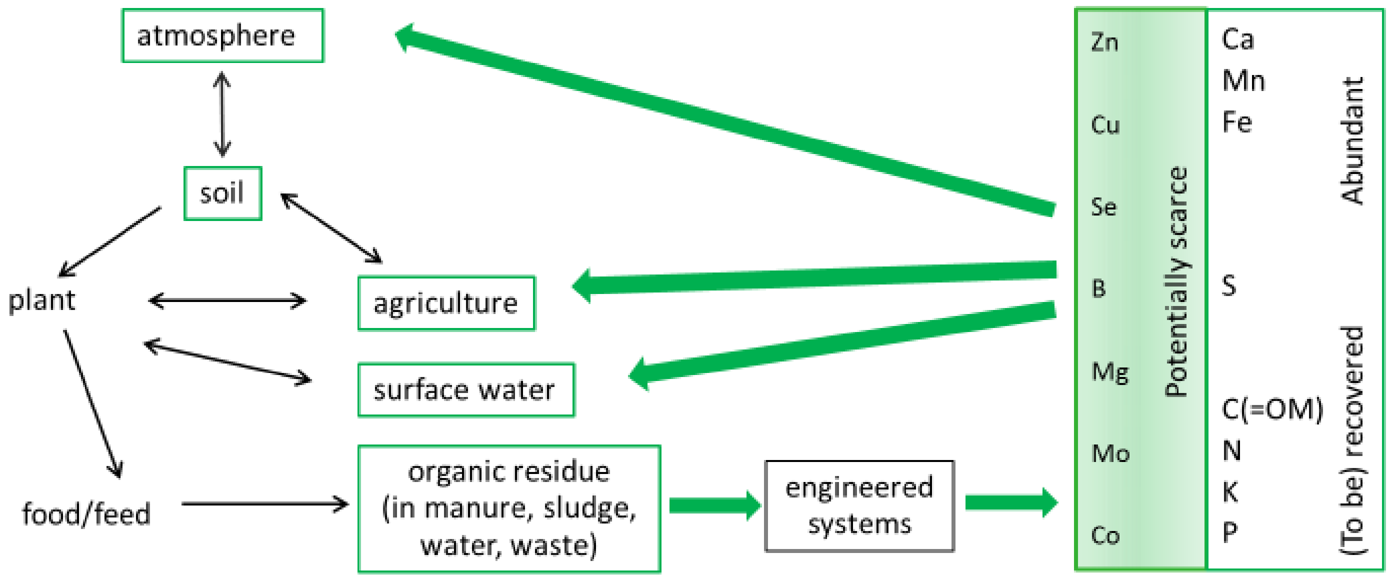
Motivation

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

Several chemical elements are essential for plant growth. 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.



Dr.ir. Miriam van Eekert
e-mail: miriam.vaneekert@wur.nl
tel. 0317-483360

Dr.ir. Jan Weijma
e-mail: jan.weijma@wur.nl
tel. 0317-483851

WAGENINGEN UNIVERSITY & RESEARCH

Restoring circular nutrient cycles in food systems – from a regional perspective

Sept 2017 - 2021

Researcher	Supervisors	Promotors
Bernou Zoë van der Wiel	Prof. dr. Florian Wichern Dr. ir. Jan Weijma	Prof. dr. ir. Cees Buisman Dr. ir. Corina van Middelaar

Motivation

Growing population and changing diets have led to increased food demand, and this trend will continue. The resulting intensification of agriculture has unbalanced nutrient use, in turn this causes environmental, economic and social issues. Future nutrient management has to focus on restoring cycles to overcome inefficient use of available nutrients and dependency on non-renewable resources.

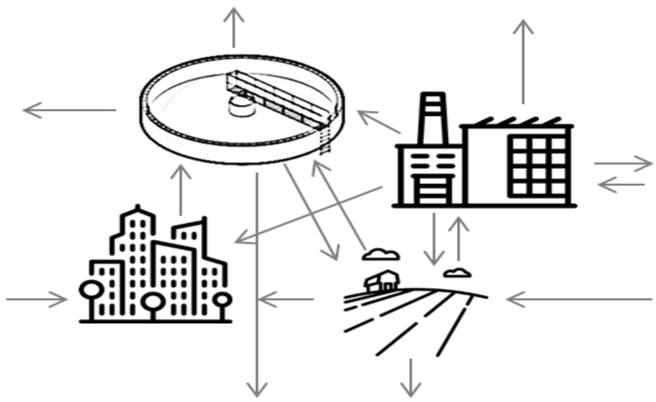
Restoring circularity from a regional perspective

Nutrients, such as nitrogen (N) and phosphorus (P) - which are essential to sustain life for living organisms including bacteria, animals and plants, are also detrimental to the environment when they are in excess. Moreover, intensification of food production can be linked to a decline in organic matter (C) of soils used for agricultural activities. Other nutrients, specifically potassium (K), are also important for efficient production of food.

Approach

The model region in this research project, the district Cleves (depicted in grey, with the Netherlands being the Western border), North Rhine-Westphalia, Germany, is a so-called nutrient saturated area. The district is characterized by intensive livestock production, intensive production of cash crops, vegetables and ornamentals. The high nutrient load in the area has resulted in nutrient load in the groundwater above the European Water Framework Directive. Moreover, a decline in soil organic carbon can be observed.

In order to understand the current regional nutrient flows, a substance flow analysis (SFA) will be performed on the 4 most important substances for efficient food production: P, N, K and C. All biomass flows which are (potentially) important for food production will be quantified, therefore multiple sectors will be considered. Understanding of the flows will facilitate determination of points of inefficiency. Moreover, an inventory of available measures applicable in the region to tackle nutrient losses to the environment and to restore nutrient cycles will be performed in order to identify promising measures. Lastly, consequential life cycle assessment (CLCA) as a tool to determine the effect of measures on restoring nutrient cycles will be explored.



CV Researcher;	Bernou Zoë van der Wiel
Graduated;	Wageningen University, Animal Sciences, specialization Animal Production Systems (2016)
Hobbies;	Horse riding, hiking, climbing
e-mail;	bernou-zoe.vanderwiel@hochschule-rhein-waal.de
tel;	00492821806739847

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

Environmental Technology

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

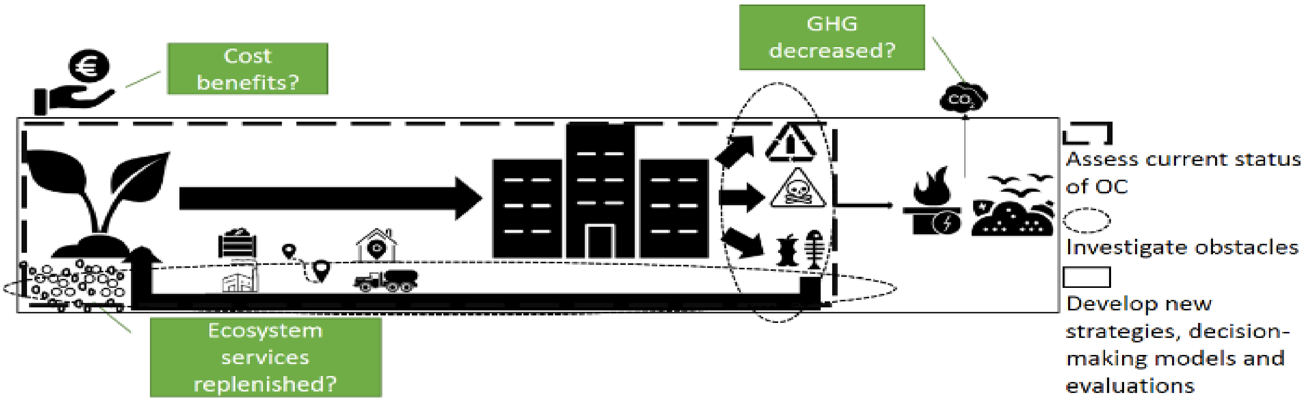
The variety of urban organic residue streams used as input, technologies applied and nutrients (mainly N,P,K) produced make a difficult comparative assessment for the applicability of the products and their effect on the SOC content and the different ecosystem services that agricultural soil could provide.

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.



CV Researcher:	Jiyao Liu
Graduated:	Wageningen University, Environmental Technology (2017)
Hobbies:	Painting, Traveling, Reading, Body fitness
E-mail:	Jiyao.Liu@wur.nl
Tel:	0317-484993

China Scholarship Council

Wageningen University & Research

Inorganic solid waste & modeling. Nanoparticles.

Dr. Renata D. van der Weijden

Prof. dr. ir. Cees Buisman
Prof. dr. Ir. Huub Rijnaarts

Environmental Technology

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.

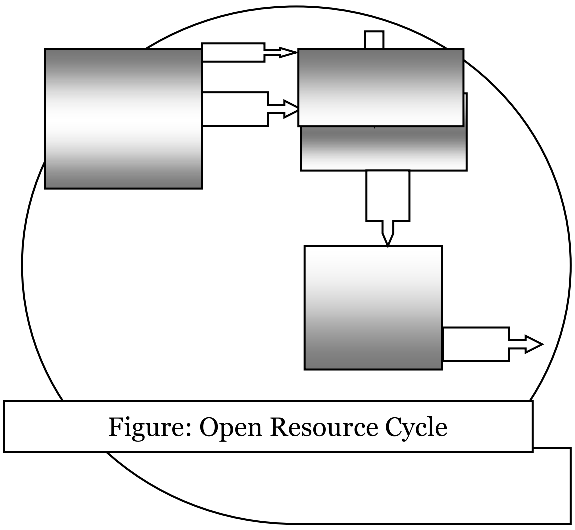


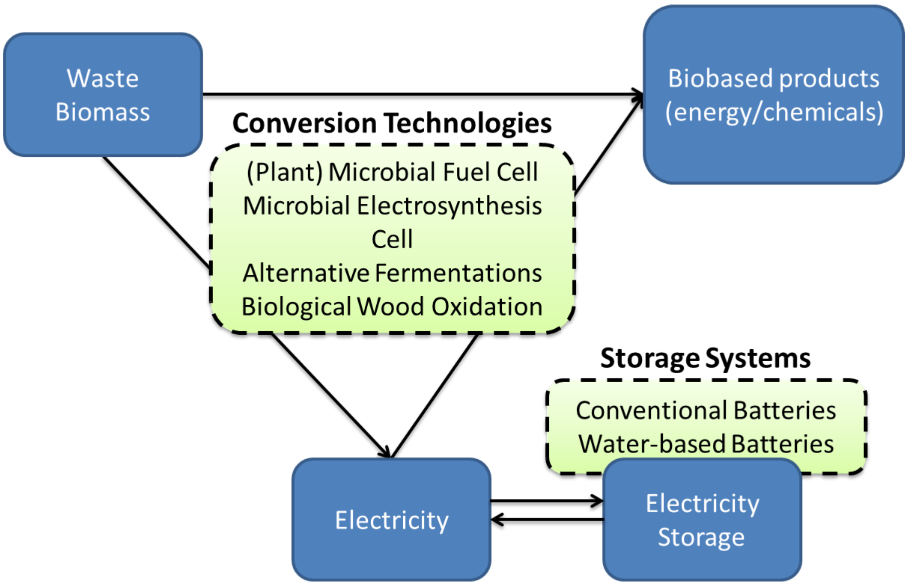
Figure: Open Resource Cycle

Renata van der Weijden
e-mail:renata.vanderweijden@wur.nl
Tel: 0317-483339

WAGENINGEN UNIVERSITY & RESEARCH

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.

