Environmental Technology 2018

Metropolitan and Environmental Solutions

WAGENINGEN
UNIVERSITY & RESEARCH

100 years
1918 — 2018

Introduction

This brochure aims at informing you on the activities of the Environmental Technology (ETE) Group of Wageningen University over the year 2017. 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 2017 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), 15 members of scientific staff, 8 Laboratory and technology supporting co-workers, 2 postdocs, 68 PhD students, and 66 graduating MSc and 19 BSc students.

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

- David Strik, Mathijs van der Zwart and Cees Buisman won the Lettinga Award with their proposal 'Dark photosynthesis: anaerobic biosynthesis of food from wastewater and electricity'. This award is to stimulate and implement anaerobic technology in society.
- Victor Ajao was awarded the best oral presentation in the IWA Young Water Professionals conference in Belgium.
- Annemerel Mol won the UFW-KLV thesis award for her master thesis 'Bio-electro chemical battery' in the category Environmental Sciences.
- ETE spin-off company Plant-e won the Dutch Innovation Award in the category Social Impact. The prize is an initiative of the Dutch broadcasing company AVROTROS and the Erasmus University in Rotterdam.

Research

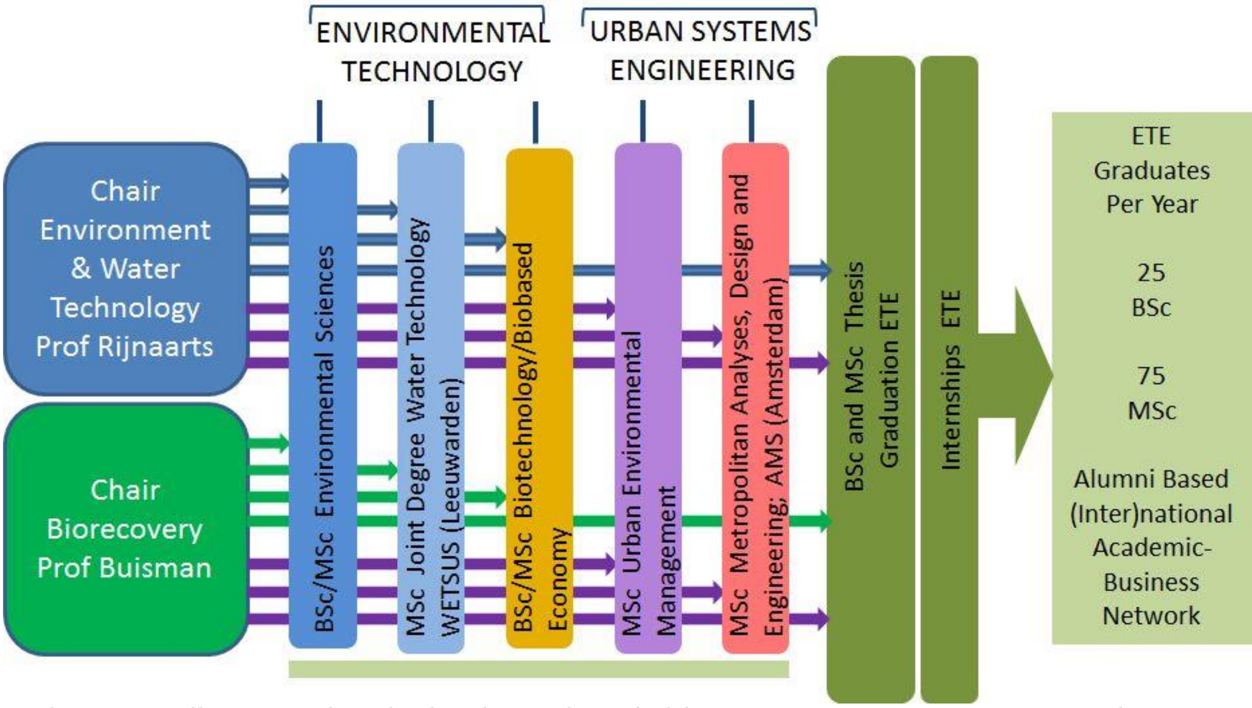
Our research program is characterized as follows:

⇒ **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 delevering 25 BSc and 75 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)

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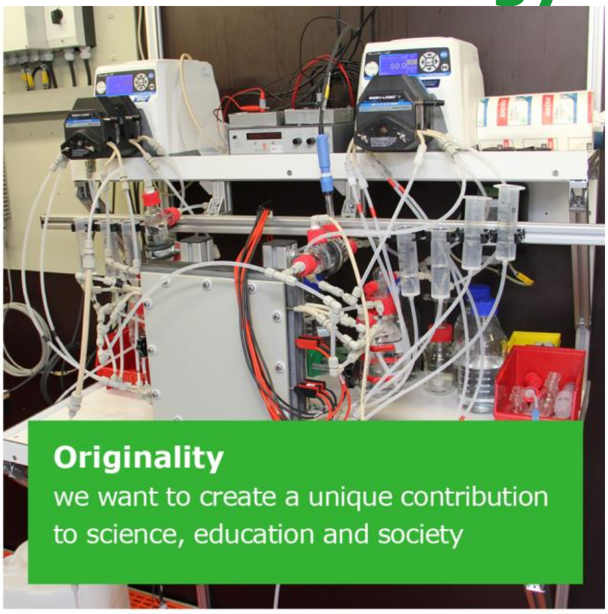
Mission and Vision

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



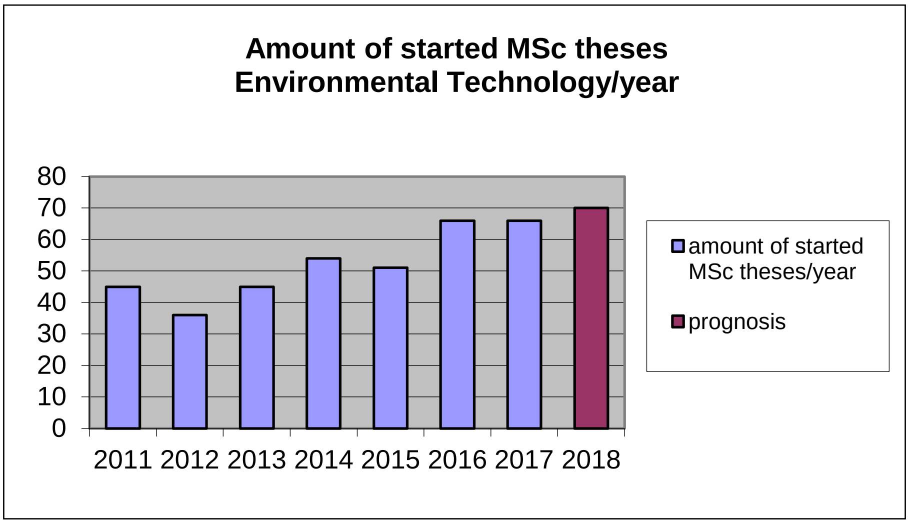
Originality
we want to create a unique contribution to science, education and society

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 2017

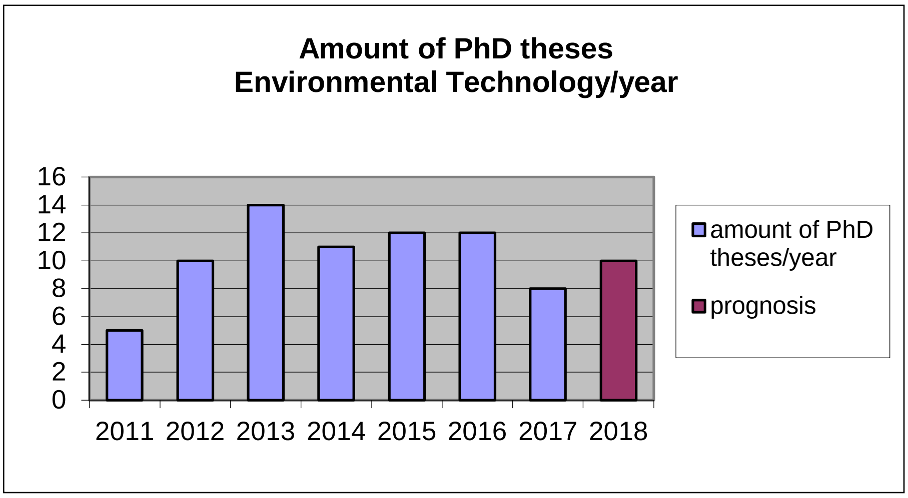
In 2017 66 MSc student started a thesis. In the coming years we expect an increase, based on the expected increase on the total number of students, both in the master water technology in Leeuwarden, as well as at Wageningen University



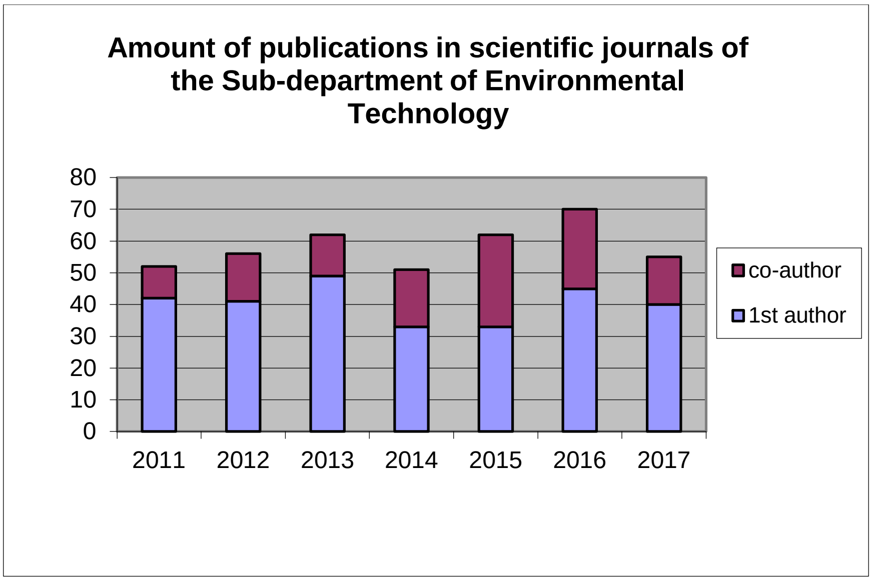
In 2017 we had 8 PhD defences. By the beginning of 2018 68 PhD students were working on their PhD research and did not yet graduate.

PhD Theses Environmental Technology 2017

Name	Promotor(s)	Title
Bruna Raquel Figueiredo Oliveira	Rijnaarts	Lift up of Lowlands. Beneficial use of dredged sediments to reverse land subsidence
Anna Patricya Florentino	Stams	Physiology and application of sulfur-reducing microorganisms from acidic environments
Pau Rodenas Motos	Buisman	Bioelectrochemical Metal Recovery with Microbial Fuel Cells
Wei-Shan Chen	Buisman/Kroeze	Microbial chain elongation based on methanol
Nadejda Andreev	Lens	Lactic acid fermentation of human excreta for agricultural application
Yujie He	Rijnaarts	Removal of pharmacetuically active compounds in contstructed wetlands
Justine van Eenennaam	Murk/Rijnaarts	Marine snow formation during oil spills
Bob van Laarhoven	Buisman	Valorisation of waste streams from by-product to worm biomass



The complete Publication List of the Sub-department of Environmental Technology 2015 can be found at the end of this brochure.



Education

The Sub-department Environmental Technology offers an education and research programme that is focused on sustainable technological solutions for the worldwide environmental problems. Our approach is to combine several disciplines in order to achieve innovations for environmental solutions. Relevant research disciplines are biotechnology, microbiology, surface chemistry, organic chemistry, chemical technology, physical technology, etc. We also consider the social impact of our work to be very relevant and therefore we co-operate with other University groups, such as Environmental Policy, Environmental Economy and Management Studies.