e-mail: Annemiek.terHeijne@wur.nl
Tel: 0317-483447

e-mail: David.Strik@wur.nl
Tel: 0317-483447

Integral Blueprints for Flexible Engineering and Design (part of Water Nexus)

Environmental Technology

March 2016 - 2020

Researcher	Supervisor	Promotor
MSc. Joeri Willet	Dr. ir. Koen Wetser Dr. ir. Jouke Dykstra	Prof. dr. Ir. Huub Rijnaarts

Motivation

Water, especially fresh water, is crucial for sustaining human populations and enabling economic growth. Worldwide 1.2 billion people live in physical water scarcity, and 1.6 billion in economic water shortage. Global industrial water use is expected to increase by 400%. A paradigm shift in the way water is supplied to industry is needed to ensure water abstractions remain within the carrying capacity of ecosystems providing water resources.

Challenge

Industry requires significant quantities of water to operate. In the Netherlands 68% of the fresh water produced is used by industry. In most cases the water is part of the process, but is not part of the final product (high temperature steam production, cooling liquid in cooling towers, etc.). This range of applications raises questions concerning the quality of the water which is actually required for each of these processes:

- Is it really needed to use high quality fresh water to produce steam?
- Can process water be cascaded for more effective use?
- Can part of the process be operated with saline water?

The central paradigm shift within the Water Nexus program is to consider saline water as a resource, instead of a threat:

Saline water where possible, freshwater where essential.

Method

In this research GIS methods are combined with Linear Programming in order to determine the optimal network to supply (industrial) water users with the water quality they require.

Through GIS the local landscape features affecting the costs of water transport are determined (Fig 1). The Linear Programming optimization algorithm is then used to determine the optimal combination of connections and the capacity of each connection (Fig 2).

Through this approach it is possible to minimize water supply costs and determine which water source, fresh or brackish, is most suitable for specific users.

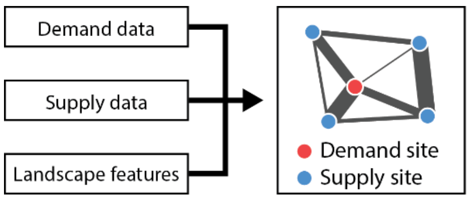


Figure 1. Generation of possible network through GIS

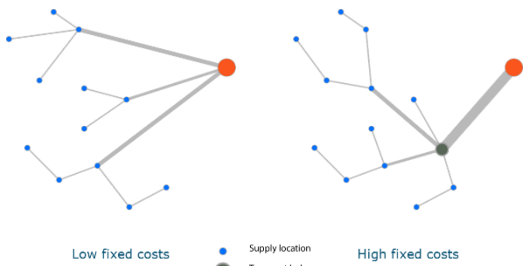


Figure 2. Generation of optimal transport network through Linear Programming

CV Researcher; Joeri Willet

Graduated; Wageningen University, Urban Environmental Technology & Management (2015)

Hobbies; Climbing, hiking, reading

e-mail; joeri.willet@wur.nl

tel; +31645791747

WAGENINGEN UNIVERSITY & RESEARCH

Incorporation of sustainability into desalination treatment train modelling and evaluations

2016 - 2021

Researcher
Jess Wreyford

Supervisor
Dr. ir. Jouke Dykstra
Dr. ir. Koen Wetser

Promotor
Prof. dr. ir. Huub Rijnaarts

Motivation

Water scarcity is a growing concern across the world and is exacerbated by mismatched supply and demand. While the majority of available fresh water is considered inaccessible, accessible fresh water is becoming contaminated as a result of over-withdrawal, pollution, and salinization. Salinization specifically has become a common issue due to salt water intrusion and saline waste water reentering the system. Desalination has become a common method for turning this unusable saline water into useable water. Desalinization, however, is also known to be costly and energy intensive. To address this, research in desalination has focused on either improving existing or developing new technologies. More recently, the focus on technology combinations have been investigated. These investigations, however, are primarily focused on specific technology pairings.

Technological challenge

1: Expansion of treatment train modelling

The Desalination Evaluation, Screening, And Learning for Treatment-trains (DESALT) model was developed as part of the Water Nexus. The focus of this model is the testing and comparison of treatment trains (Figure 2) as an alternative approach to furthering desalination research and promoting the use of saline water.

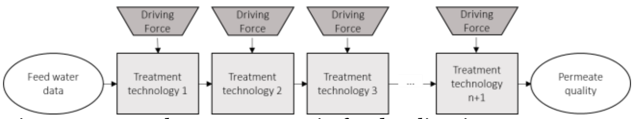


Figure 1: Example treatment train for desalination

Currently, DESALT evaluates treatment trains in series, however, there is the opportunity to expand the model to account for recirculation or feed water alterations. Research on incorporating this requires Python modelling skills and familiarity with treatment technologies.

Technological challenge 2: Brine Management

While desalination is effective at providing desirable water, it also produces heavily concentrated brine. Brine is most commonly disposed of in either seas / oceans or in landfills. The effects of this brine on the environment are not always known and the alternatives to disposal are not always considered. The aim of this research is to expand upon the existing foundation of brine management knowledge, incorporate information on existing technologies and approaches, and develop a multi-criteria assessment framework.

Potential MSc research questions:

- What methods are required to incorporate recirculation into the DESALT model?
- What approach can best promote environmentally compatible brine in the desalination process?

Methods:

- Literature review
- Calculations through Excel
- Programming via Python

CV Researcher: Jess Wreyford
Graduated: BSc Mech. Engr., UCSB (2007); MSc Mech. Engr., UW (2009); MSc. Sustainable Development, UU (2016)
Hobbies: Cycling, gardening, camping, travelling
e-mail: jessica.wreyford@wur.nl
tel: 06 3470 6393
website: www.wageningenur.nl/ete

Modelling and optimisation of scenarios for resource recovery from urban sanitation

Urban Systems Engineering
Environmental Technology

Jan 2018 - 2021

Researcher	Supervisor	Promotor
Maria van Schaik	Dr. ir. Hans Cappon Dr. ir. Wei-Shan Chen	Prof. dr. ir. Huub Rijnaarts

Motivation

The history of linear processes, from resource to waste, increases the pressure on many basic human needs including energy, food and water. During the last decades, increasing interest towards resource recovery (energy, nutrients and water) from wastewater, more strongly emphasised the development of technologies capable of resource recovery. However, finding suitable solutions is not straightforward due to technical and economic challenges. This research aims to develop mathematical models which can facilitate decision making to find feasible resource recovery solutions at optimal scales considering local demand-supply.

Technological challenges

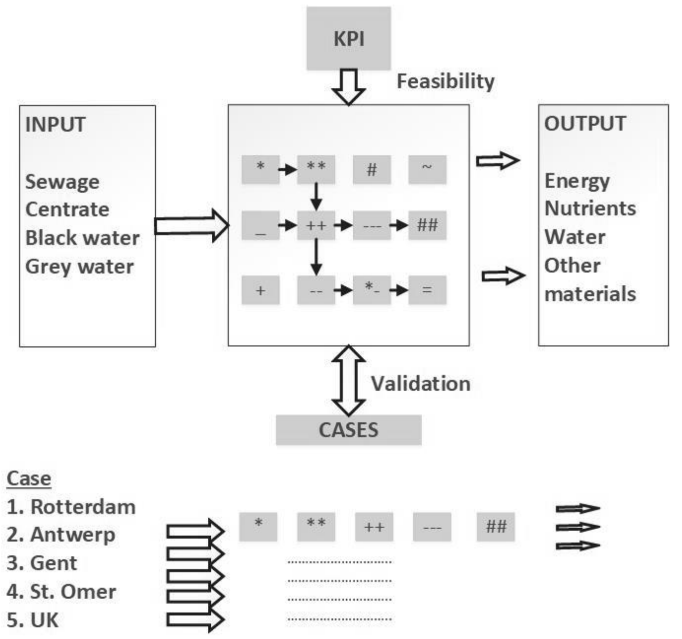
Large varieties in quality and quantity of wastewater, environmental impact, due to the consumption of energy and chemicals, are challenging the decision makers when choosing the suitable technologies in different locations. Moreover social aspects such as acceptance of final products in the market should be addressed. Thus, the major challenge of this research project is related to integration of all aspects (techno-economical, environmental and socio-cultural) into a solution with broad acceptance in its local environment.

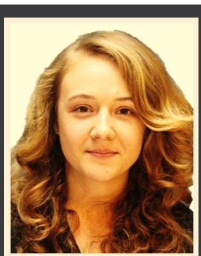
Method

This project wishes to optimize the sequence of technologies for resource recovery from wastewater using scenario studies.

Process modelling of individual potential technologies and combinations of technologies, create the opportunity to study the relationships. System analysis will be carried out in terms of economic, environmental and social aspects.

Five different stakeholders are responsible for pilot tests of technologies and will be providing test data which will be used for model validation. These stakeholders will also provide weighting factors for different key performance indicators (KPIs) used for technology and scenario evaluation. The provided weights are representing stakeholder's priorities and will be used for multi-objective scenario optimization for each individual location.





CV Researcher;	Maria van Schaik
Graduated;	Wetsus Academy, Water Technology (2017)
Hobbies;	Rugby
e-mail;	maria.vanschaik@wur.nl
tel;	06 87 42 96 84
website;	https://www.interreg2seas.eu/nl/nereus

Interreg Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling
HZ University of Applied Sciences
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.