The Sub-department of 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 2018
ETE10806	Introduction Environmental Technology	• An industrial company • Waste water treatment plant RWZI Bennekom
ETE21306	Water Treatment	• Water treatment plant Apeldoorn
ETE22806	Principles of Urban Environmental Management	• NIOO Wageningen • AVR Duiven • ACRESS Lelystad
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	•
ETE 32806	Managing Urban Environmental Infrastructure	• Green Village Delft • Infrastructural sites
ETE 33806	Planning and Design of Urban Space	• Culembourg – EVA Lanxmeer: • Nieuwegein Centrum West
ETE 34306	Energy, Water and Waste Cycles in the Built Environment	• PuurWaterFabriek Emmen • BioFarm Groningen
ETE34806	Chemical and Biological Resource Quality in Circular Economies	• Circular water in Green house complex in Zuid-Holland
ETE50401/ ETE50406	Capita Selecta Environmental Technology	•
ETE50803/ ETE50806	Capita Selecta Urban Environmental Technology and Management	•
XWT20805	The Global Water Cycle	•
XWT30305	Biological Water Treatment and Recovery Technology	•
XWT32305	Colloid Chemistry	•

Theses and Internships	
ETE80903 BSc Thesis Environmental Technology Part 1: Design Tools	ETET80909 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

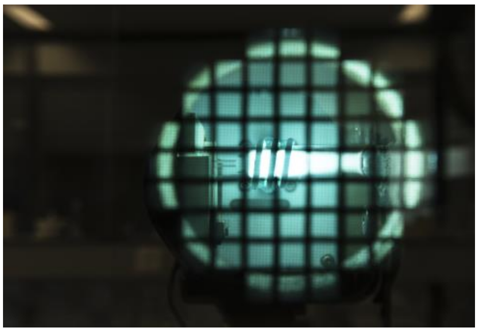
MODUTECH is supported by a well-equipped analytical research environment with an analytical staff of 5 persons (3.9 fte). They have broad practical knowledge in research and take care of the lab organisation, equipment and support in teaching and guiding the students and researchers in their practical 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

Biorecovery

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.*

Reusable Water

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

Urban *System Engineering*

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

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

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

Scientific Staff Environmental Technology

Biorecovery and Urban Systems Engineering		Reusable Water and Urban Systems Engineering	
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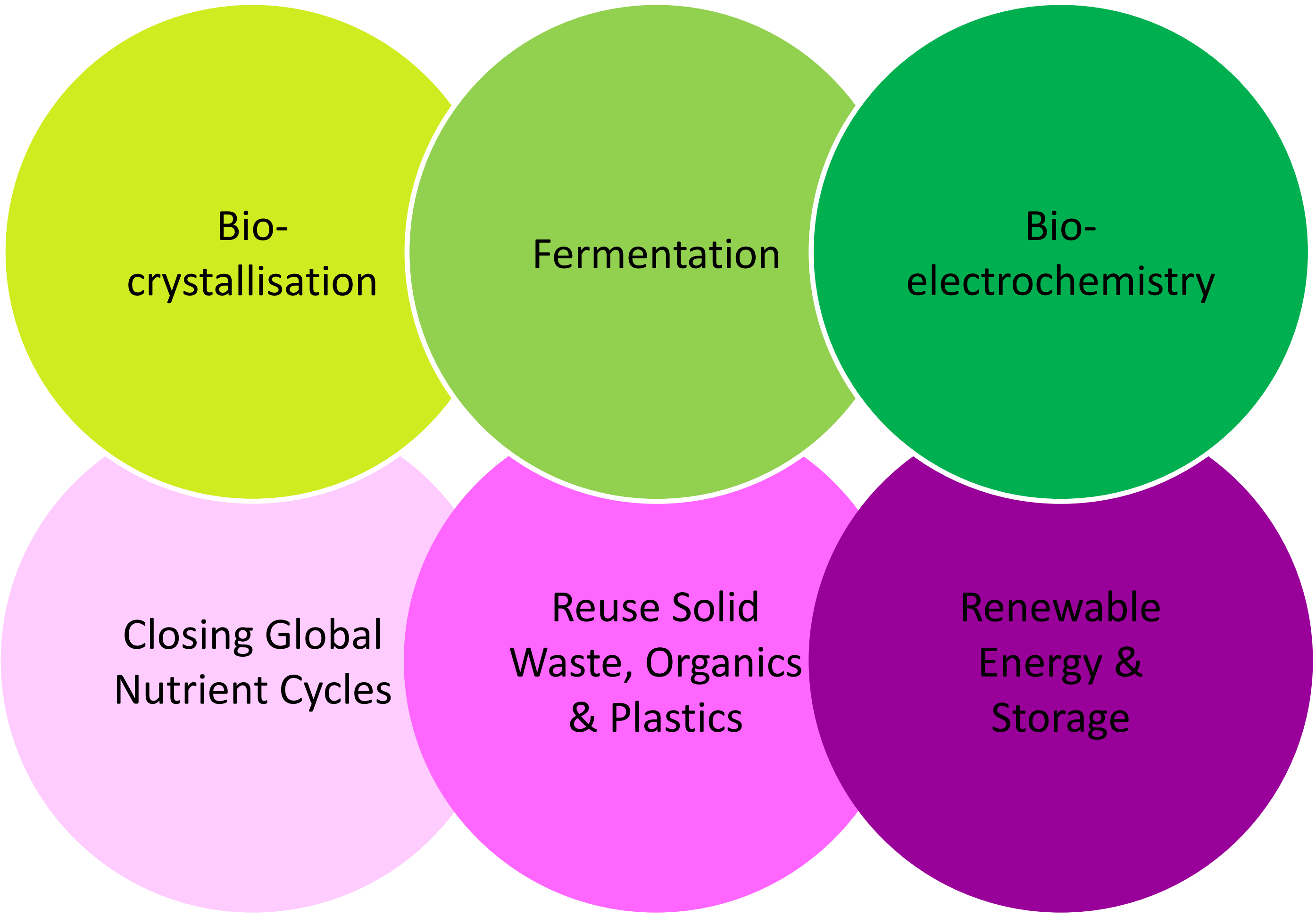
Biorecovery

Sub-department of
Environmental Technology

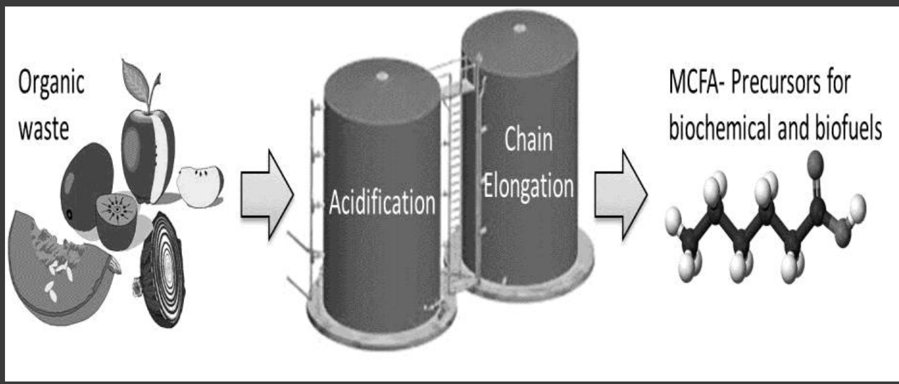
Biorecovery



Biorecovery

Biorecovery

Sub-department of
Environmental Technology



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.

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

Mar 2015 - 2019

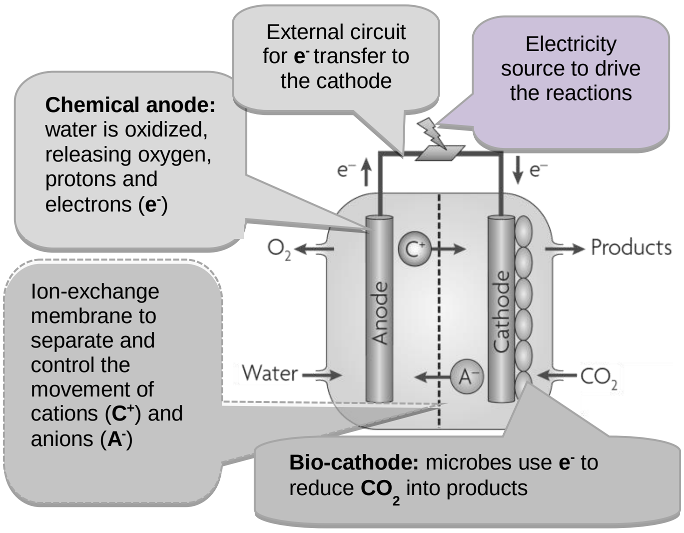
Researcher	Supervisor	Promotor
Konstantina Roxani Chatzipanagiotou	Dr. ir. David Strik	Prof. dr. ir. Cees Buisman Prof. dr. Harry Bitter, BCT

Motivation

CO_2 is the primary contributor to global warming. The conversion of waste CO_2 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 CO_2 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.

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Bio-electrochemically assisted recovery of nutrients from urine

Sub-department of Environmental Technology

Nov 2012 - 2016

Researcher	Supervisors	Promotor
Mariana Rodríguez Arredondo	Dr. Annemiek ter Heijne Dr. Philipp Kuntke	Prof. dr. ir. Cees Buisman

Motivation

There is a need for fertilizers in agriculture to ensure sufficient food production. These fertilizers are made from phosphorous (**P**) and ammonia (**NH_3**). P is limited and scarce and NH_3 comes from energy-intensive processes, such as the Haber-Bosch process.

Urine is a potential source of these nutrients. It contributes to 80% of the nitrogen (N) and 50% of the P load in conventional domestic wastewater. Its high N and P concentration compared to normal sewer water enables a more effective and energy efficient recovery. Additionally, the nutrient load to the wastewater treatment plants is lowered and the water consumption reduced by the use of separation toilets or water free urinals.

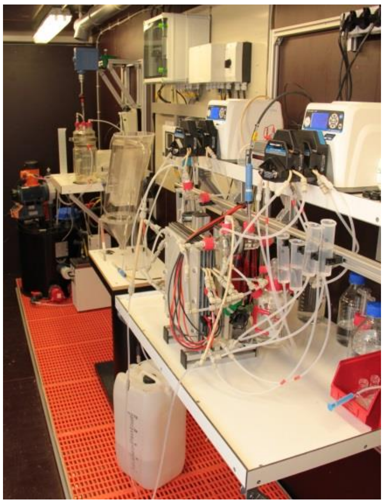

Fig.1 *ValueFromUrine pilot plant*

Technological challenge

The aim is to develop, demonstrate and evaluate an innovative and energy-efficient bio-electrochemical system (BES) that allows for the recovery of valuable nutrients (P and NH_3) from urine while producing chemicals (NaOH, KOH) and, electricity or hydrogen (H_2) (Fig. 2 and 3).

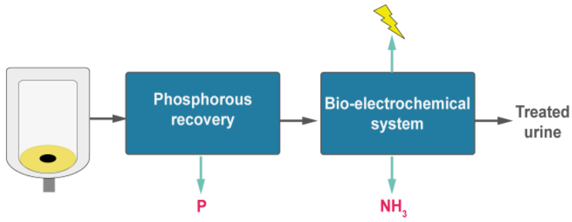

Fig.2 *General process scheme. P is recovered via struvite precipitation.*

The process must be optimized and the material costs lowered in order to make it more economically attractive. For that reason, the research involves:

- Optimization of coulombic efficiency and current density of the anode; NH_3 and alkaline recovery of the cathode
- Testing different configurations of cell stacks to decrease start-up and operation problems and increase current density

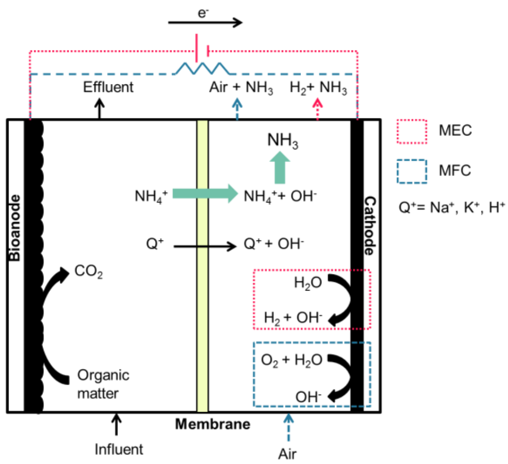

Fig.3 *Working principle of two different BES: microbial fuel cell (MFC) and microbial electrolysis cell (MEC). Biological oxidation of organics drives transport of cations through the membrane.*

Project funded by the EU FP7 (Grant No. 308535)

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Capacitive bio-anodes for electricity production in Microbial Fuel Cells

Sub-department of 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.

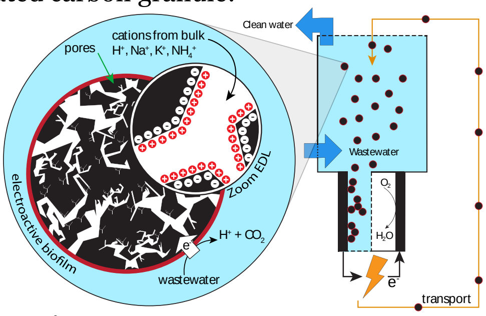

Figure 1

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.

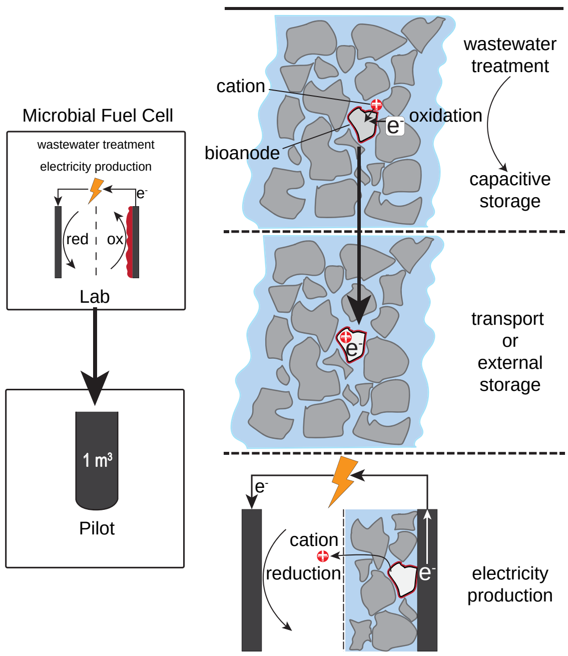

Figure 2

•.

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Sub-department of Environmental Technology

Characterization of Capacitive Materials for their Application in Bio-Anodes

Nov 2014 - 2018

Researcher	Supervisor	Promotor
Leire Caizán Juanarena	Dr. ir. Annemiek ter Heijne	Prof. dr. ir. Cees Buisman

Motivation

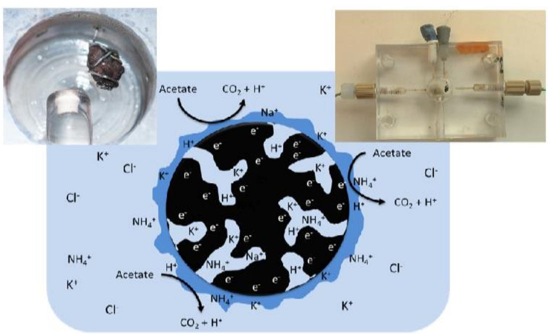
The depletion of fossil fuels, the increased environmental concerns and the rising of world energy consumption has led to the need of alternative energy sources that are clean and renewable. Microbial Fuel Cell (MFC) is a CO_2 neutral, sustainable and efficient technology to recover electricity from organics in wastewater. Classical MFCs have limitations like energy losses in the anode/cathode or high material costs that can be overcome with capacitive MFCs, which use capacitive materials like activated carbon granules where the biofilm can attach.

Principle of Capacitive MFC

Activated carbon (AC) granules have a conductive surface with many pores that provides large surface area for the growth of biofilms(see figure below). These electrochemically active microorganisms will extract electrons from wastewater and store them within the capacitive granules. At the same time, protons and other cations present in the wastewater will be attracted towards the granule and form an electrical double layer to maintain electroneutrality.

Fig.1: Conversion of acetate by microorganisms in AC granules and storage of released electrons. On top, set-up of a single-granule test cell.

Technological challenge

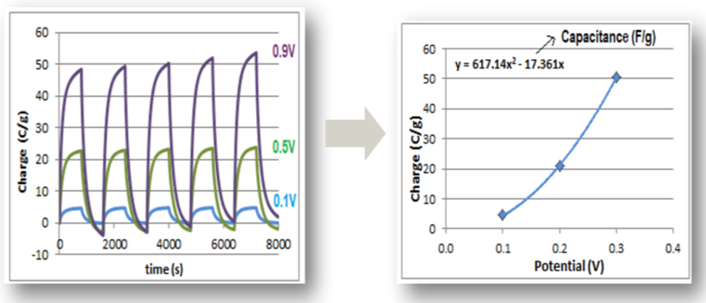


The present study aims to develop and study a MFC by combining an electro-active biofilm with capacitive, activated carbon granules. The two key objectives are:

- To develop a single-granule test cell and a measurement strategy in order to study charge-discharge behavior and quantify charge storage by electro-active biofilms on a single capacitive granule under well controlled conditions. Factors such as pH, buffer concentration, flow rates or acetate concentration will be studied for their effect in charge storage of granules.

- To conceptually understand the biological charging and discharging through the development of a mathematical model that integrates bioelectrochemical and capacitive charging models. This model, together with the experimental data, will help in the understanding of the basic processes that determine charge storage.

Fig. 2: Left-Charge over time of an AC granule at 0.1V, 0.5V and



0.9V in 0.1M salt solution. Right-Charge at different potentials leads to the calculation of charge storage/ capacitance.

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WAGENINGEN UNIVERSITY & RESEARCH

Enabling renewable energy generation by reverse electrodialysis:

Fouling & Process Design

Sub-department of
Environmental Technology

Apr 2017 - 2021

Researcher	Supervisor	Promotor
Elias J. Bodner	Dr. M. Saakes Dr. ir. T. Sleutels Dr. ir. B. Hamelers Dr. ir. A. ter Heijne	Prof. dr. ir. C. Buisman

Motivation

Reverse electrodialysis (RED) is a potentially very attractive technology for the production of energy from the mixing of fresh and salt water. In RED, a concentrated salt solution and a less concentrated salt solution are brought into contact through an alternating series of anion exchange membranes (AEMs) and cation exchange membranes (CEMs). AEMs allow anions to permeate towards the anode and CEMs allow cations to be transported towards the cathode. The difference in chemical potential is the driving force for this process. At the electrodes a (reversible) redox reaction converts the ionic current into an electrical current (Fig. 1).

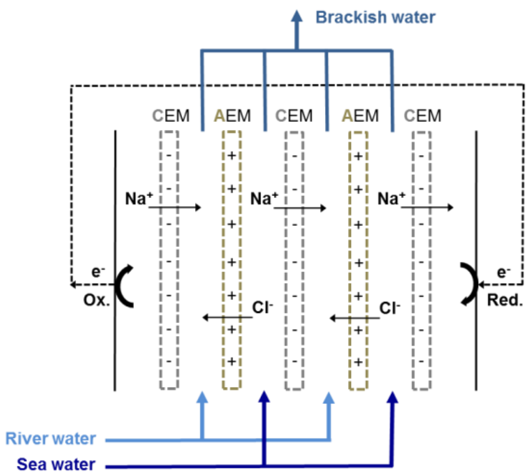

Fig. 1: Simplified principle of RED.

Fouling, with its various types (organic, inorganic, biofouling, scaling, etc.) is one of the most severe problems within many membrane-based technologies. The full-scale RED plant at the Afsluitdijk, operated with natural feed waters, has shown, that fouling is a significant aspect, dramatically decreasing the overall effective power output (Fig. 2). More detailed information about fouling is required when RED is performed under natural conditions. It is believed, that a sufficient RED performance requires a tailored process design. A reasonable feed water pre-treatment is indispensable to inhibit fouling from occurring and thus enabling a sustainable energy production by RED.

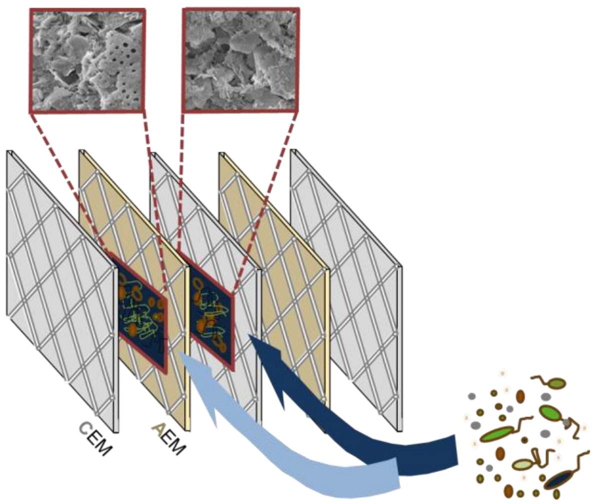

Fig. 2: Illustration of fouling within RED applications. SEM images taken from Vermaas et al. 2013.

Challenges

- identifying the impact of individual foulants, revealing the mode of action of the main one(s) under natural conditions
- proposing and testing process modifications including foremost pre-treatment steps/combinations.

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Optimization of the BioScorodite process for safe Arsenic disposal

Sub-department of Environmental Technology

Apr 2012 - 2016

Researcher
Silvia Vega Hernández

Supervisor
Dr. ir Jan Weijma

Promotor
Prof. dr. ir. Cees Buisman

Motivation

Arsenic is a major contaminant in the non-ferrous metallurgical industry and treatment of arsenic-rich wastewaters is one of the most important environmental issues for the mining and metallurgical industries. Arsenic in metallurgical waste streams originate in particular from complex ores that are mined for copper, lead, zinc, cobalt, gold and silver. The demand for these metals has grown dramatically in the past years, creating a surplus of arsenic.
The immobilization of Arsenic as the very stable mineral Scorodite ($FeAsO_4 \cdot 2H_2O$) is the preferred route to safe long-term storage.

Technological Principle:

In the BIOSCORODITE PROCESS a new biological process concept, the principle of biocrystallisation is introduced. In this process scorodite is crystallized with the aid of arsenite and ferrous (Fe^{2+}) oxidizing bacteria.
Previous investigations showed that scorodite crystallization can be controlled by iron-oxidizing bacteria growing at pH 1.3 and a temperature of 75-80ºC in the presence of arsenate (AsO_4^{3-}).
However, in many relevant waste streams arsenic is present as arsenite (AsO_3^{3}), which remains in solution at the pH of less than 1.3 required for scorodite formation from arsenate and ferric. Biological arsenite oxidation is still a challenge, as is the conditions for crystallizing the most stable BioScorodite

Research challenges

- Find a suitable thermoacidophile culture for arsenic oxidation and study the kinetic of biological Arsenite oxidation at pH 1.5.
- Effect of conditions pH/Temperature on the cristallynity and stability of scorodite formed from biologically oxidized arsenite and iron ferrous.
- Optimize the operational window of an airlift reactor to generate bioscorodite from As(III) and Fe(II) including the treatment of high concentrated arsenic streams.

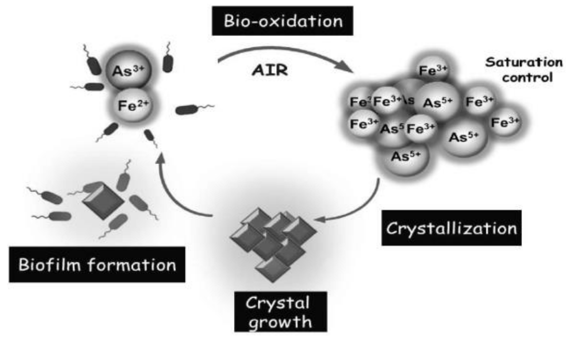

Fig1. Theoretical concept of BioScorodite crystallization

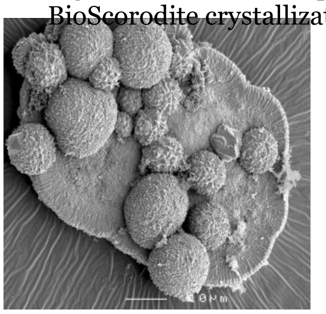

Fig 2. SEM picture BioScorodite

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WAGENINGEN UNIVERSITY & RESEARCH

Electricity generation by Plant Microbial Fuel Cells in tropical wetlands

Sub-department of Environmental Technology

Feb 2016 – Feb 2020

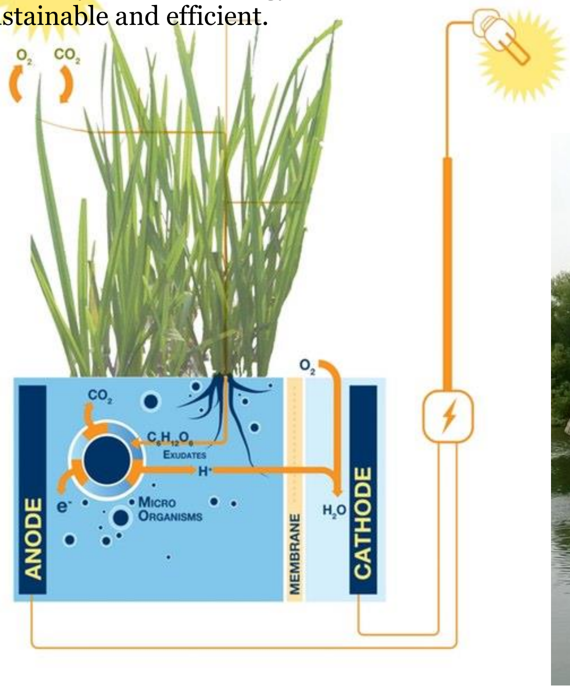
Researcher	Supervisor	Promotor
Emilius Sudirjo, MSc	Dr. ir. David Strik	Prof. dr. ir. Cees Buisman

Motivation

Environment devastation, global warming issues, energy security, and rising energy cost are among present energy challanges which stimulate renewable energy development. New sources for sustainable bioenergy production must be found. The Plant Microbial Fuel Cell (PMFC) generates electricity without harvesting the biomass. The PMFC can be applied in wetlands and generated up to 0.24W/m2 for-over two weeks. Recent research has shown that PMFC can be integrated in wetlands, potentially at large scale, producing electricity and protect the environment from devastation.

Principles of the Plant Microbial Fuel Cells

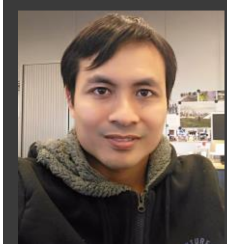
PMFC is a system that produces bioenergy *in situ* in which plants and bacteria convert solar energy into electricity. This technology is clean, renewable, sustainable and efficient.



Technological challenge

To be able to apply this technology into tropical wetland application, several technological challenges must be overcome:
(i) PMFC make use of expensive electrode materials. Therefore cheaper (bio-based) electrode materials must be developed. To utilise these materials, research on the diversity of electron transfer mechanisms is needed.
(ii) It is important to find out what plant/wetland type is most attractive for PMFC installation. Tropical wetland consists of wide range of plant species and can have high productivity. Therefore, recently developed tubular PMFCS can be used in tropical wetlands and must be investigated on performance.

When these challenges are tackled, a beautiful resort in a remote wetland can be powered by a PMFC system.



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KABUPATEN LANDAK

WAGENINGEN UNIVERSITY & RESEARCH

Cyanophycin from Urine

Mar 2016 - 2020

Researcher
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Supervisors
Dr. ir. Marcel Janssen
Dr. ir. Hardy Temmink

Promotor
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).

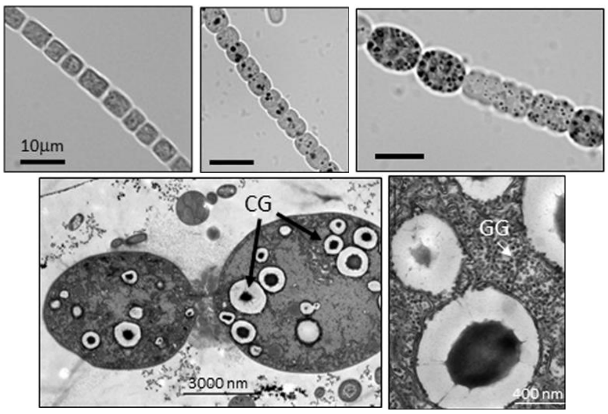

Figure 1. Akinetes development and CG. (Sukenik et al., 2015)

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.