CV Researcher;	Darja Kragić Kok
Graduated;	Wageningen University, Environmental Technology (2005)
Hobbies;	Photography, scuba diving, art cinema
e-mail;	darja.kragic@wur.nl
tel;	0317-481449
website;	www.leaf-wageningen.nl

A context-dependent decision support model for sustainable industrial water supply (ENTIRE Project)

Environmental Technology

May 2017 - 2021

Researcher	Supervisor	Promotor
Farzaneh Firoozyar	Dr. ir. Katarzyna Kujawa Dr. ir. Koen Wetser	Prof. dr. ir. Huub Rijnaarts

Background

Freshwater scarcity due to climate change such as saltwater intrusion, land subsidence, coastal erosions and flooding threaten the operation of industrial and infrastructure systems and future development of the industrial zones (IZs) in delta regions. Optimisation of sectorial, spatial and temporal allocation of water flows on the level of an industrial zone entails technological and institutional challenges.
The aim of this research is to enhance sustainable development of industrial zones in delta regions by making a decision support model to find the most feasible technological-cum-institutional innovations for optimizing industrial water supply.
This project is part of bigger projects; ENTIRE and Water nexus.

Project challenge

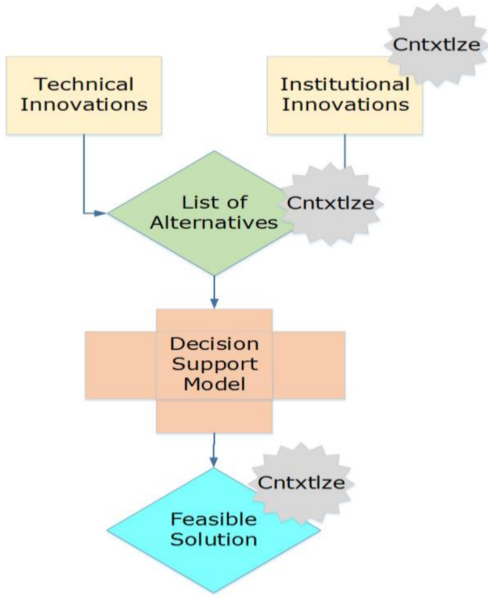
The project will be done in four steps:

Step 1: List of contextual factors and control variables
A system diagram for an industrial zone is going to be made. The system diagram is a conceptual model which is actor specific (has a problem owner) and shows the relation between the factors inside and outside the industrial zone. Control variables are tactics or strategies the problem owner has control over to solve the water supply problem. The strategies cannot be applied without considering the contextual factors. Contextual factors are variables that influence the system's development but cannot be influenced by the problem owner himself. The contextual factors are uncertain and can feed the driving forces of the possible scenario-analysis.

Step 2: Making Scenarios
Strategic scenarios (among other types of scenarios) will be made. Strategic scenarios respond to "what can happen if we act in a certain way?" and focus on control variables under the influence of contextual factors.

Step 3: Making a Decision Model
With the help of a decision model an optimum solution for the water supply system of an industrial zone can be chosen by the stakeholders. A decision model can be a multi criteria analysis, cost benefit analysis, optimization programming or a combination of them.

Step 4: Case Studies Vietnam and Netherlands
The model will be tested via series of workshops. Actors who will participate in workshops will be industries, governmental and non-governmental bodies. Feedbacks will be collected from them and the model will be further improved.



CV Researcher;	Farzaneh Firoozyar
Graduated;	Technical University of Delft (2010)
Hobbies;	Traveling, reading book
e-mail;	Farzaneh.firoozyar@wur.nl
tel;	0317-485502
website;	

TRƯỜNG ĐẠI HỌC VĂN LANG UNIVERSITY
Đạo đức - Ý chí - Sáng tạo

WAGENINGEN UNIVERSITY & RESEARCH

Technology and Infrastructure Innovations for Water Supply in Industrial Zones

Urban Systems Engineering
Environmental Technology

Aug 2016 - 2020

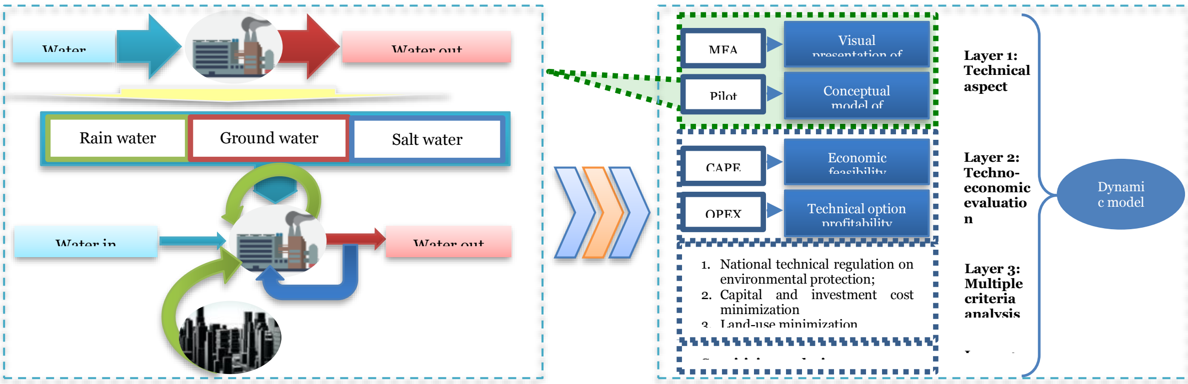
Researcher	Supervisor	Promotor
Le Minh Truong	Dr.ir. Katarzyna Kujawa	Prof. Huub Rijnaarts Assoc. Prof. Tran Thi My Dieu

Motivation

Deficiency in industrial and urban water in the future will become a factor limiting the possibilities for further economic development. The workshop which was organized by the ENTIRE - research team in Vietnam with participation of industrial zone companies, industrial zone authorities, environmental policy makers, water supply companies, and environmental companies has put forward three main considerations:

- Continuously increasing water demand has stressed water resources and put pressure on water supply to industries and industrial zones;
- Salt intrusion and competing claims on water services by stakeholders, and restrictions on groundwater exploration are serious challenges;
- Major interest is in innovative research on new sustainable industrial water use.

Technological challenge



Two important knowledge gaps in water supply in the Vietnamese Mekong delta are the following:

1. There is no systematic method to design a circular industrial water supply system;
2. There is no insight in temporal and spatial scales and dynamics of water availability and water needs that is specific to the Vietnamese situation.

Based on material flow analysis (MFA), a set of relevant water quality parameters is determined defining the demand side for industrial water quality, quantities, wastewater quantity, characteristic, time and space. In the next step, Urban Harvest Approach (UHA) strategies which are demand minimization, output minimization and multi-sourcing will be applied to identify technical and operation options to prevent pollution. These strategies will be achieved through pilot experiments with various treatments dealing with the relevant parameters for water quality and quantity. Treatment processes include both natural systems and engineered systems. Lastly, a dynamic model will be developed to design multi-source and circular based water system.

CV Researcher: Le Minh Truong

Graduated: Wageningen University, Environmental Technology (2016)

Email: truong.le@wur.nl

Website: www.wur.nl/ete

WAGENINGEN UNIVERSITY & RESEARCH

Closing urban water cycle to enable safe reuse in peri-urban agriculture in tropical deltas

Environmental Technology

March 2017 - 2021

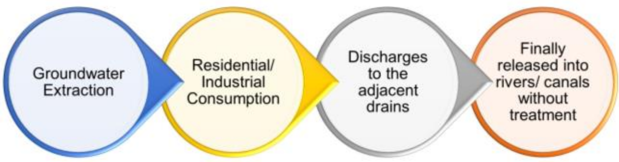
Researcher	Supervisor/Co-Promotor	Promotor
ir. Kamonashish Haldar	Dr. ir. Katarzyna Kujawa	Prof. dr. ir. Huub Rijnaarts

Background

- Coastal region of Bangladesh is highly vulnerable to climate change and urbanization induced environmental pollution is threatening the access to good quality and quantity drinking as well as irrigation water.
- World Bank study on climate change effect on Bangladesh estimated that by 2050 river water resource for irrigation will shrunk by 29.7%

Motivation

- Water re-use in Bangladesh is yet to be realized due to a number of reasons including inadequate knowledge on proper reuse practice, inadequacy of wastewater infrastructure, policy regulations etc.
- Annually urban areas of Bangladesh generate 725 million m^3 of wastewater which can be an alternative as future irrigation source.



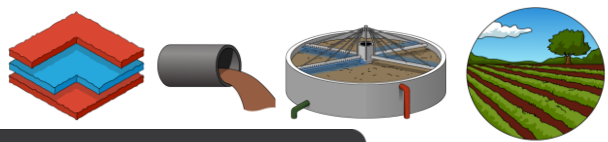
Aim

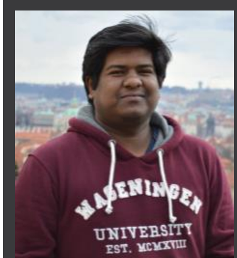
- The aim of the project is to develop a sustainable wastewater management framework integrating risk mitigation strategies for safe re-use in agriculture.

Methods

Expected Outcome

- Assessment of irrigation water demand in peri-urban agriculture and wastewater generation in the urban areas
- Understanding the spatial and temporal variation of surface water quality
- Quantitative Microbial Risk Assessment (QMRA) for the use of WW in agriculture
- Analyzing and mapping stakeholder's perception towards planned water re-use
- Scenarios for wastewater treatment options facilitating safe re-use in agriculture





CV Researcher:	Kamonashish Haldar
Graduated:	Wageningen University, Urban Environmental Management (2015)
Hobbies:	Travelling, Cooking
e-mail:	kamonashish.haldar@wur.nl
Tel:	0317485502
Research Interest:	Water re-use, urban-rural linkage, spatial planning

WAGENINGEN UNIVERSITY & RESEARCH

Urban Systems Engineering
Sub-department of Environmental Technology

Transition of urban infrastructure towards circular & resilient cities

Dec 2018 – Sep 2020

Researcher	Supervisor	Promotor
Recruiting (starting April/September 2019)	Dr.ir. Wei-Shan Chen	Prof. dr. ir. Huub Rijnaarts

Motivation & Technological Challenge

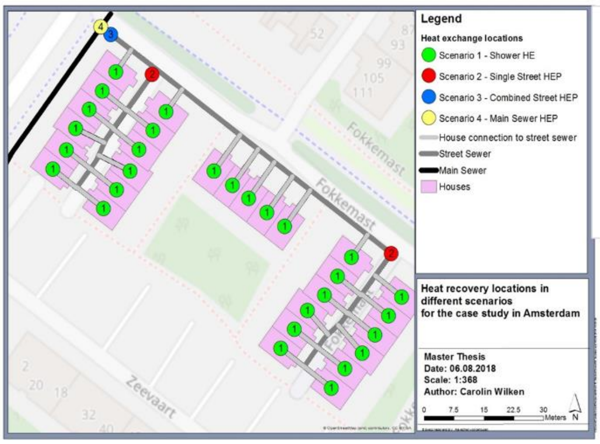
In 2050, there will be likely 10 billion people on the Earth and more than 70% of them will live in urbanised area. At least doubled urban infrastructures are needed to provide the basic services in the coming decades for both new and existing cities, especially for safe ty and sanitary purpose. Existing 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.