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Removal and recovery of phosphate from wastewater by electrochemical induced calcium phosphate precipitation

Sub-department of Environmental Technology

Mar 2016 – 2020

Researcher	Supervisor	Promotor
Yang Lei	Dr. Renata D. van der Weijden, Dr. Michel Saakes	Prof. dr. ir. Cees Buisman

Motivation

Phosphate is an essential nutrient for life, unfortunately phosphate ore reserves in the world are diminishing. On the other hand, excess phosphate in wastewater can leads to water pollution, i.e., eutrophication. Therefore, the removal and recovery of phosphate from wastewater would provide an excellent solution for both problems. The most common ways for removing phosphate are precipitation with iron/aluminum. They are effective but not sustainable, because phosphate in the iron and aluminum precipitates is hardly bio-available. Herein, an attempt to produce bio-available calcium phosphate by a novel electrochemical means is therefore suggested.

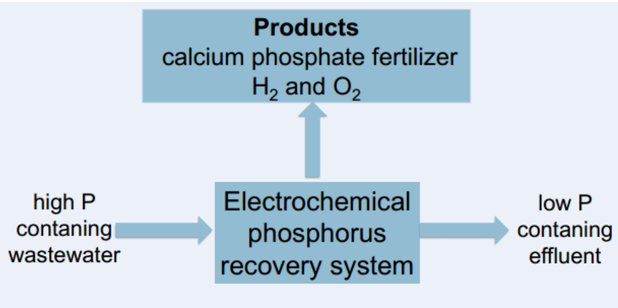

Figure 1. General overview of the electrochemical P recovery system.

Technological challenge

Electrochemical precipitation, as a promising method for removal of phosphate from waste streams, has received increased interest, because of the availability and low (chemicals consumption) costs of the technology, the low temperatures used which would lead to crystalline products, and also, the ability to control the thickness, composition and microstructure of deposition. In general, several processes, including acid-base reactions, a decrease in solubility by an increase in pH and a decrease in solubility by an increase of free constituent ions (OH-) are involved in the precipitation of CaP via the electrochemical system. Therefore, it is possible to harvest phosphate with the electrochemical precipitation system. But there are still many concerns that need to be investigated before it can be applied to treat real wastewater. At present, our challenges are to identify the influence of water constitutions and more importantly, how to collect the formed CaP precipitation in this system.

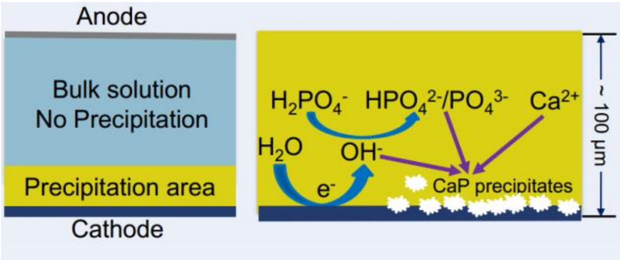

Figure 2. Mechanism of electrochemical induced calcium phosphate precipitation.

Accordingly, the main goal of this research will be to develop a WWTP integrated electro-precipitation system, for calcium phosphate removal and recovery. The detailed objectives are listed below:

1) Recover the CaP product that would allow re-use (harvesting) of the CaP.
2) The solution chemistry and scaling tendencies in combination with CaP products will be investigated theoretically and experimentally.
3) Integrate electrochemical phosphate recovery in the WWTP.

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Sub-department of Environmental Technology

Novel biochemicals production from organic residues – The isobutyrate platform

April 2016 - 2020

Researcher
Ir. Kasper de Leeuw

Supervisor
Dr. ir. David Strik

Promotor
Prof. dr. ir. Cees Buisman

Motivation

There is an increasing demand for sustainable solutions to quench our thirst for oil-derived carbon compounds. Anaerobic treatment provides the means to efficiently produce renewable chemicals from organic residues. The recent discovery of controllable isobutyrate production during mixed culture fermentation opens the possibility to develop new biorecovery technologies.

Isobutyrate is a platform chemical that can be used for a wide range of products, including: flavors, fragrances, animal feed additives, emulsifiers and organic solvents. Classical synthesis of isobutyrate uses fossil fuels and involves hazardous polluting chemicals. The new technology will help to close the carbon cycle and contribute to a healthier environment.

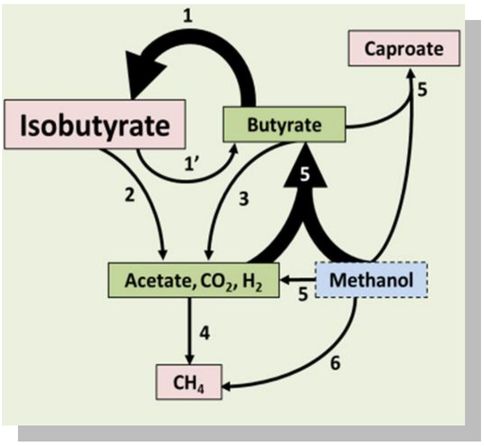
Technological principle

Anaerobic treatment is a widespread method to produce biochemicals. A mayor advantage of this methods is that the energy-content of organic residue streams is largely maintained in the product, allowing for high yields and low costs during production of biochemicals. The most important factor that defines the anaerobic process is the applied selective pressure.

Up-flow anaerobic filters with continuous production of MCFAs

Acidification and chain elongation pilot reactors at ChainCraft B.V. in Amsterdam

In this research an isobutyrate biorefinery is developed and evaluated on potential applications.



Overview of potential conversion routes in iso-chain elongation system

Research challenges

- Pinpoint control mechanisms of selection pressure on microbiomes which lead to effective bioreactor operation
- Clarify the bioformation pathway(s) of isobutyrate formation.
- Identify the key microbes and use their characteristics to optimize the process

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NWO Netherlands Organisation for Scientific Research

CHAINCRAFT

WAGENINGEN UNIVERSITY & RESEARCH

Bioelectrochemical Systems for Ammonia Recovery from Wastewater

Sept 2017 - 2021

Researcher	Supervisor	
Steffen Georg	Dr. Philipp Kuntke Dr. ir. Annemiek ter	

Sub-department of Environmental Technology

Motivation

An increasing world population and rising nutrient demand will require higher agricultural output and therefore more fertilizer to sustain humanity. At the same time, nutrients in wastewater need to be removed to protect waterbodies from eutrophication. Therefore nutrient recovery from wastewater streams is important to create a sustainable future. Bioelectrochemical Systems (BES) such as microbial electrolysis cells (MECs) can convert biodegradable organic compounds in waste streams into electricity. This electrical current can be used to recover total ammonia nitrogen (TAN) as resource (i.e. fertilizer), combining both needs in an elegant and energy efficient solution.

Technological challenge

Organic compounds in wastewater are degraded and ammonium (NH_4^+) recovered by combining a MEC with a membrane distillation unit (Trans Membrane ChemiSorption, TMCS) (Figure 1). Microorganisms growing on the anode of the BES convert organic compounds into electricity. The electric current is used to drive NH_4^+ across a membrane to the cathode. There, H_2 and OH^- are produced by water reduction and the ionic NH_4^+ is deprotonated under these alkaline conditions into gaseous ammonia (NH_3). This NH_3 is extracted from the cathode via the TMCS, where it diffuses through a gas permeable membrane into an acid solution. This converts NH_3 back into NH_4^+ and hence a solubilized, ready-to-use resource.

Current research recovers TAN from human urine. Since urine collection is not widely performed, new wastewater streams need to be identified to broaden the applicability of TAN recovery with BES. A literature search for suitable wastewater streams showed several promising wastewaters for TAN recovery. These will be investigated by laboratory screening with small BESs and degradation assays. These wastewaters will also be tested in lab-scale BES reactors to identify suitable operating conditions. Furthermore, limiting factors for bioelectrogenic degradation of organics as well as wastewater toxicity for electrogens will be examined. Additionally, new reactor setups combining recent insights into (bio)electrochemical systems will be assessed and implemented in reactor operating conditions. Resulting insights will be used to design, build and operate an up-scaled BES using the most suitable wastewater stream found in lab-scale experiments. Thereby, TAN will be recovered as valuable resource and the effluent will be cleaned from organic compounds at the same time.

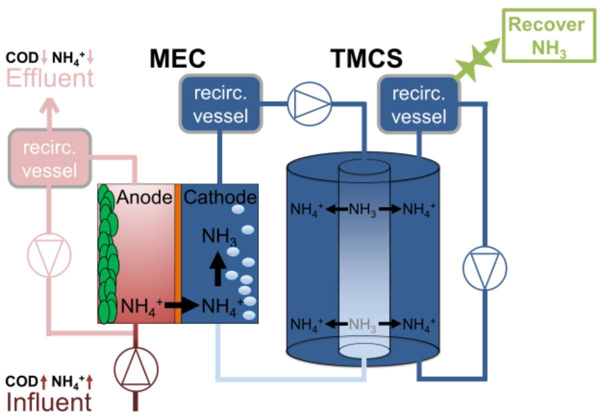

Figure 3: *Removal of high (↑) to low (↓) COD and NH_4^+ from wastewater in a microbial electrolysis cell (MEC) and subsequent recovery of NH_4^+ in a TMCS unit to gain valuable nitrogen resource.*

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Biological removal of H2S in the presence of thiols in the biological desulfurization process

Sub-department of Environmental Technology

Feb 2016 - 2020

Researcher	Supervisor	Promotor
Karine Kiragosyan	Dr. Paweł Roman Dr. ir. Johannes B.M. Klok	Prof. dr. ir. Albert Janssen

Motivation

Removal of sulfur containing compounds from sour gas streams plays a crucial role in environmental protection by decreasing sulfur dioxide emissions into the atmosphere. Among all available desulfurization technologies, biological processes are the most sustainable technologies for hydrogen sulfide removal. Besides H_2S, sour gas streams can contain volatile organic sulfur compounds, such as thiols. Both organic and inorganic sulfur compounds are toxic, characterized with the obnoxious smell and potential corrosive effects [1].

A recent pilot study showed that with the addition of anaerobic bioreactor sulfur selectivity increased and the process did not abrupt with thiols addition. The added anaerobic bioreactor enabled selective pressure for sulfide oxidizing bacteria which are able to oxidize sulfide more efficiently. However, further insight into the underlining processes is required to fully understand work of newly proposed line-up.

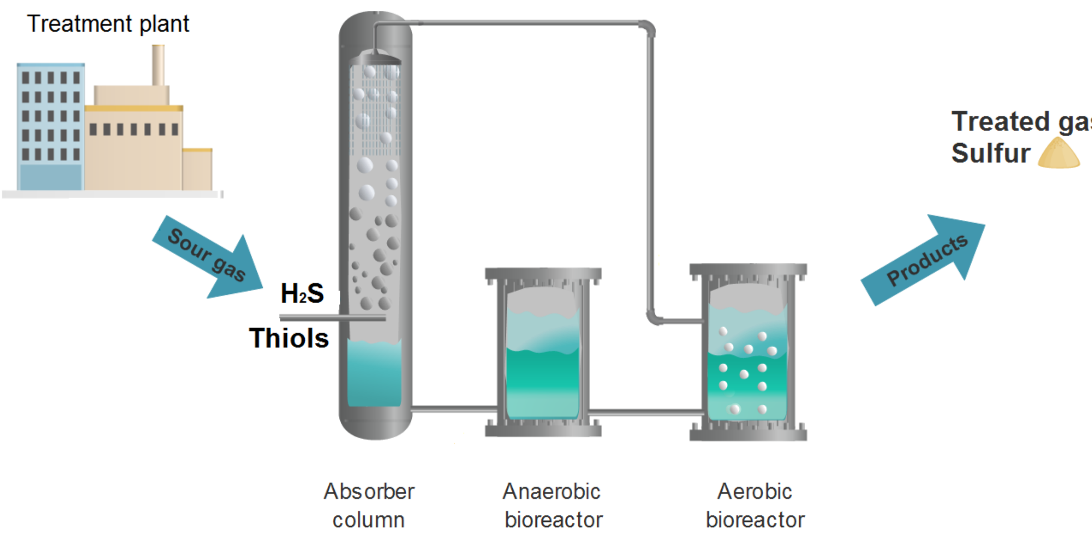
The biotechnological desulfurization process offers:

- H_2S removal and recovery as elemental sulfur
- Operation at atmospheric pressure and ambient temperature
- Environmentally friendly process
- Produced elemental sulfur can be used as a soil fertilizer, fungicide and for sulfuric acid production

Technological challenge

To investigate the newly proposed biodesulfurization line-up and the reactions that are taking place, with the emphasys on the microbial communities composition shifts in the presence of thiols.