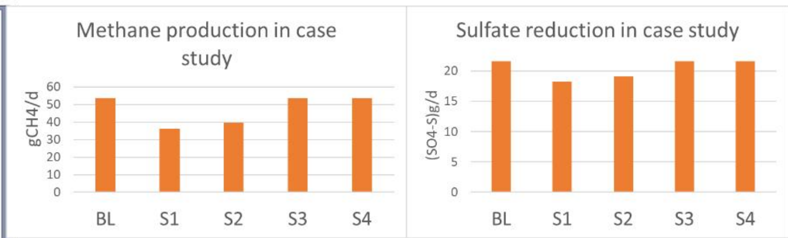
The current paradigm of designing and building urban infrastructures lacks a systematic and interdisciplinary approach. The conventional urban infrastructural engineering approach mostly focuses on optimising a single infrastructure to provide an improved service but ignores the interdependences among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

CV Researcher; Dr.ir. Wei-Shan Chen
Graduated; Wageningen University, MSc Environmental Technology (2012)
e-mail; Wei-shan.chen@wur.nl
tel; 0317486941
website; www.ete.wur.nl

AMS
AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS
WAGENINGEN UNIVERSITY
WAGENINGEN UR

BESTSEWER- Bioelectrochemical system for mitigating sewer gas formation and related sewer pipe corrosion

Feb 2019 - 2023

Researcher	Supervisor	Promotor
Yue Sun	Dr. Wei-Shan Chen Dr. Annemiek ter Heijne	Prof. dr. ir. Huub Rijnaarts

Motivation

As an important part of urban infrastructure, the sewer system plays an important role in collecting and transporting wastewater. However, the generation of harmful gases in sewer aggravates global warming and sewer pipe corrosion. H_2S and CH_4 are the harmful sewer gases of most concern.

Current sewer gas control strategies rely primarily on the addition of chemical reagents (H_2O_2, $KMnO_4$, nitrate, etc.). These strategies not only require capital and energy inputs but also are not sustainable.

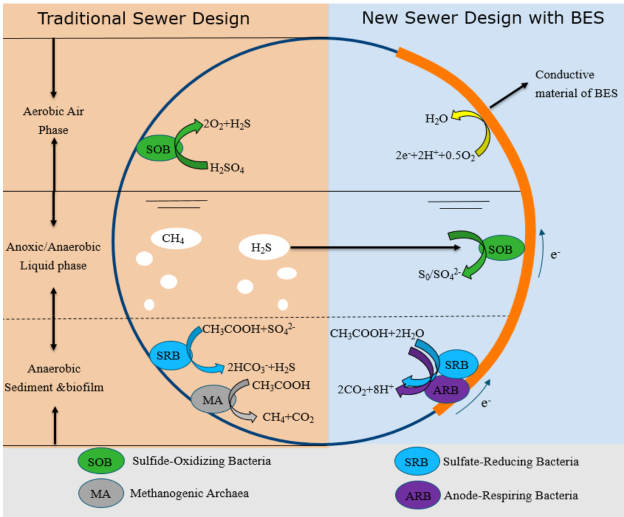


Figure 1. Schematically cross-sectional illustration of bacterial reactions in traditional and BES-based sewer system.

Note: In the traditional sewer system, methanogenic archaea (MA) and sulfate-reducing bacteria (SRB) can utilize degradable organics (acetate, etc.) to form methane and sulfide within anaerobic phases. In the BES-based sewer system, anode respiring bacteria (ARB) can compete electron donors (e.g., acetate) with SRB and MA and possibly inhibit the activity of SRB and MA.

Due to its potential to regulate microbial competition, bioelectrochemical systems (BES) are expected to be an alternative to achieve sewer gas control (Fig 1). Compared with current sewer gas control strategies, the operation of BES requires no addition of chemicals and is more sustainable.

Hence, the aim of this project is to employ BES to continuously steer biological processes within sewers to avoid hazards (explosive and/or toxic gas emissions, greenhouse gas emission) and economic losses (sewer pipe corrosion).

Research challenge

This project focuses on using BES to regulate microbial competition to control sewer gas. The challenge is that this strategy has not yet been proposed or studied to author's best knowledge. Therefore, scientific feasibility of this strategy will be demonstrated first and then proceed with engineering research. This project will be divided into four sections.

- The feasibility of using BES for sewer gas control by regulating the competition between ARB, SRB and MA will be demonstrated.
- The BES sewer performance will be optimized by investigating the effect of hydraulics, and sewer sediment and biofilm.
- Technical solutions for the installation of BES reactors in the sewer system will be developed.
- The long-term performance of BES on inhibiting the formation of sewer gas in real-life sewer system will be studied.

CV Researcher; Yue Sun

Graduated; Wageningen University, Environmental and Bio-based Technology (2018)

Hobbies; Football, cooking, music

E-mail; yue.sun@wur.nl

Tel; +31(0)626836763

Urban metabolic dynamics – Identifying spatial and temporal variability

March 2015-2019

Researcher	Supervisors	Promotor
Ilse Voskamp	Dr. Nora Sutton Dr.ing Sven Stremke	Prof. dr. ir. Huub Rijnaarts

Motivation

Urban areas have a metabolism that converts inputs into outputs. Nowadays this metabolism is mainly linear, where resources are used mostly once and then discharged to the environment. Transitions towards more circular urban metabolism are thought to improve resource use efficiency and increase resilience of urban systems through functional substitution. In ecosystems diversity of metabolic functions is crucial for circulation of nutrients, for developing multiple pathways of resource flows and cascading of energy. As a result, functionally diverse eco-systems are more resilient to disturbance.

Urban metabolism studies generally use the city or regional as a unit of investigation. This does not match the level at practical urban planning and design operates; namely the building, block, neighbourhood or district scale. As a result they do not show the wide diversity of functions that exist within urbanisations, which are essential to work towards more circular metabolism. Yet, another reason urban metabolism has not been applied by planners and designers is that existing studies lack a spatial dimension. Both factors lead to lack of knowledge of diversity urban metabolic functions and their spatial distribution. Also, the concept of time is not properly dealt with in current metabolic studies (Moffatt & Kohler 2008). Resulting in the fact that the concept of urban metabolism has not widely been applied in planning and design (Kennedy et al. 2010).

Aims and Objectives

This research aims to study Amsterdams energy and/or water flows in detail, revealing metabolic variability within the city. Students can chose to study either specific neighborhoods (using MFA) or to resource 'chains' through the city (using SFA). Preferably, a correlation study is done to link the identified spatial and temporal variability of urban metabolism with the heterogeneity of city characteristics, like demographic, spatial and economic parameters.

Methods and requirements on candidate

In this research, students will use methods such as Material and Substance Flow Analysis (MFA / SFA). Also a literature review could be included to identify and compare the studies that have researched spatial variability and/or temporal dynamics of urban metabolism on their method and results.
Preferably, the student has well developed GIS skills. These skills are essential to do the correlation study.

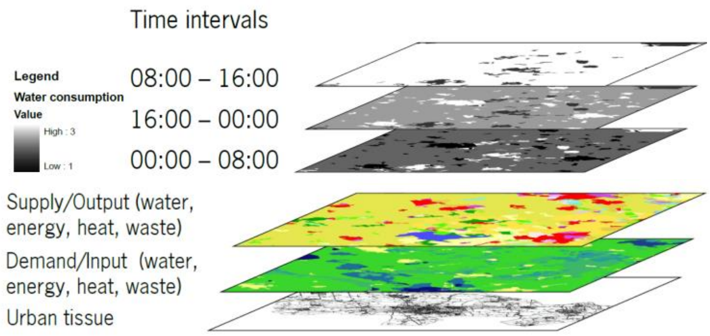


Figure 1: Spatial and temporal variability of urban metabolism.

CV Researcher;	Ilse Voskamp
Graduated;	Wageningen University, Urban Environmental Technology & Management (2014)
Hobbies;	Hiking, cycling, gardening
e-mail;	Ilse.Voskamp@wur.nl
tel;	0317-485495
website;	www.wur.nl/en/project/PhD-Ilse-Voskamp.htm

Urban Systems Engineering
Environmental Technology

AMS AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

WAGENINGEN UNIVERSITY & RESEARCH

Assessing the Capacity of Blue-Green Infrastructure

Aug 2019 – Jul 2022

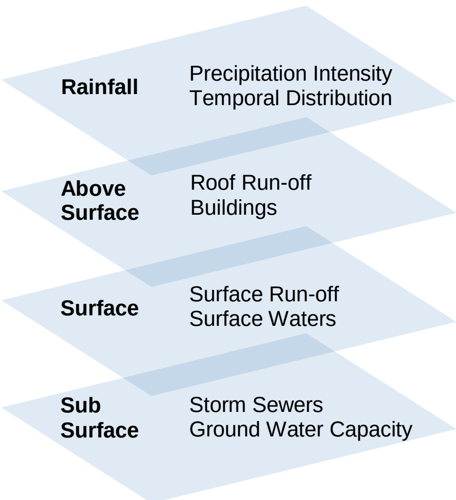
Researcher
dr. ir. Adithya Thota Radhakrishnan

Supervisor
dr. ir. Wei-Shan Chen
dr. Nora Sutton

Motivation

Vast urbanization has led to the deterioration of urban water resources, both in terms of quality and quantity. Urban areas that are characterised by having high density of built environment and impervious surfaces cause the increase in frequency of pluvial flooding. Taking climate variability into consideration, addressing the issues of sustainable water management have become pertinent. Blue-Green Infrastructures (BGI) serve to mitigate the adverse effects of urbanization and climate variability by addressing the issues of pluvial flooding and poor urban surface water quality. However, the limit to the handling capacity of BGI with respect to the maximum rainfall intensity is unknown. To enhance the application and functionality of these BGI, information about the impact of their implementation is necessary.

Figure: The parts that comprise the different components of the urban landscape.