With the addition of the anaerobic bioreactor we hypothesize to enhance bacterial growth and eliminate cell death, when high concentration of thiols



Research graphical abstract with a newly proposed line-up for hydrogen sulfide removal in the presence of thiols

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Increasing sustainability of biological gas desulfurization

Sub-department of Environmental Technology

Okt 2016 - 2020

Researcher
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Supervisors
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Promotor
Prof. dr. ir. Cees Buisman

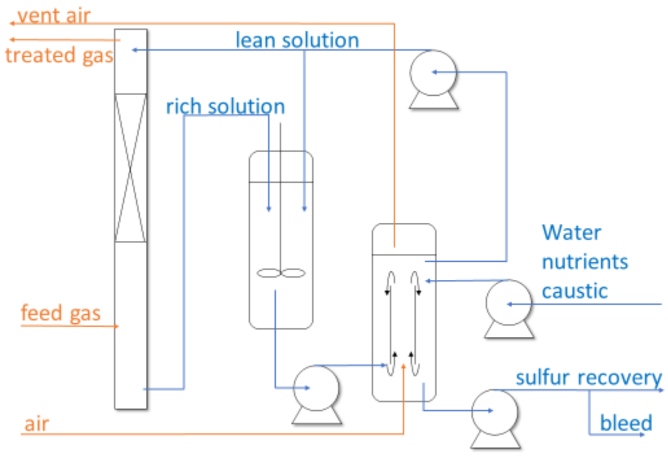
Motivation

H2S 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 H2S from the gas stream and sulfide oxidizing bacteria (SOB) to convert the H2S to elemental sulfur (S^o). 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:

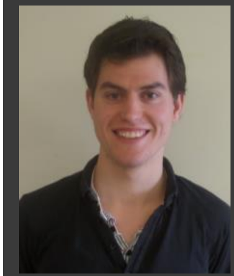
$HS^- + ½\ O_2 + HCO_3^- \rightarrow S^o + H_2O + CO_3^{2-}$

The regenerated solution is recycled to the top of the absorber again. Sulfide can also be oxidized to either sulfate (biologically) or thiosulfate (chemically):

$HS^- + 2O_2 \rightarrow SO_4^{2-} + H^+$

$HS^- + O_2 \rightarrow ½\ S_2O_3^{2-} + ½\ H_2O$

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.



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WAGENINGEN UNIVERSITY & RESEARCH

Sustainable heat production using biological wood oxidation

Sub-department of Environmental Technology

Feb 2017 - 2021

Researcher	Supervisor	Promotor
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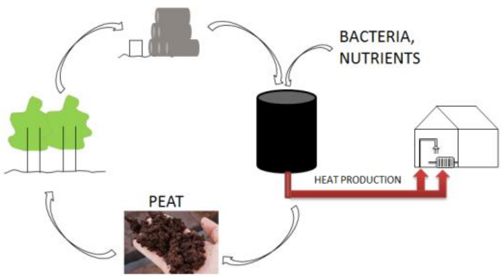
Motivation

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.

$$CH_{1.5}O_{0.7} + 1.03O_2 \rightarrow CO_2 + 0.734H_{2}0 + \text{Heat}$$



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 size. Also other factors, , such as the nutrient supply (i.e. N, P, K), moisture content, temperature and aeration will influence heat production.

Sterile

Non sterile

The main challenges are:

(1) To optimize the temperature, moisture content, aeration strategy, and nutrient supply
(2) To study the interactions between different microorganisms, especially fungi and bacteria
(3) To study the heat production for different types of woods, different wood sizes
(4) To study the suitability of the wood residues as soil improvement
(5) To operate a scale-up reactor for heat recovery from wood

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Controlling Properties of Sulfur Particles Formed in Biological Desulfurization

Sub-department of
Environmental Technology

Aug 2016 - 2020

Researcher	Supervisors	Promotor
Annemerel Mol	Dr. Renata van der Weijden Dr. ir. Jan Klok	Prof. dr. ir. Cees Buisman

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 (Fig. 1). This 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.

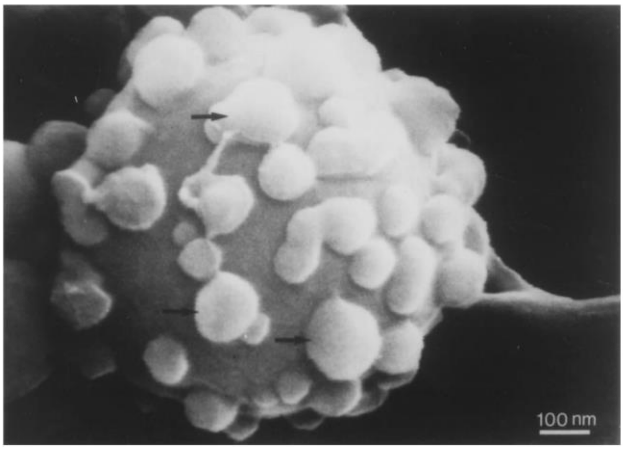

Figure 1 *Thiobacillus* excreting sulfur [Janssen, A. et al. (1996)]

Technological challenge

In the desulfurization 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).

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

$$HS^- + \tfrac{1}{2}O_2 \rightarrow \tfrac{1}{8}S_8^{0} + OH^- \qquad (2)$$

In addition to elemental sulfur, other sulfur compounds are formed as by-product, like sulfuric acid (Eq.3).

$$HS^- + 2O_2 \rightarrow SO_4^{2-} + H^+ \qquad (3)$$

While formation of elemental sulfur is proton-neutral, the formation of other S-products requires compensation of produced protons by addition of NaOH.
Although the optimization of sulfur formation has been studied extensively, specific properties of the formed sulfur, like filterability and settleability, remain subject of interest. Knowledge on how to control particle properties will lead to higher recovery of the biosulfur.

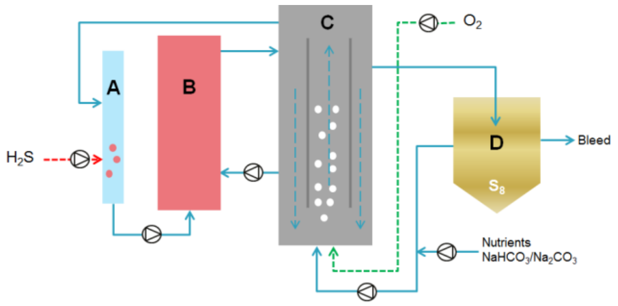

Figure 2 Novel reactor line-up

The optimization of sulfur formation and recovery is aimed for by operating a novel reactor line-up including an anoxic reactor B (Fig 2), which is compared to the classic Thiopaq line-up in terms of (1) sulfur particle properties, (2) microbial composition and (3) long term stability. Also the relation between these parameters is assessed.

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WAGENINGEN UNIVERSITY & RESEARCH

Microbial electrosynthesis: CO_2 to chemicals using biological catalysts

Sub-department of Environmental Technology

Researcher
Dr. Ludovic Jourdin

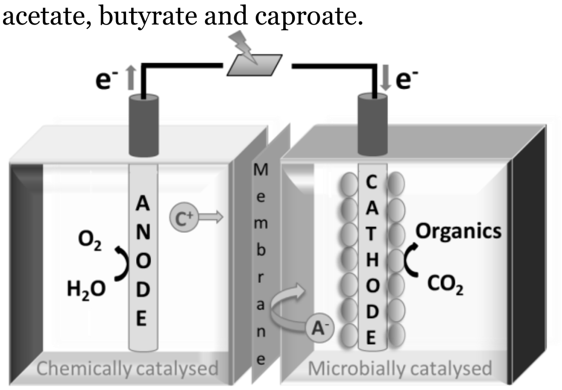
Supvervisors
Dr.ir. David Strik
Prof. dr. ir. Cees Buisman

Motivation

Fossil fuels supply most of the world's energy and raw material sources for chemicals production. However, fossil sources are non-renewable and depleting. Moreover, water scarcity and CO_2 accumulation in the atmosphere represent global concerns. These issues have resulted in the need for chemicals produced from renewable sources, with low water consumption. Recycling and converting CO_2 into chemicals in an environmentally sound way is an attractive prospect. One clean technology is microbial electrosynthesis (MES).

Principle of MES

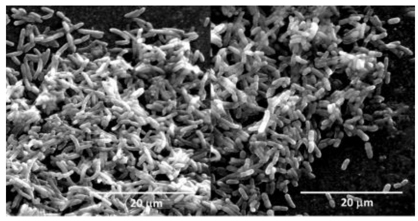
MES is an emerging technology in which naturally occurring microorganisms are used as cheap catalysts. These microorganisms convert (renewable) electrical energy delivered from an electrode (cathode), and CO_2, into chemicals like acetate, butyrate and caproate.



This technology may become a new chemical production technology within a biobased economy, using minimal amount of water.

Research objectives & challenges

Our work on novel electrode modification led to a breakthrough in production rates. Efficient microbial community, which formed adherent biofilms on these electrodes, were enriched.



However, various exciting challenges remains, towards the practical implementation of MES technology:

- Development of cheap(er) electrode material
- Increasing production rates further
- Production of higher value chemicals at high selectivity
- In-line products separation
- Mechanisms understanding at microbial level
- Investigating fundamental mechanisms of electron transfer (electrode-biofilm interface and within the biofilm)
- Feasibility study – Technological & commercial potential of MES
- And more!

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STW Nieuwe technologie mogelijk maken

WAGENINGEN UNIVERSITY & RESEARCH

Extremophilic bioreduction of elemental sulfur for recovery of valuable metals

Sub-department of Environmental Technology

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).

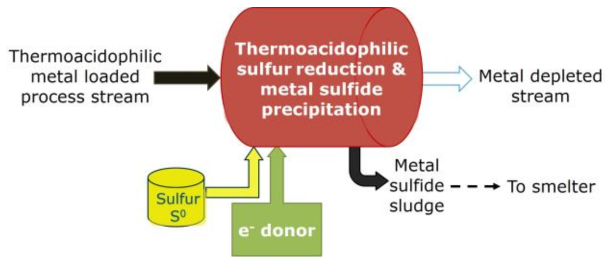
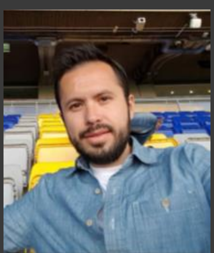


Figure 1. Elemental sulfur reduction process pursued.



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WAGENINGEN UNIVERSITY & RESEARCH

Selenium Bio-recovery (Removal) from Wastewater to Low ppb Levels

Sub-department of Environmental Technology

Nov 2017 - 2021

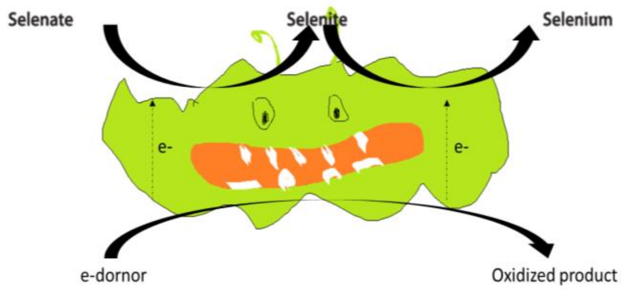
Researcher	Supervisor	Promotor
Bingnan Song	Dr. Renata van der Weijden Dr.ir. Jan Weijma	Prof. dr. ir. Cees Buisman

Motivation

Selenium (Se) is a double-edged sword due to its beneficial effects on living organisms, wide application in high-tech electronics, and toxic risks to the environment even at low concentration. Removal and recovery of Se from wastewater provides a solution for both; Se resource and Se contamination issues.
To achieve this, bio-crystallization is attractive in terms of sustainability, cost and suitability for treating dilute and variable selenium-laden wastewaters. The objective of this project is to find an optimal operation method to remove/recover Se to ultra-low levels from wastewater.

Technological challenge

During the bacterial metabolism process, selenate and selenite can be reduced into elemental selenium as final product.

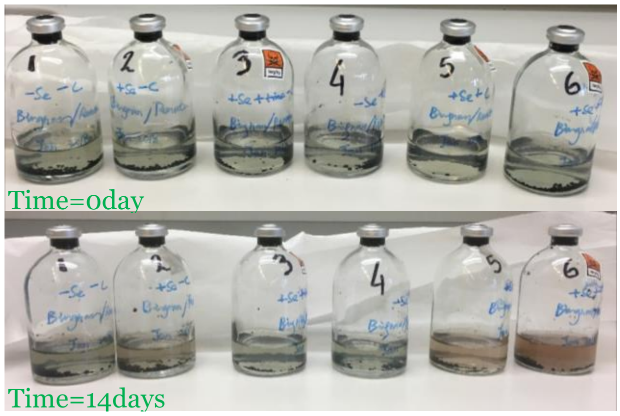


However, the amorphous bio-produced elemental selenium is hard to recover due to the low quantity, small size, unstable structure and attachment with the biomass. Besides, few studies have investigated the removal of Selenium down to ultra-low levels. Per EPA regulations, a maximum of 5μg L⁻¹ of selenium in wastewater can be discharged into the environment due to the harmful effects and bio-accumulation features of Se. Thus, there is an increasing demand for developing a system to remove Se to levels below 5 ppb, recover the Se by crystallization, and have adequate kinetics to be able to treat high volumes of wastewater streams.
Thus, the aims of this project are:

1. To optimize the bio-reduction process of selenate to selenite by maximizing selenite production and decreasing the production of elemental selenium;
2. To select suitable conditions for reducing low levels of Se to ultra-low levels;
3. To deal with low temperature effects on kinetics in a process design;
4. To develop a method to better separate the produced elemental selenium from the biomass and to recycle the bacteria;

$$SeO_4^{2-} \xrightarrow{bio} SeO_3^{2-} \xrightarrow{chemical} SeS_x \xrightarrow{bio} Se$$

Pictures of batch tests for anaerobic selenate reduction process with 2mM selenate as original concentration, t=0days and t=14days:



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Wageningen University & Research

Plant microbial fuel cell: Mechanistic characterization

Sub-department of Environmental Technology

March 2018-2022

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

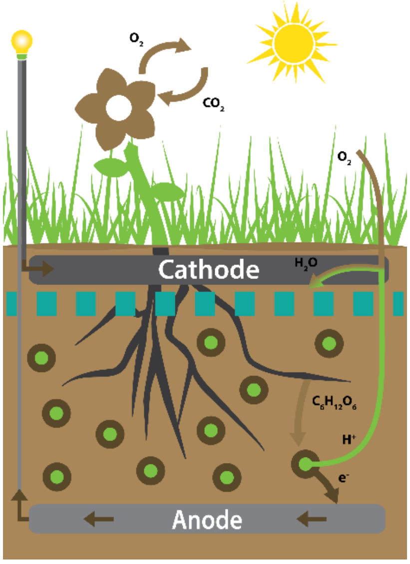
Motivation

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

Plant microbial fuel cells applied in the field

Technological Principle

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



Concept of a plant microbial fuel cell.

Research Challenge

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

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Y

Chain elongation from biomass streams– Production of longer fatty acids

Sub-department of
Environmental Technology

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.

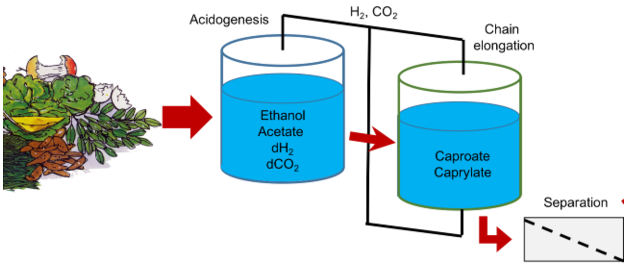

Fig. 1 Envisioned biorefinery

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.

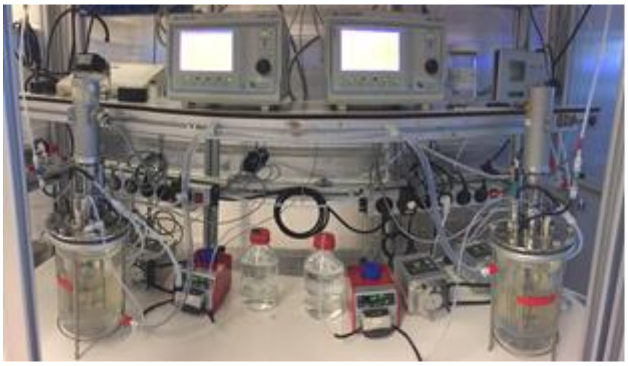

Fig. 2 Chain elongation reactors set-up

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

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

October 2017-2021

Researcher	Supervisor	(Co-)Promotors
Merijn Moerland, MSc	Dr. ir. Miriam van Eekert	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[i], 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.

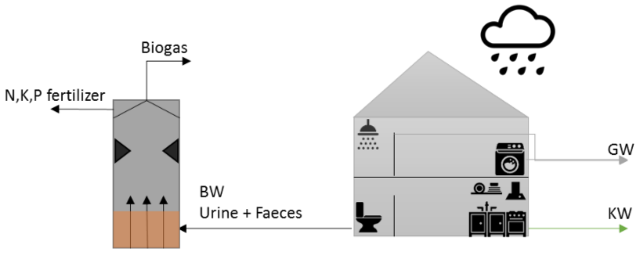

Figure 4 Schematic overview of the concept

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 5 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

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

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Sub-department of
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Urban Systems Engineering and Biorecovery

Closing Global Nutrient Cycles

Reuse Solid Waste, Organics & Plastics

Renewable Energy & Storage

Urban Systems Engineering and Biorecovery

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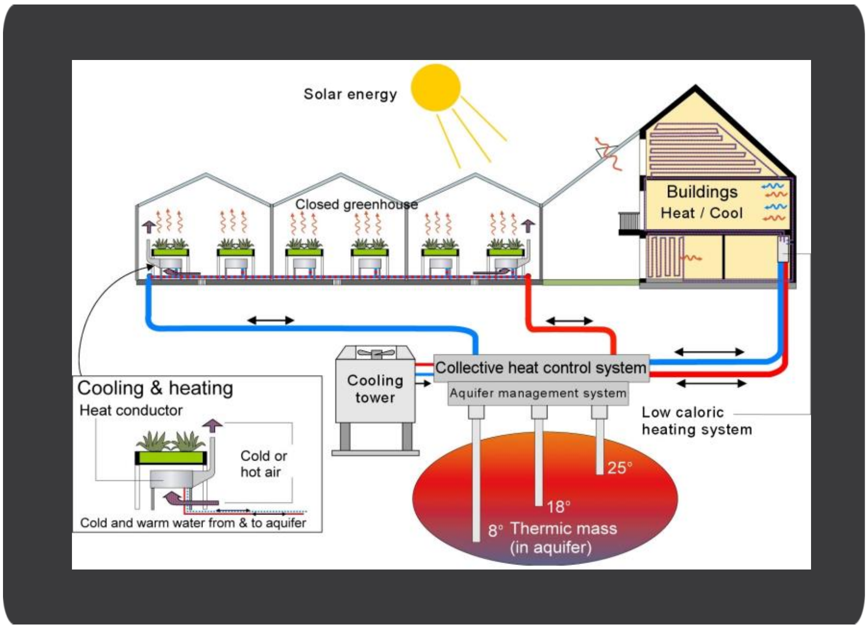

Environmental Issues

The intensity and scale of urbanization worldwide pose major challenges to cities' authorities in providing basic urban services such as water and energy supply, sanitation, and management of solid waste. A growing demand mainly occurring in urban areas for renewable energy, clean water, materials and minerals results in an increasing worldwide recognition that new approaches and paradigm shifts - away from the current linear thinking to manage our resources - are needed. Here, depletion of resources such as fossil fuels and phosphorus demands a rethinking of our urban areas. A further motivation is that we are still unable to provide basic services to everyone. As an 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].

Our Research

The vision of our research is to reduce environmental impact and mitigate resource depletion by closing resource cycles and achieving a circular (urban) metabolism. Our research focuses on development of concepts and integration of technologies for sustainable urban water, materials and energy cycles. We develop and evaluate new concepts for collection, transport, treatment, supply and use of energy, water and materials, which we consider as valuable resources and which qualities have to be preserved. Furthermore, we select appropriate technologies for these concepts in accordance with the local circumstances, needs and habits. Our research includes (peri-) urban areas and industrial sites, for which we aim at an optimal, sustainable and highly effective balance between supply and demand of water, energy and resources. Here, we include the effect of different urban typologies and urban agriculture on the resource cycles. 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, so as to facilitate recovery and reuse of water and other resources such as energy, nutrients and compost.

Our Approach

Cities and their challenges are addressed in accordance with the principle of cyclic, rather than linear, thinking and analysis. The focus is on Bio recovery integration in Reuse of Solid Waste, in creating feedbacks of urban nutrients and organics to agriculture (Fertilizers & Organic Reuse in Agriculture) and integration of sustainable energy technologies in Cities (Renewable Energy). Furthermore, concepts are developed in cooperation with stakeholders on a practically relevant scale. In our research, the non-technological, socio-economic contexts, in which we want to integrate our concepts, receive due attention. Due to the broader transdisciplinary approach of our research, cooperation with other WUR departments takes place in various research projects.

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

Renewable Energy

Dr. ir. Annemiek ter Heijne
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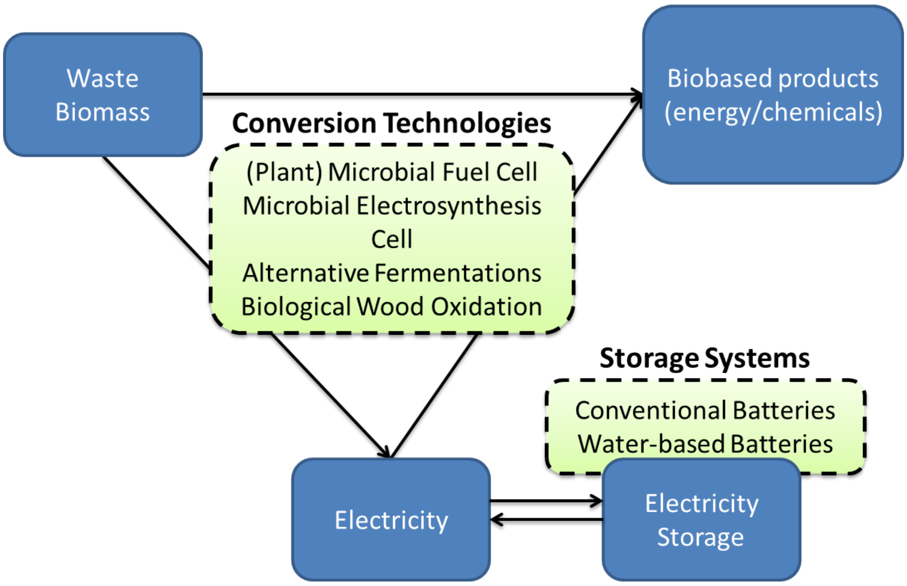

Motivation

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

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

Challenge

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

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Inorganic solid waste & modeling. Nanoparticles.

Dr. Renata D. van der Weijden

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

Sub-department of
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Motivation

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

Research aims and challenges

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

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

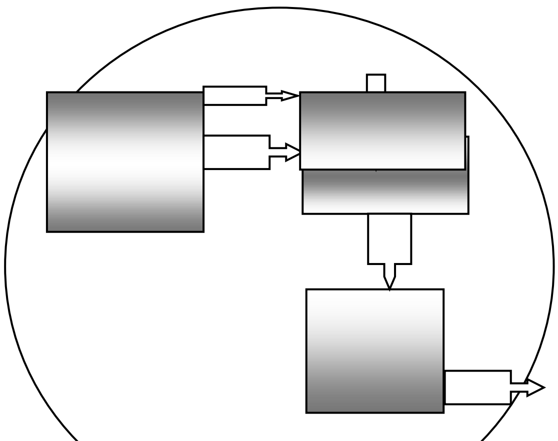

Figure: Open Resource Cycle

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Nutrient cycling pyramid

Sub-department of
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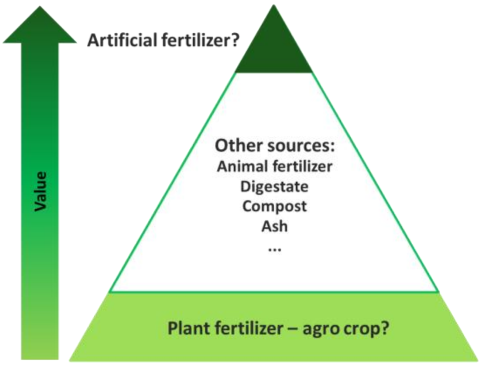
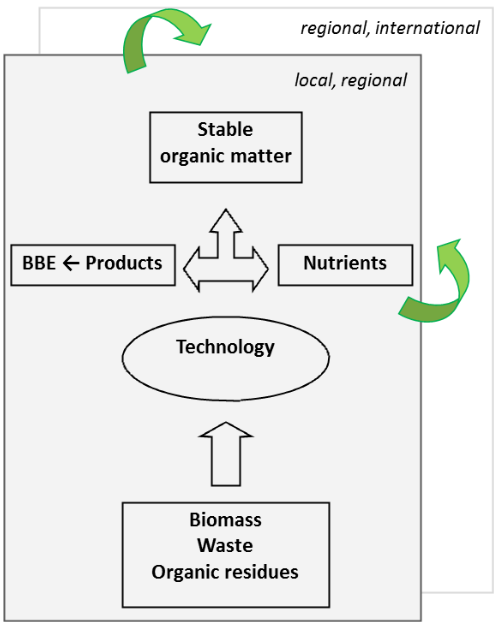


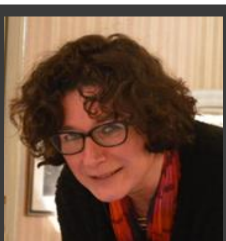
Motivation

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.