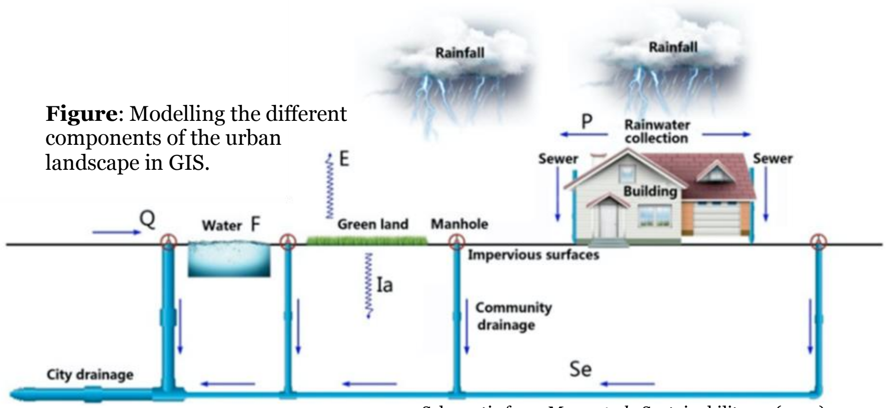
Method

Using geo-spatial and temporal mapping, the changes imparted by BGIs to the urban surface run-off is analyzed. These impacts will not only be assessed at a single infrastructure level, but at a scale of an urban area. This further provides information on the suitability of a BGI to the focus area in terms of the target water quantity and quality. The resulting knowledge will be purposed for developing a tool/framework for spatial planning of BGIs. The GIS tool will consist of different modules to handle runoff, surface flow and pipe network flow that will also consider changes in quality of water with time.

Research Questions

- What is the best method to model surface runoff from BGIs?
- What is the limit to the functioning of BGIs with respect to rainfall intensities?
- How do BGIs respond to different rainfall patterns?

Figure: Modelling the different components of the urban landscape in GIS.



Schematic from *Meng et al.*, Sustainability, 11 (2019).

CV Researcher; Adithya Thota Radhakrishnan
Graduated; PhD, Water Management, TU Delft (2019)
MSc, Chemical Engineering, TU Eindhoven (2014)
Hobbies; Climbing, Mountaineering, Cycling
e-mail; Adithya.thotaradhakrishnan@wur.nl
tel; 0634-336009

Environmental Technology

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

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

Environmental Technology

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.

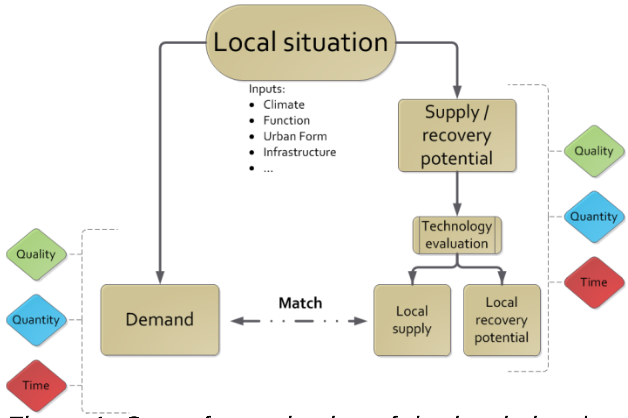


Figure 1: Steps for evaluation of the local situation and technology selection

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

Contact

Katarzyna Kujawa
Email: katarzyna.kujawa@wur.nl
Tel: 0317-48 5405

Wei-Shan Chen
Email:Wei-Shan.Chen@wur.nl
Tel: 0317-486941

WAGENINGEN UNIVERSITY & RESEARCH

Hidden pitfalls of the energy transition: a study on CO_2 dependency.

Mar 2019 – 2023

Researcher	Supervisors	Promotor
Ivonne Servin Balderas	Dr. Annemiek ter Heijne Dr. Koen Wetser	Prof. dr. ir. Cees Buisman

Urban Systems Engineering
Environmental Technology

Motivation

The energy transition from fossil fuels to renewable energy is in full progress. This transition is inevitable due to great dependency on fossil fuels and its consequences such as climate change and economic instability. When fossil fuels are burned they emit water, Carbon Dioxide (CO_2), Nitrogen and Sulfur oxides among others. CO_2 is one of the main greenhouses gasses and approximately 80% of its emissions are related to fossil fuels.

CO_2 as a raw material has a great potential. The current potential CO_2 uptake is 70 times lower that the emissions in 2017. However, as society moves away from fossil materials, it might be expected that more carbon based goods be produced from CO_2. In Fig. 1 are mentioned some examples.

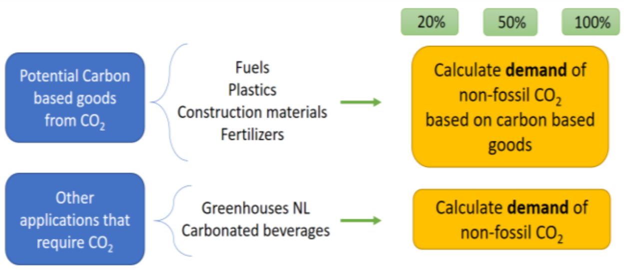


Fig. 1. The potential demand of CO2 and its applications might rise and diversify as society moves away from fossil fuels.

An extreme reduction of CO_2 emissions might be expected. Only a few point sources independent of fossil materials would emit non-fossil CO_2 as a waste stream. Fig. 2 shows the possible change in the sources of CO_2.

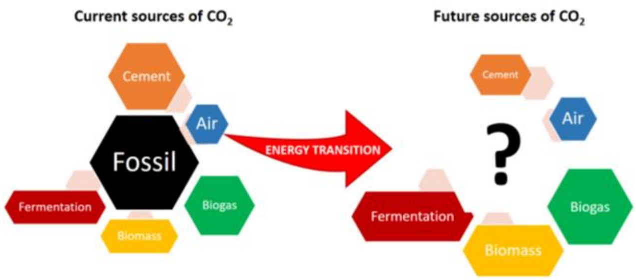


Fig. 2. The sources of CO_2 may diminish through time and the quality and quantities may not be enough for the production of carbon based goods.

Objective

As the energy transition evolves, it is unknown how much CO2 will be needed and if the supply will be enough. The general objective of this research is to study the hidden pitfalls for the role of CO_2 in the energy transition in the years 2019, 2030, and 2050. This study will answer the next question: **What could be the role of CO_2 for the production of carbon based goods as the energy transition becomes stronger?**

To answer this question four steps are required:

- Case study on methanol production based on CO_2 as an overview of the possibilities and opportunities of using non-fossil CO_2.
- Identify the possible applications and demand of CO_2 for carbon based goods production.
- Identify and quantify the possible point sources of non-fossil CO_2.
- Match the potential demand and supply of non-fossil CO_2.

CV Researcher;	Ivonne Servin-Balderas
Graduated;	Wageningen University, Environmental Technology (2018)
Hobbies;	Swimming
e-mail;	Ivonne.servinbalderas@wur.nl
tel;	0317-483 339
website;	

CONACYT Consejo Nacional de Ciencia y Tecnología
WAGENINGEN UNIVERSITY & RESEARCH

Multifunctional urban water quality: FUNqyWATER

Sep 2017 - 2021

Researcher	Supervisors	Promotor
Suzanne van der Meulen	Dr. Nora Sutton Dr. ir. Frans v.d Ven Dr. ir. Pieter v. Oel	Prof. dr. ir. Huub Rijnaarts

Motivation

In many western economies, there is growing demand for use of urban water for recreation, food production, thermal energy provision and other uses. Densification of urban areas puts pressure on urban water systems to provide multiple use functions. Water quality in European cities improves and together with technological advancements, this results in new opportunities for urban water use. The potential supply of use functions is however limited by water quality, quantity and accessibility of water bodies. Urbanization and industrialization have affected these parameters, while extreme wet and dry periods resulting from climate change will exert an additional pressure on urban water systems. Scientists and practitioners suggest delineation of management units in the water system to manage use and to guide investments in this system. Thus, better insight into locally specific potential for multifunctional urban water use is required.

Challenge

Existing literature and assessment frameworks do not provide the scientific basis for an integrated assessment of urban surface waters. They do not take into account all use functions that these waters may provide. Nor do they account for bundles of use functions, temporal and spatial variability, or a clear distinction between use function potential, use and demand.

Research goals

FUNqyWATER aims at a scientifically underpinned assessment framework that enables identification of the potential for multifunctional use of urban surface water and of water management options to optimize potential for multifunctional use.

The underlying research goals are:

1) Assess trends in urban surface water use and future demand for use functions resulting in a selection of use functions to be included in the framework.
2) Establish criteria and indicators to determine the potential provision of these use functions, and to integrate them for bundles of use functions.
3) Identify the key parameters that influence temporal and spatial variability for potential supply of use functions.
4) Assess water management measures to optimize potential provision of use functions.
5) Test the framework for applicability in two case studies: Toronto (Canada) and Amsterdam (The Netherlands).

Amsterdam is one of the study areas for assessment of the use of urban surface water and functional quality of the water system . (Picture by Marc Brink)

CV Researcher;	Suzanne van der Meulen
Graduated;	Universiteit van Amsterdam, MSc. Physical Geography (2004)
Hobbies;	Cycling, swimming
e-mail;	Suzanne.vandermeulen@wur.nl
tel;	+31(0)317483338
website;	www.wur.nl/ete https://www.deltares.nl/nl/experts/suzanne-van-der-meulen-3/

Publication List Environmental Technology 2019

Refereed article in a journal

- Characteristics of Fe and Mn bearing precipitates generated by Fe(II) and Mn(II) co-oxidation with O_2, MnO_4 and HOCl in the presence of groundwater ions
  Ahmad, Arslan ; Wal, Albert van der; Bhattacharya, Prosun ; Genuchten, Case M. van (2019)
  Water Research 161 . - p. 505 - 516.
- Valorization of glycerol/ethanol-rich wastewater to bioflocculants: recovery, properties, and performance
  Ajao, Victor ; Millah, Siti ; Gagliano, Maria Cristina ; Bruning, Harry ; Rijnaarts, Huub ; Temmink, Hardy (2019)
  Journal of Hazardous Materials 375 . - p. 273 - 280.
- Exceptional Water Desalination Performance with Anion-Selective Electrodes
  Arulrajan, Antony C. ; Ramasamy, Deepika L. ; Sillanpää, Mika ; Wal, Albert van der; Biesheuvel, P.M. ; Porada, Slawomir ; Dykstra, Jouke E. (2019)
  Advanced Materials 31 (10).
- Exploring the impact of data uncertainty on the performance of a demand response program
  Azari, Delaram ; Shariat Torbaghan, Shahab ; Cappon, Hans ; Keesman, Karel J. ; Rijnaarts, Huub ; Gibescu, Madeleine (2019)
  Sustainable Energy, Grids and Networks 20 .
- Anaerobic biological fermentation of urine as a strategy to enhance the performance of a microbial electrolysis cell (MEC)
  Barbosa, Sónia G. ; Rodrigues, Telma ; Peixoto, Luciana ; Kuntke, Philipp ; Alves, Maria Madalena ; Pereira, Maria Alcina ; Heijne, Annemiek Ter (2019)
  Renewable Energy 139 . - p. 936 - 943.
- Integrated nutrient recovery from source-separated domestic wastewaters for application as fertilisers
  Bisschops, Iemke ; Kjerstadius, Hamse ; Meulman, Brendo ; Eekert, Miriam van (2019)
  Current Opinion in Environmental Sustainability 40 . - p. 7 - 13.
- The RED Fouling Monitor : A novel tool for fouling analysis
  Bodner, E.J. ; Saakes, M. ; Sleutels, T. ; Buisman, C.J.N. ; Hamelers, H.V.M. (2019)
  Journal of Membrane Science 570-571 . - p. 294 - 302.
- The granular capacitive moving bed reactor for the scale up of bioanodes
  Borsje, Casper ; Sleutels, Tom ; Saakes, Michel ; Buisman, Cees J.N. ; Heijne, Annemiek ter (2019)
  Journal of Chemical Technology and Biotechnology 94 (8). - p. 2738 - 2748.
- Hydrophobic eutectic mixtures as volatile fatty acid extractants
  Bruinhorst, Adriaan van den; Raes, Sanne ; Maesara, Sausan Atika ; Kroon, Maaike C. ; Esteves, A.C.C. ; Meuldijk, Jan (2019)
  Separation and Purification Technology 216 . - p. 147 - 157.
- In situ removal of four organic micropollutants in a small river determined by monitoring and modelling
  Brunsch, Andrea F. ; Langenhoff, Alette A.M. ; Rijnaarts, Huub H.M. ; Ahring, Alexander ; Laak, Thomas L. ter (2019)
  Environmental Pollution 252 . - p. 758 - 766.
- Comparative Analysis of Photocatalytic and Electrochemical Degradation of 4-Ethylphenol in Saline Conditions
  Brüninghoff, Robert ; Duijne, Alyssa K. Van; Braakhuis, Lucas ; Saha, Pradip ; Jeremiasse, Adriaan W. ; Mei, Bastian ; Mul, Guido (2019)
  Environmental Science and Technology 53 (15). - p. 8725 - 9735.
- Estimation of the water cycle related to shale gas production under high data uncertainties : Dutch perspective
  Butkovskyi, Andrii ; Cirkel, Gijsbert ; Bozileva, Elvira ; Bruning, Harry ; Wezel, Annemarie P. Van; Rijnaarts, Huub H.M. (2019)
  Journal of Environmental Management 231 . - p. 483 - 493.

- Combination of bioelectrochemical systems and electrochemical capacitors: Principles, analysis and opportunities
  Caizán-Juanarena, Leire ; Borsje, Casper ; Sleutels, Tom ; Yntema, Doekle ; Santoro, Carlo ; Ieropoulos, Ioannis ; Soavi, Francesca ; Heijne, Annemiek ter (2019)
  Biotechnology Advances .
- 3D biofilm visualization and quantification on granular bioanodes with magnetic resonance imaging
  Caizán-Juanarena, Leire ; Krug, Julia R. ; Vergeldt, Frank J. ; Kleijn, J.M. ; Velders, Aldrik H. ; As, Henk van; Heijne, Annemiek ter (2019)
  Water Research 167 .
- Electrochemical and microbiological characterization of single carbon granules in a multi-anode microbial fuel cell
  Caizán-Juanarena, Leire ; Servin-Balderas, Ivonne ; Chen, Xuan ; Buisman, Cees J.N. ; Heijne, Annemiek ter (2019)
  Journal of Power Sources 435 .
- Recovery of calcium phosphate granules from black water using a hybrid upflow anaerobic sludge bed and gas-lift reactor
  Cunha, Jorge Ricardo ; Schott, Chris ; Weijden, Renata D. van der; Leal, Lucía Hernández ; Zeeman, Grietje ; Buisman, Cees (2019)
  Environmental Research 178 .
- Bulk pH and Carbon Source Are Key Factors for Calcium Phosphate Granulation
  Cunha, Jorge Ricardo ; Morais, Sara ; Silva, Joana C. ; Weijden, Renata D. Van Der; Hernández Leal, Lucía ; Zeeman, Grietje ; Buisman, Cees J.N. (2019)
  Environmental Science and Technology 53 (3). - p. 1334 - 1343.
- Protein hydrolysis and fermentation under methanogenic and acidifying conditions
  Duong, Thu Hang ; Grolle, Katja ; Nga, Tran Thi Viet ; Zeeman, Grietje ; Temmink, Hardy ; Eekert, Miriam Van (2019)
  Biotechnology for Biofuels 12 (1).
- Ecotoxicological benthic impacts of experimental oil-contaminated marine snow deposition
  Eenennaam, Justine S. van; Rohal, Melissa ; Montagna, Paul A. ; Radović, Jagoš R. ; Oldenburg, Thomas B.P. ; Romero, Isabel C. ; Murk, Albertinka J. ; Foekema, Edwin M. (2019)
  Marine Pollution Bulletin 141 . - p. 164 - 175.
- Redox-flow battery design for a methane-producing bioelectrochemical system
  Geppert, Florian ; Liu, Dandan ; Weidner, Eckhard ; Heijne, Annemiek ter (2019)
  International Journal of Hydrogen Energy 44 (39). - p. 21464 - 21469.
- Recycling nutrients contained in human excreta to agriculture: Pathways, processes, and products
  Harder, Robin ; Wielemaker, Rosanne ; Larsen, Tove A. ; Zeeman, Grietje ; Öberg, Gunilla (2019)
  Critical Reviews in Environmental Science and Technology 49 (8). - p. 695 - 743.
- Biotechnological strategies for the recovery of valuable and critical raw materials from waste electrical and electronic equipment (WEEE) – A review
  Işıldar, Arda ; Hullebusch, Eric D. van; Lenz, Markus ; Laing, Gijs Du; Marra, Alessandra ; Cesaro, Alessandra ; Panda, Sandeep ; Akcil, Ata ; Kucuker, Mehmet Ali ; Kuchta, Kerstin (2019)
  Journal of Hazardous Materials 362 . - p. 467 - 481.
- A review of mixing, design and loading conditions in household anaerobic digesters
  Jegede, A.O. ; Zeeman, G. ; Bruning, H. (2019)
  Critical Reviews in Environmental Science and Technology 49 (22). - p. 2117 - 2153.
- Effect of mixing regimes on cow manure digestion in impeller mixed, unmixed and Chinese dome digesters
  Jegede, Abiodun O. ; Zeeman, Grietje ; Bruning, Harry (2019)
  Energies 12 (13).
- Development of an optimised Chinese dome digester enables smaller reactor volumes; pilot scale performance
  Jegede, Abiodun O. ; Zeeman, Grietje ; Bruning, Harry (2019)
  Energies 12 (11).
- Evaluation of liquid and solid phase mixing in Chinese dome digesters using residence time distribution (RTD) technique
  Jegede, A.O. ; Zeeman, G. ; Bruning, H. (2019)
  Renewable Energy 143 . - p. 501 - 511.

- Enhanced selectivity to butyrate and caproate above acetate in continuous bioelectrochemical chain elongation from CO_2: Steering with CO_2 loading rate and hydraulic retention time
  Jourdin, Ludovic ; Winkelhorst, Marijn ; Rawls, Brian ; Buisman, Cees J.N. ; Strik, David P.B.T.B. (2019)
  Bioresource Technology Reports 7 .
- Development and validation of a physiologically based kinetic model for starting up and operation of the biological gas desulfurization process under haloalkaline conditions
  Kiragosyan, Karine ; Klok, Johannes B.M. ; Keesman, Karel J. ; Roman, P. ; Janssen, Albert J.H. (2019)
  Water Research 4 .
- Development of quantitative PCR for the detection of Alkalilimnicola ehrlichii, Thioalkalivibrio sulfidiphilus and Thioalkalibacter halophilus in gas biodesulfurization processes
  Kiragosyan, Karine ; Veelen, Pieter van; Gupta, Suyash ; Tomaszewska-Porada, Agnieszka ; Roman, Pawel ; Timmers, Peer H.A. (2019)
  AMB Express 9 .
- Decentralized valorization of residual flows as an alternative to the traditional urban waste management system: The case of Peñalolén in Santiago de Chile
  Kraker, Jeltsje de; Kujawa-Roeleveld, Katarzyna ; Villena, Marcelo J. ; Pabón-Pereira, Claudia (2019)
  Sustainability 11 (22).
- Performance of secondary wastewater treatment methods for the removal of contaminants of emerging concern implicated in crop uptake and antibiotic resistance spread : A review
  Krzeminski, Pawel ; Tomei, Maria Concetta ; Karaolia, Popi ; Langenhoff, Alette ; Almeida, C.M.R. ; Felis, Ewa ; Gritten, Fanny ; Andersen, Henrik Rasmus ; Fernandes, Telma ; Manaia, Celia M. ; Rizzo, Luigi ; Fatta-Kassinos, Despo (2019)
  Science of the Total Environment 648 . - p. 1052 - 1081.
- Branched Medium Chain Fatty Acids : Iso-Caproate Formation from Iso-Butyrate Broadens the Product Spectrum for Microbial Chain Elongation
  Leeuw, Kasper D. De; Buisman, Cees J.N. ; Strik, David P.B.T.B. (2019)
  Environmental Science and Technology 53 (13). - p. 7704 - 7713.
- Electrical energy from CO_2 emissions by direct gas feeding in capacitive cells
  Legrand, L. ; Schaetzle, O. ; Tedesco, M. ; Hamelers, H.V.M. (2019)
  Electrochimica Acta 319 . - p. 264 - 276.
- Calcium Carbonate Packed Electrochemical Precipitation Column: New Concept of Phosphate Removal and Recovery
  Lei, Yang ; Narsing, Santosh ; Saakes, Michel ; Weijden, Renata D. Van Der; Buisman, Cees J.N. (2019)
  Environmental Science and Technology 53 (18).
- Energy Efficient Phosphorus Recovery by Microbial Electrolysis Cell Induced Calcium Phosphate Precipitation
  Lei, Yang ; Du, Mengyi ; Kuntke, Philipp ; Saakes, Michel ; Weijden, Renata van der; Buisman, Cees J.N. (2019)
  ACS sustainable chemistry & engineering 7 (9). - p. 8860 - 8867.
- Influence of Cell Configuration and Long-Term Operation on Electrochemical Phosphorus Recovery from Domestic Wastewater
  Lei, Yang ; Remmers, Jorrit Christiaan ; Saakes, Michel ; Weijden, Renata D. Van Der; Buisman, Cees J.N. (2019)
  ACS sustainable chemistry & engineering 7 (7). - p. 7362 - 7368.
- Fate of calcium, magnesium and inorganic carbon in electrochemical phosphorus recovery from domestic wastewater
  Lei, Yang ; Hidayat, Ipan ; Saakes, Michel ; Weijden, Renata van der; Buisman, Cees J.N. (2019)
  Chemical Engineering Journal 362 . - p. 453 - 459.
- Theory of Ion and Electron Transport Coupled with Biochemical Conversions in an Electroactive Biofilm
  Lichtervelde, A.C.L. De; Heijne, A. Ter; Hamelers, H.V.M. ; Biesheuvel, P.M. ; Dykstra, J.E. (2019)
  Physical Review Applied 12 (1).