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WAGENINGEN
UNIVERSITY & RESEARCH

Recycling of organic matter: sense and nonsense

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

Prof. dr. ir. Cees Buisman

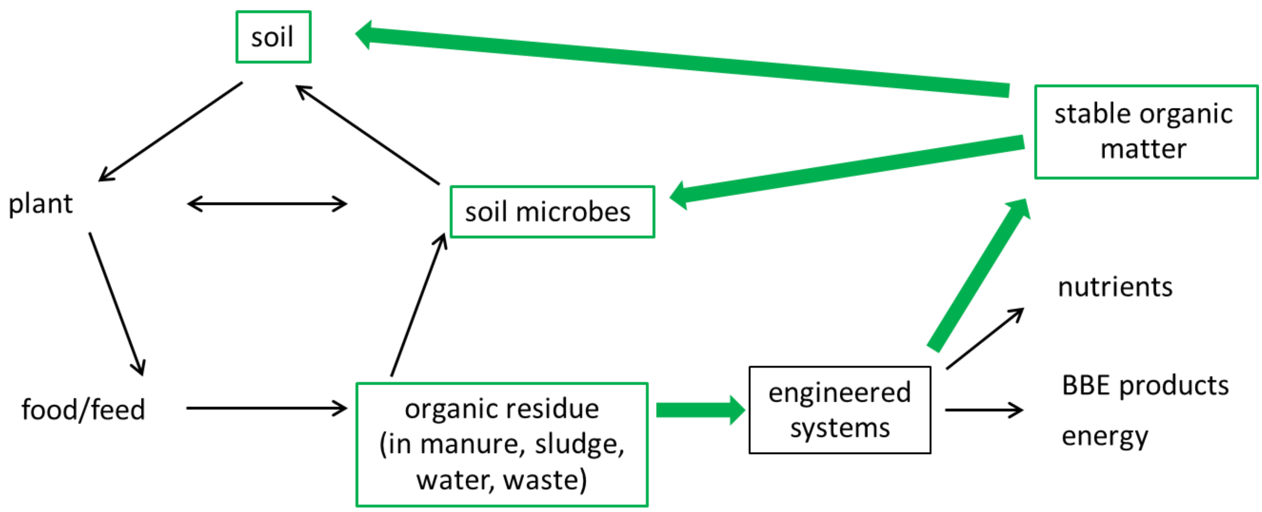
Sub-department of Environmental Technology

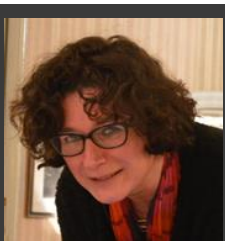
Motivation

The world population is growing and this poses an increasing challenge with respect to food production and the environment. Depletion of organic matter (OM) in (agricultural) soils is an (internationally) occurring problem and there is also an increasing demand for nutrients to match the demand in agriculture. Compost is a commonly applied source of OM (and to a lesser extent nutrients) to replenish the existing shortage. Digestate of anaerobic treatment, sewage sludge, black water and other organic waste streams could also serve as potential sources to replenish the organic matter in soil. These sources as such are often not suitable for application or not allowed because of e.g. insufficient stability of the organic matter, and/or presence of e.g. heavy metals or pathogens. There is 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. Also, organic carbon is often one of the products in these processes but the produced C may not always be applicable for further use on soils. Amongst others the amount of effective organic matter (EOM, i.e. the amount of OM remaining after 1 year after application) will be of importance.

Research challenge

The variety of waste streams used as input, technologies applied and nutrients (C, N,P,K, others) produced make a difficult comparative assessment for the applicability of the products and their effect on the microbial population in soils and the different ecosystem services that soil could provide. Therefore, we plan to construct a database that couples the origin of OM via the technology applied to the characteristics of the OM product (EOM content, physicochemical quality, effect on microbial population, micronutrients, ...) on which management strategies for recycling of organic matter at different scales can be based.





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Micronutrients: recycling to sustain life on Earth and Mars?

Sub-department of Environmental Technology

Dr. ir. Miriam van Eekert
Dr. ir. Jan Weijma

Prof. dr. ir. Cees Buisman

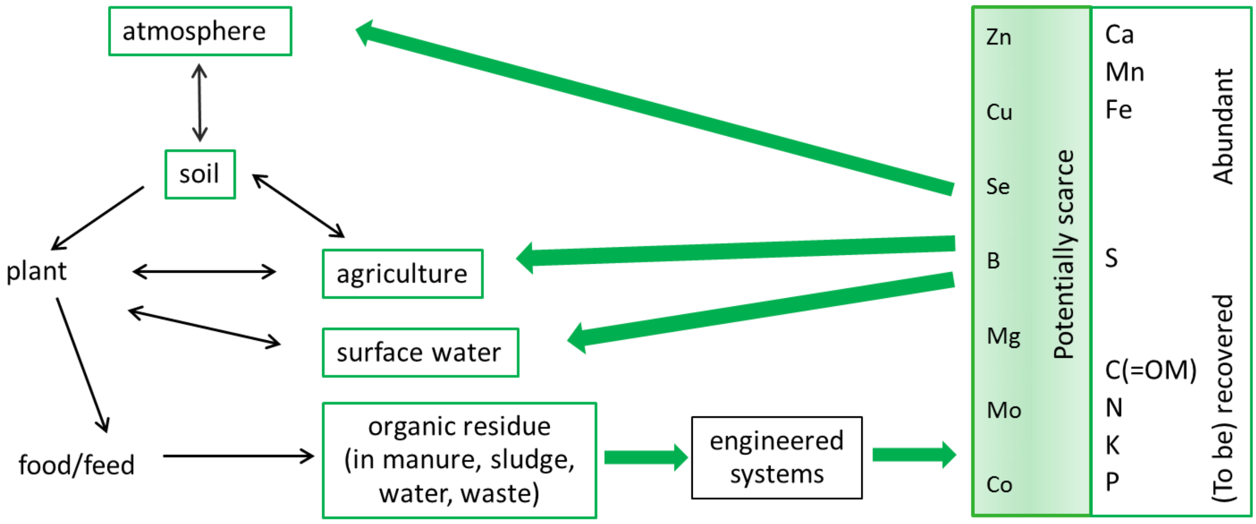
Motivation

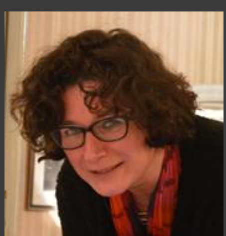
Nutrient cycles need to be closed in view of the circular economy, food security for all humans, and with the prospect of humans going to Mars. For this, management strategies are to be developed.

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.





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WAGENINGEN UNIVERSITY & RESEARCH

Sub-department of
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AgriSan-Increasing Urban Self-Sufficiency by Integrating Urban Agriculture and New Sanitation

Apr 2015 - 2019

Researcher	Supervisor	(Co-)Promotors
Rosanne Wielemaker	Dr. ir. Jan Weijma	Prof. dr. ir. Grietje Zeeman Dr. ir. Jan Weijma Prof. dr. Ir. Oene Oenema

Motivation

More than half of the world's population currently resides in cities, contributing to a host of environmental problems. High quality inputs, such as food and drinking water, enter the city, and low quality outputs, such as diluted wastewater, exit the city without consideration for reuse and recycling (**Figure 1**).

A paradigm shift is needed to a circular metabolism, in which waste from one process equals food for another (**Figure 2**). Coupling Urban Agriculture (UA) and New Sanitation (NS), presents an opportunity for resource exchange for mutual benefit.

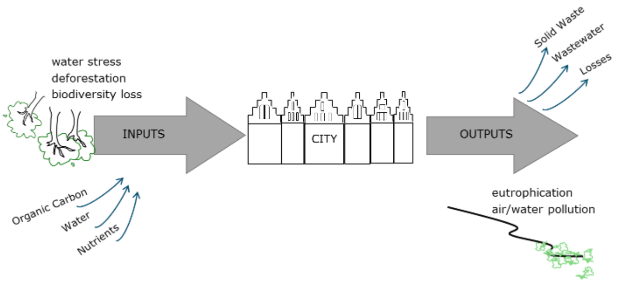

Figure 1: Linear metabolism, nutrient and water flows

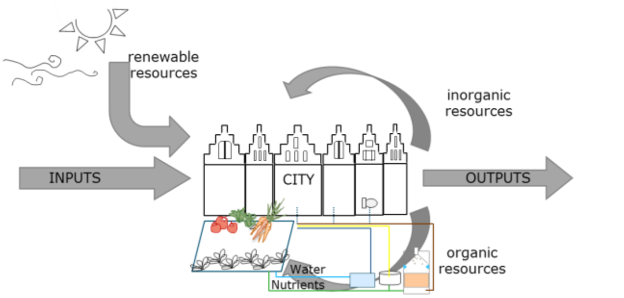

Figure 2: Circular metabolism, nutrient and water flows through integrated urban agriculture and new sanitation

Technological/Methodological challenge

The compatibility of nutrient flows between UA and NS is unknown, in terms of quantity and quality (parameters for human and environmental hygiene). In addition, no methodological tool currently exists to match their input-output flows and establish a "common language" between the two systems, which explores opportunities, constraints and trade-offs.

Objective

To understand the compatibility of the nutrient flows between UA and NS to increase urban resource management

- Quantify and qualify input-output flows and identify relevant temporal and spatial patterns
- Develop suitable criteria for compatibility and matchmaking
- Develop and test a simulation model that matches input-output flows under context-specific conditions
- Validate the developed framework

This research aims to provide clear recommendations on where and to what extent urban agriculture and new sanitation can create fruitful synergies and local solutions.

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

Sub-department of Environmental Technology

Sept 2017 - 2021

Bernou Zoë van der Wiel

Prof. dr. Florian Wichern
Dr. ir. Jan Weijma

Prof. dr. ir. Cees Buisman
Dr. ir. Corina van Middelaar

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

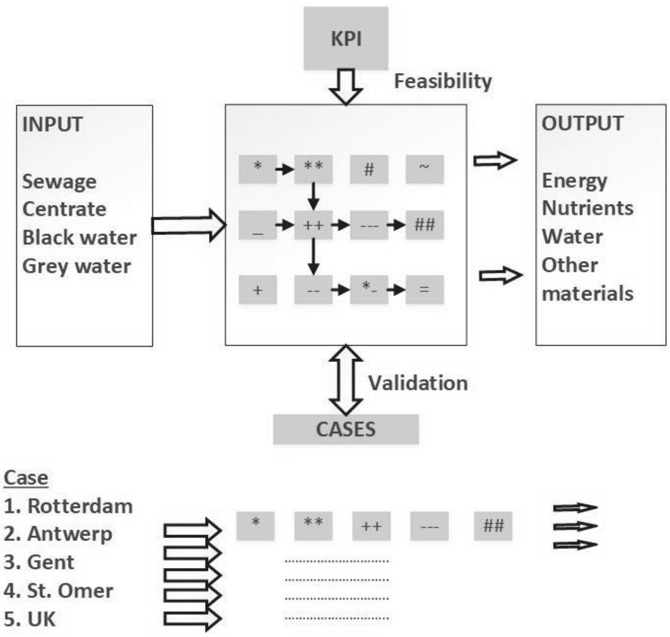
Large varieties in quality and quantity of wastewater, environmental impact, due to the consumption of energy and chemicals, are challenging the decision makers when choosing the suitable technologies in different locations. Moreover social aspects such as acceptance of final products in the market should 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.

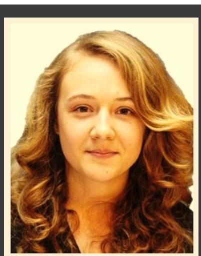
Method

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.





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Sub-department of Environmental Technology

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

Sept 2017 - 2021

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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.

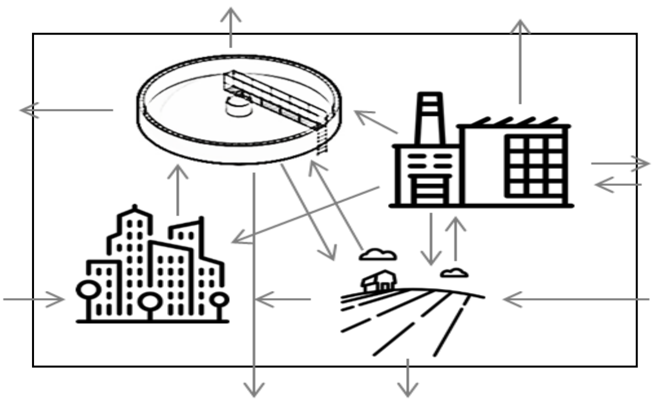
Restoring circularity from a regional perspective

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.



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

October 2017-2021

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Supervisor
Dr. ir. Miriam van Eekert

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Sub-department of Environmental Technology

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[i], 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.

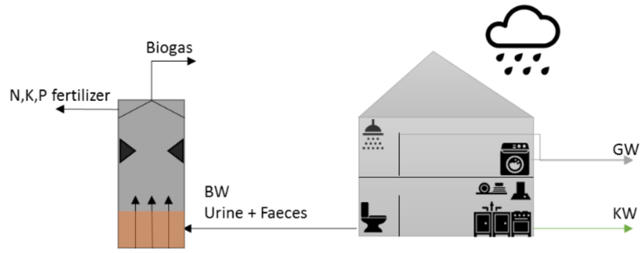

Figure 1 Schematic overview of the concept

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

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

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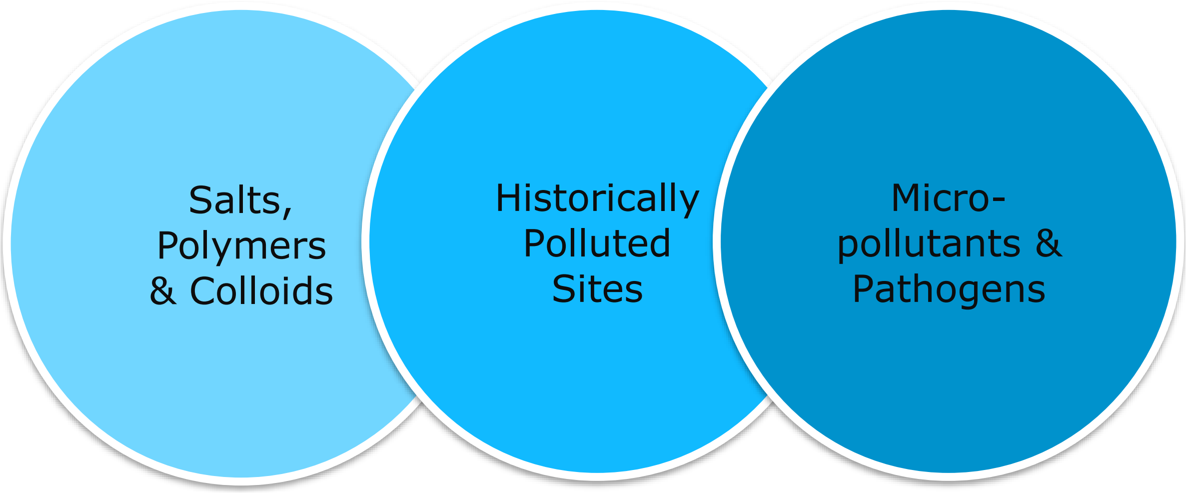
Reusable Water

Sub-department of
Environmental Technology

Reusable Water



Reusable Water

Sub-department of
Environmental Technology

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.