- Arsenic in Argentina : Technologies for arsenic removal from groundwater sources, investment costs and waste management practices
  Litter, Marta I. ; Ingallinella, Ana M. ; Olmos, Valentina ; Savio, Marianela ; Difeo, Gonzalo ; Botto, Lía ; Torres, Elsa Mónica Farfán ; Taylor, Sergio ; Frangie, Sofía ; Herkovits, Jorge ; Schalamuk, Isidoro ; González, María José ; Berardozzi, Eliana ; García Einschlag, Fernando S. ; Bhattacharya, Prosun ; Ahmad, Arslan (2019)
  Science of the Total Environment 690 . - p. 778 - 789.
- Arsenic in Argentina: Occurrence, human health, legislation and determination
  Litter, Marta I. ; Ingallinella, Ana M. ; Olmos, Valentina ; Savio, Marianela ; Difeo, Gonzalo ; Botto, Lía ; Farfán Torres, Elsa Mónica ; Taylor, Sergio ; Frangie, Sofía ; Herkovits, Jorge ; Schalamuk, Isidoro ; González, María José ; Berardozzi, Eliana ; García Einschlag, Fernando S. ; Bhattacharya, Prosun ; Ahmad, Arslan (2019)
  Science of the Total Environment 676 . - p. 756 - 766.
- Influence of different redox conditions and dissolved organic matter on pesticide biodegradation in simulated groundwater systems
  Luo, Yujia ; Atashgahi, Siavash ; Rijnaarts, Huub H.M. ; Comans, Rob N.J. ; Sutton, Nora B. (2019)
  Science of the Total Environment 677 . - p. 692 - 699.
- Comparison of Two Sustainable Counter Electrodes for Energy Storage in the Microbial Rechargeable Battery
  Molenaar, Sam D. ; Elzinga, Margo ; Willemse, Sonja G. ; Sleutels, Tom ; Heijne, Annemiek ter; Buisman, Cees J.N. (2019)
  ChemElectroChem 6 (9). - p. 2464 - 2473.
- Selective adsorption of nitrate over chloride in microporous carbons
  Mubita, T.M. ; Dykstra, J.E. ; Biesheuvel, P.M. ; Wal, A. van der; Porada, S. (2019)
  Water Research 164 .
- Haloalkaliphilic microorganisms assist sulfide removal in a microbial electrolysis cell
  Ni, Gaofeng ; Harnawan, Pebrianto ; Seidel, Laura ; Heijne, Annemiek Ter; Sleutels, Tom ; Buisman, Cees J.N. ; Dopson, Mark (2019)
  Journal of Hazardous Materials 363 . - p. 197 - 204.
- Potential impact of hydrodynamic shear force in aquifer thermal energy storage on dissolved organic matter releasement : A vigorous shaking batch study
  Ni, Zhuobiao ; Li, Xiao ; Wang, Yafei ; Wang, Yue ; Qiu, Rongliang ; Rijnaarts, Huub ; Grotenhuis, Tim (2019)
  Science of the Total Environment 677 . - p. 263 - 271.
- Analysis of adoption rates for Needs Driven versus Value Driven innovation water technologies
  O'Callaghan, Paul ; Adapa, Lakshmi M. ; Buisman, Cees (2019)
  Water Environment Research 91 (2). - p. 144 - 156.
- A sustainability assessment of bioethanol (EtOH) production: The case of cassava in Colombia
  Pabon-Pereira, Claudia ; Slingerland, Maja ; Hogervorst, Sanna ; Lier, Jules van; Rabbinge, Rudy (2019)
  Sustainability 11 (14).
- Opinion paper about organic trace pollutants in wastewater : Toxicity assessment in a European perspective
  Pedrazzani, Roberta ; Bertanza, Giorgio ; Brnardić, Ivan ; Cetecioglu, Zeynep ; Dries, Jan ; Dvarionienė, Jolanta ; García-Fernández, Antonio J. ; Langenhoff, Alette ; Libralato, Giovanni ; Lofrano, Giusy ; Škrbić, Biljana ; Martínez-López, Emma ; Meriç, Süreyya ; Pavlović, Dragana Mutavdžić ; Papa, Matteo ; Schröder, Peter ; Tsagarakis, Konstantinos P. ; Vogelsang, Christian (2019)
  Science of the Total Environment 651 . - p. 3202 - 3221.
- Low carbon heating and cooling by combining various technologies with Aquifer Thermal Energy Storage
  Pellegrini, M. ; Bloemendal, M. ; Hoekstra, N. ; Spaak, G. ; Andreu Gallego, A. ; Rodriguez Comins, J. ; Grotenhuis, T. ; Picone, S. ; Murrell, A.J. ; Steeman, H.J. (2019)
  Science of the Total Environment 665 . - p. 1 - 10.
- Diffusion of hydrophilic organic micropollutants in granular activated carbon with different pore sizes
  Piai, Laura ; Dykstra, Jouke E. ; Adishakti, Mahesa G. ; Blokland, Marco ; Langenhoff, Alette A.M. ; Wal, Albert van der (2019)
  Water Research 162 . - p. 518 - 527.

- Rapid metal mobilisation through litter, water and bioweathering as the legacy of historical copper smelting
  Potysz, Anna ; Pędziwiatr, Artur ; Hedwig, Sebastian ; Lenz, Markus (2019)
  Journal of Geochemical Exploration 206 .
- Layer-by-layer membrane modification allows scandium recovery by nanofiltration
  Remmen, Kirsten ; Schäfer, Roman ; Hedwig, Sebastian ; Wintgens, Thomas ; Wessling, Matthias ; Lenz, Markus (2019)
  Environmental Science : Water Research & Technology 5 (10). - p. 1683 - 1688.
- Increasing the Selectivity for Sulfur Formation in Biological Gas Desulfurization
  Rink, Rieks De; Klok, Johannes B.M. ; Heeringen, Gijs J. Van; Sorokin, Dimitry Y. ; Heijne, Annemiek Ter; Zeijlmaker, Remco ; Mos, Yvonne M. ; Wilde, Vinnie De; Keesman, Karel J. ; Buisman, Cees J.N. (2019)
  Environmental Science and Technology 53 (8). - p. 4519 - 4527.
- The concept of load ratio applied to bioelectrochemical systems for ammonia recovery
  Rodríguez Arredondo, Mariana ; Kuntke, Philipp ; Heijne, Annemiek ter; Buisman, Cees J.N. (2019)
  Journal of Chemical Technology and Biotechnology 94 (6). - p. 2055 - 2061.
- Renewable Energy from Finite Resources: Example of Emerging Photovoltaics
  Schmidt, Felix ; Schäffer, Andreas ; Lenz, Markus (2019)
  Chimia 73 (11). - p. 874 - 879.
- Enhancing biological stability of disinfectant-free drinking water by reducing high molecular weight organic compounds with ultrafiltration posttreatment
  Schurer, R. ; Schippers, J.C. ; Kennedy, M.D. ; Cornelissen, E.R. ; Salinas-Rodriguez, S.G. ; Hijnen, W.A.M. ; Wal, A. van der (2019)
  Water Research 164 .
- Continuous n-valerate formation from propionate and methanol in an anaerobic chain elongation open-culture bioreactor
  Smit, Sanne M. De; Leeuw, Kasper D. de; Buisman, Cees J.N. ; Strik, David P.B.T.B. (2019)
  Biotechnology for Biofuels 12 (1). - 16 p.
- Influence of solution composition on fouling of anion exchange membranes desalinating polymer-flooding produced water
  Sosa-Fernandez, P.A. ; Miedema, S.J. ; Bruning, H. ; Leermakers, F.A.M. ; Rijnaarts, H.H.M. ; Post, J.W. (2019)
  Journal of Colloid and Interface Science 557 . - p. 381 - 394.
- Removal of divalent ions from viscous polymer-flooding produced water and seawater via electrodialysis
  Sosa-Fernandez, P.A. ; Post, J.W. ; Leermakers, F.A.M. ; Rijnaarts, H.H.M. ; Bruning, H. (2019)
  Journal of Membrane Science 589 .
- Performance and long distance data acquisition via LoRa technology of a tubular plant microbial fuel cell located in a paddy field in West Kalimantan, Indonesia
  Sudirjo, Emilius ; Jager, Pim De; Buisman, Cees J.N. ; Strik, David P.B.T.B. (2019)
  Sensors 19 (21).
- Activated carbon mixed with marine sediment is suitable as bioanode material for Spartina anglica sediment/plant microbial fuel cell: Plant growth, electricity generation, and spatial microbial community diversity
  Sudirjo, Emilius ; Buisman, Cees J.N. ; Strik, David P.B.T.B. (2019)
  Water 11 (9).
- Marine Sediment Mixed With Activated Carbon Allows Electricity Production and Storage From Internal and External Energy Sources: A New Rechargeable Bio-Battery With Bi-Directional Electron Transfer Properties
  Sudirjo, Emilius ; Buisman, Cees J.N. ; Strik, David P.B.T.B. (2019)
  Frontiers in Microbiology 10 . - 15 p.
- Optimization of algae production on urine
  Tuantet, Kanjana ; Temmink, Hardy ; Zeeman, Grietje ; Wijffels, René H. ; Buisman, Cees J.N. ; Janssen, Marcel (2019)
  Algal Research 44 .
- Immobilization of arsenic as scorodite by a thermoacidophilic mixed culture via As(III)-catalyzed oxidation with activated carbon
  Vega-Hernandez, Silvia ; Weijma, Jan ; Buisman, Cees J.N. (2019)
  Journal of Hazardous Materials 368 . - p. 221 - 227.

- Hydrogen production in reactors: The influence of organic loading rate, inoculum and support material
Vilela, Rogério ; Saia, Flávia Talarico ; Gregoracci, Gustavo Bueno ; Duarte, Rubens ; Andrade, Pedro ; Zaan, Bas van der; Langenhoff, Alette ; Damianovic, Márcia H.R.Z. (2019)
International Journal of Hydrogen Energy 44 (50). - p. 27259 - 27271.
- Non-target screening reveals the mechanisms responsible for the antagonistic inhibiting effect of the biocides DBNPA and glutaraldehyde on benzoic acid biodegradation
Wagner, Thomas V. ; Helmus, Rick ; Quiton Tapia, Silvana ; Rijnaarts, Huub H.M. ; Voogt, Pim de; Langenhoff, Alette A.M. ; Parsons, John R. (2019)
Journal of Hazardous Materials 386 .
- Energy Efficiency of Capacitive Deionization
Wang, Li ; Dykstra, J.E. ; Lin, Shihong (2019)
Environmental Science and Technology 53 (7). - p. 3366 - 3378.
- Upsetting the apple cart? Export fruit production, water pollution and social unrest in the Elgin Valley, South Africa
Wessels, Matthijs ; Veldwisch, Gert Jan ; Kujawa, Katarzyna ; Delcarme, Brian (2019)
Water International 44 (2). - p. 188 - 205.
- Restoring nutrient circularity: A review of nutrient stock and flow analyses of local agro-food-waste systems
Wiel, Bernou Zoë van der; Weijma, Jan ; Middelaar, Corina Everarda van; Kleinke, Matthias ; Buisman, Cees Jan Nico ; Wichern, Florian (2019)
Resources, Conservation and Recycling: X 3 .
- Identifying Amsterdam's nutrient hotspots: A new method to map human excreta at building and neighborhood scale
Wielemaker, Rosanne ; Stuiver, John ; Zeeman, Grietje ; Weijma, Jan (2019)
Journal of Industrial Ecology .
- Fertile cities: Nutrient management practices in urban agriculture
Wielemaker, Rosanne ; Oenema, Oene ; Zeeman, Grietje ; Weijma, Jan (2019)
Science of the Total Environment 668 . - p. 1277 - 1288.
- Review of methods to assess sustainability of industrial water use
Willet, Joeri ; Wetser, Koen ; Vreeburg, Jan ; Rijnaarts, Huub H.M. (2019)
Water Resources and Industry 21 .
- Toward sustainable management of phosphorus flows in a changing rural–urban environment: recent advances, challenges, and opportunities
Wu, Jiechen ; Hartmann, Tobias Edward ; Chen, Wei Shan (2019)
Current Opinion in Environmental Sustainability 40 . - p. 81 - 87.
- Effects of barium on the pathways of anaerobic digestion
Wyman, V. ; Serrano, A. ; Borja, R. ; Jiménez, A. ; Carvajal, A. ; Lenz, M. ; Bartacek, J. ; Fermoso, F.G. (2019)
Journal of Environmental Management 232 . - p. 397 - 403.
- Effect of dissolved natural organic matter on the photocatalytic micropollutant removal performance of TiO_2 nanotube array
Ye, Yin ; Bruning, Harry ; Liu, Wanrong ; Rijnaarts, Huub ; Yntema, Doekle (2019)
Journal of Photochemistry and Photobiology. A, Chemistry 371 . - p. 216 - 222.

Non-refereed article in a journal

- Environmental arsenic in a changing world
Ahmad, Arslan ; Bhattacharya, Prosun (2019)
Groundwater for Sustainable Development 8 . - p. 169 - 171.
- Arsenic in Drinking Water : Is 10 µg/L a Safe Limit?
Ahmad, Arslan ; Bhattacharya, Prosun (2019)
Current Pollution Reports 5 (1). - p. 1 - 3.

- Corrigendum to “Opinion paper about organic trace pollutants in wastewater: Toxicity assessment in a European perspective"
Pedrazzani, Roberta ; Bertanza, Giorgio ; Brnardić, Ivan ; Cetecioglu, Zeynep ; Dries, Jan ; Dvarionienė, Jolanta ; García-Fernández, Antonio J. ; Langenhoff, Alette ; Libralato, Giovanni ; Lofrano, Giusy ; Škrbić, Biljana ; Martínez-López, Emma ; Meriç, Süreyya ; Mutavdžić Pavlović, Dragana ; Papa, Matteo ; Schröder, Peter ; Tsagarakis, Konstantinos P. ; Vogelsang, Christian (2019)
Science of the Total Environment 669 . - p. 1062 - 1062.

Refereed book chapters

- Testing the Effect of MOSSFA (Marine Oil Snow Sedimentation and Flocculent Accumulation) Events in Benthic Microcosms
Foekema, E.M. ; Eenennaam, Justine van; Hollander, D.J. ; Langenhoff, A.A.M. ; Oldenburg, Thomas B.P. ; Radović, Jagoš R. ; Rohal, Melissa ; Romero, Isabel C. ; Schwing, Patrick T. ; Murk, A.J. (2019)
In: Scenarios and Responses to Future Deep Oil Spills / Murawski, S.A., Ainsworth, C.H., Gilbert, S., Hollander, D.J., Paris, C.B., Schlueter, M., Wetzel, D.L., - p. 288 - 299.
- Effect of marine snow on microbial oil degradation
Langenhoff, A.A.M. ; Rahsepar, Shokouh ; Eenennaam, J.S. van; Radović, Jagoš R. ; Oldenburg, Thomas B.P. ; Foekema, E.M. ; Murk, A.J. (2019)
In: Deep Oil Spills / Murawski, S.A., Ainsworth, C.H., Gilbert, S., Hollander, D.J., Paris, C.B., Schlueter, M., Wetzel, D.L., - p. 301 - 311.

PhD Theses internally prepared

- Granular activated carbon in capacitive microbial fuel cells
Caizán Juanarena, Leire (2019)
Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): A. ter Heijne. - Wageningen : Wageningen University, - 202
- Integrated pollution prevention and control for the municipal water cycle in a river basin context: validation of the three-step strategic approach
Galvis Castaño, Alberto (2019)
Wageningen University. Promotor(en): H.J. Gijzen, co-promotor(en): N.P. van der Steen. - Leiden : CRC Press/Balkema, - 200
- Electrochemical phosphorus removal and recovery
Lei, Yang (2019)
Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): R.D. van der Weijden; M. Saakes. - Wageningen : Wageningen University, - 247
- Bioelectrochemical chain elongation
Raes, Sanne M.T. (2019)
Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): Strik. D.P.B.T.B.. - Wageningen : Wageningen University, - 167
- (Bio)electrochemical recovery of ammonia from urine
Rodríguez Arredondo, Mariana (2019)
Wageningen University. Promotor(en): C.J.N. Buisman, co-promotor(en): A. ter Heijne; P. Kuntke. - Wageningen : Wageningen University, - 169
- Fertile cities : Nutrient flows from new sanitation to urban agriculture
Wielemaker, Rosanne (2019)
Wageningen University. Promotor(en): G. Zeeman; O. Oenema, co-promotor(en): J. Weijma. - Wageningen : Wageningen University, - 315

Remaining Output

- Exploring groundwater microbial communities for natural attenuation potential of micropollutants
  Aldas Vargas, A.B. ; Hauptfeld, Tina ; Hermes, G.D.A. ; Atashgahi, S. ; Smidt, H. ; Rijnaarts, H.H.M. ; Sutton, N.B. (2019)
  BioRxiv, - 29 p. https://doi.org/10.1101/850750
- Towards combining electro-catalytic and bio-electro-catalytic CO2 reduction: microbial growth-medium electrolyte enhances electro-catalytic conversion of CO2 to formate
  Chatzipanagiotou, K.R. ; Soekhoe, V. ; Strik, D.P.B.T.B. ; Buisman, C.J.N. ; Bitter, J.H. (2019)
- Tailoring electro-catalysts to biological conditions
  Chatzipanagiotou, K.R. ; Buisman, C.J.N. ; Strik, D.P.B.T.B. ; Bitter, J.H. (2019)
- Repeated-batch food waste fermentation for n-caproate production with reduced hydroxide use and no external electron donor addition
  Contreras Davila, Carlos ; Carrión, Víctor J. ; Vonk, Vincent R. ; Buisman, C.J.N. ; Strik, D.P.B.T.B. (2019) https://doi.org/10.17026/dans-z44-2z4d
  Wageningen University & Research,
- Natuurlijke technieken voor de verwijdering van microverontreinigingen
  Langenhoff, Alette (2019) https://edepot.wur.nl/507898
- Iso-caproate formation via open culture ethanol based chain elongation
  Leeuw, Kasper de; Buisman, Cees ; Strik, David (2019)
  Wageningen University & Research,
- N-valerate formation from methanol based propionate chain elongation in mixed cultures
  Smit, Sanne de; Leeuw, Kasper de; Buisman, Cees ; Strik, David (2019)
  Wageningen University & Research,
- Methanol based elongation of propionate and propionate and acetate in continuous and batch mixed culture systems
  Smit, Sanne de; Leeuw, K.D. de; Buisman, C.J.N. ; Strik, D.P.B.T.B. (2019) ttps://doi.org/10.17026/dans-zez-ykrc
- Activated Carbon mixed with marine sediment suits as bioanode material for Spartina anglica Sediment/Plant Microbial Fuel Cell: plant growth, electricity generation and spatial less microbial community diversity
  Sudirjo, Emilius ; Buisman, C.J.N. ; Strik, D.P.B.T.B. (2019)
  Wageningen University,
- Raw experimental data from paper "Activated Carbon mixed with marine sediment suits as bioanode material for Spartina anglica Sediment/Plant Microbial Fuel Cell: plant growth, electricity generation and spatial microbial community diversity"
  Sudirjo, Emilius ; Buisman, C.J.N. ; Strik, D.P.B.T.B. (2019) https://doi.org/10.17026/dans-253-tk8w
  Wageningen University & Research,
- Ivium Raw data of Charging and Discharging experiment for article "Marine sediment mixed with activated carbon allows electricity production and storage from internal and external energy sources: a new rechargeable bio-battery with bi-directional electron transfer properties"
  Sudirjo, Emilius ; Buisman, C.J.N. ; Strik, D.P.B.T.B. (2019) https://doi.org/10.17026/dans-xed-8qkv