Historically polluted sites

Historical groundwater, soil and sediment pollution is in Western Europe still present at larger and complex urban and industrial pollution situations. For these 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.

Salts, Polymers and Colloids

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 team.

Reusable Water

Sub-department of Environmental Technology

Microbial Natural Attenuation of Micropollutants in the Water Cycle

Dec 2013 - 2015

Researcher	Collaborators	Collaborators
Nora Sutton	Dr. ir. Alette Langenhoff Prof. dr. ir. Huub Rijnaarts	Prof. dr. Hauke Smidt (microbiology)

Motivation

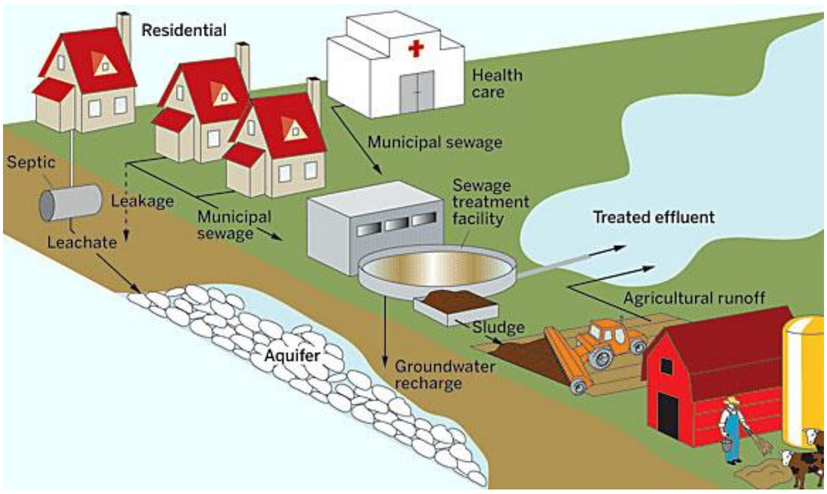
The increasing presence of organic micropollutants in different segments of the water cycle threatens future water resources. These micropollutants are currently being detected at low concentrations in groundwater and surface water used for drinking water intake. While current monitoring (chemical analyses)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

Technological challenge

This research project aims to improve the understanding of 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.

Method

The project will focus on a number of micropollutants that specifically threaten Dutch drinking water quality. Collaboration with drinking water companies will lead to a list of priority compounds for further research. For these compounds, biomolecular tools based on DNA analysis will be setup to assess the natural attenuation capacity in field samples. Additionally, ex situ degradation experiments using field samples as inoculum will be used to estimate degradation rates. Results will be integrated to form guidelines for the prediction of natural attenuation using molecular tools.



Sources, transport, and fate of micropollutants in the environment (EPA).

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WAGENINGEN UNIVERSITY & RESEARCH

Photo-catalysis in a fluidized UV-LED bed

Jan 2015 - 2019

Researcher	Supervisor	Promotor
Yin Ye	Dr. ir. Harry Bruning Dr. ir. Doekle Yntema	Prof. dr. ir. Huub Rijnaarts

Sub-department of Environmental Technology

Motivation

The presence of micropollutants, such as pharmaceuticals and pesticides, in water threaten the safety of water supply. Conventional waste water treatment processes have a low efficacy on micro-pollutants removal. So there is a need for effective removal processes to treat micropollutants containing wastewater. The fluidized LED bed reactor is a new technology, with dispersed LEDs moving freely and wirelessly powered in the photo-reactor, that might be a cost effective process to degrade micro-pollutants.

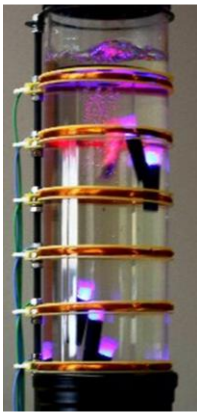
Technological challenge

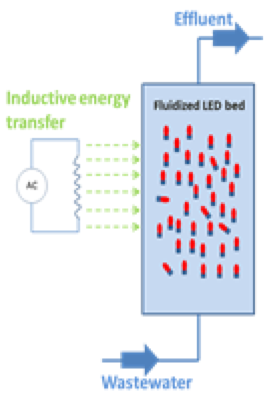
Regarding real-life application of the existing fluidized LED bed reactor, there are some main challenges:

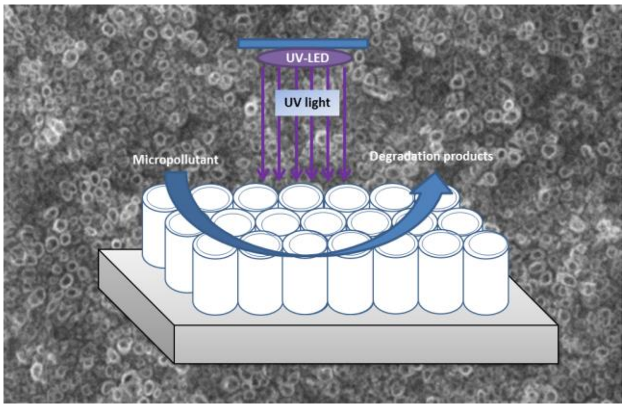
- Energy consumption
  - UV-LED energetic efficiency is relatively low
  - Overdose of UV when light emissions of LEDs overlap =energy loss
- Use of TiO_2 suspension as photo-catalyst
  - Costly solid/liquid separation process is required
  - Instability of suspended catalyst particles
- Reduced efficiency in real wastewater effluent
  - Dissolved organic matters (DOM) in real wastewater scavenge radicals and absorb UV light

In view of the challenges, this project aims at further improving the fluidized LED bed reactor. The project consists of three main topics:

- Alternative photo-chemical route based on methylene blue (MB) photo sensitization
- Use of TiO_2 nanotube arrays as immobilized catalyst
- Application in real waste water







❖ This study is carried out at Wetsus

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wetsus european centre of excellence for sustainable water technology

WAGENINGEN UNIVERSITY & RESEARCH

An integrated approach to micropollutants: Occurrence, fate and measures for removal

2015 - 2018

Researcher	Supervisor	Promotor
Andrea F. Brunsch	Dr. ir. Thomas ter Laak	Prof. dr. ir. Huub Rijnaarts

Sub-department of Environmental Technology

Motivation

Organic micropollutants are currently in the focus of those engaged in water research and management.

Small river systems in densely populated areas are particularly at risk. High wastewater loads and highly variable input patterns can exert considerable pressure on aquatic ecosystems.

Additional treatment methods at input pathways are required to reduce micropollutant loads in watercourses. Given the aim of finding the right measures to reduce micropollutants in watercourses the establishment of an emission and immission balancing is a precondition.

Retention soil filters (RSF) as a treatment technique is both low-cost and low in energy demand. Reduction capacities for individual organic micropollutants and especially the underlying physicochemical processes within the aerated soil filters have barely been studied up to now.

To reduce micropollutant emissions from wastewater treatment plants, an additional treatment step is tested. A pilot-scale retention soil filter is set up at a wastewater treatment plant in the research catchment. Three reactors filled with different filtration material are fed with effluent from the treatment plant. Elimination rates and processes within the filter are investigated.

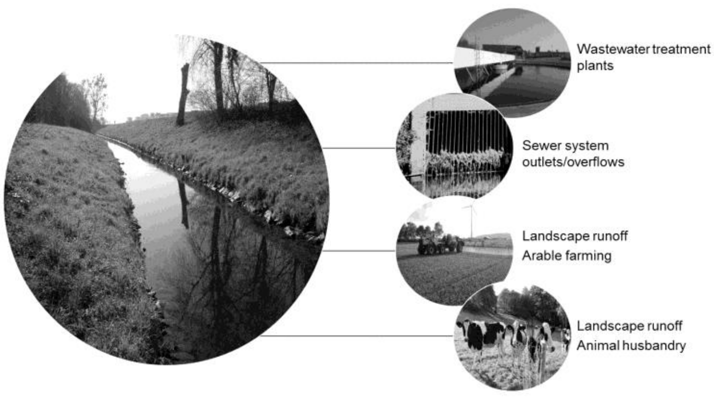
The fate of the micropollutants in the watercourse is to be simulated with the DWA water quality model. Future scenarios including the possible implementation of large scale RSF at wastewater treatment plant outlets will be simulated as well.

The challenge is to establish a detailed assessment on micropollutants with the example of a small catchment area with high anthropogenic influence.

Technological challenge

A special monitoring strategy is implemented at a small catchment area with a size of 289 km². Within this catchment area both point and non-point pollution sources are monitored. Focus of the investigations are hydrophilic and hydrophobic micropollutants. Monitoring is performed with different monitoring intervals (event specific, episode specific, frequently) and with different monitoring techniques (grab sampling, passive sampling, and automatic sampling). Fluctuation ranges in micropollutant emissions are to be determined. Furthermore, an emission balancing will be generated.

Pressure on small river systems



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WAGENINGEN UNIVERSITY & RESEARCH

Antibiotic-resistant bacteria and their genes in wastewater

Apr 2015 - 2019

Researcher	Supervisor	Promotor
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Motivation

Antibiotics have been used excessively for humans and livestock worldwide since the first clinical use of penicillin. This leads to an emergence of antibiotic resistance bacteria (ARB) and antibiotic resistance genes (ARG) in the environment. Antibiotic resistance develops faster than new antibiotics are being developed, as
developping new antibiotics is becoming increasingly challenging and costly.
The increasing threat of ARB&G from year to year requires further screening, monitoring and improved treatment technologies to remove ARB&G.

Technological challenge

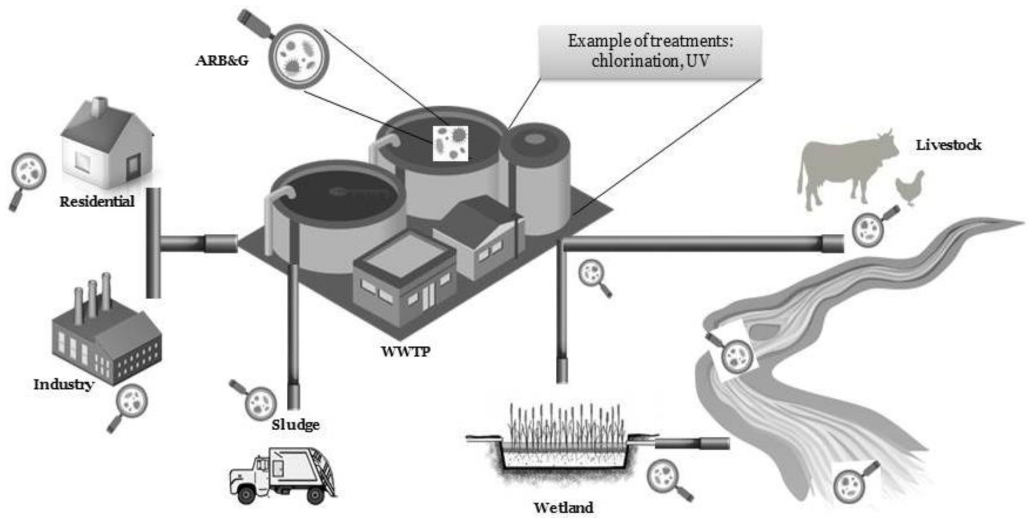
The technological challenge is to further investigate the dissemination of ARB&G from WWTPs and wetlands to catchments, the effectiveness of existing WWTPs and wetlands in removing ARB&G, as well as to develop new methods for removing ARB&G.

This research is divided into three parts:

The first part focuses on screening and monitoring of ARB&G in selected catchments, WWTPs and wetlands. This is important to get an overview of the prevalence of ARB&G in the Netherlands and to observe the effectiveness of present WWTPs and wetlands in removing ARB&G. Methods include sampling at different geographical locations, selection and measurements of antibiotics, ARB&G, and water quality and nutrient contents in water and sediment of the systems.

The second part of the research is to determine the specific resistance genes of ARB&G. This is to ensure that the bacterial isolates harbour a variety of ARB&G. The distribution of ARB&G will be determined by qPCR.

The last part of the research is to develop a new method to remove ARB&G. This can be a new technology or a combination of existing technologies.



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Reusable Water

Sub-department of Environmental Technology

Constructed wetlands for the removal of additives from saline industrial waste water

Oct 2015 - 2019

Researcher	Supervisor	Promotor
Thomas Wagner	Dr. Alette Langenhoff Dr. John Parsons	Prof. dr. ir. Huub Rijnaarts Prof. dr. Pim de Voogt

Motivation

This PhD-research is embedded in the NWO-STW Water Nexus research program. Water Nexus aims to find innovative technical solutions for problems with fresh water scarcity in delta areas. A partial solution is to lower the industrial fresh water footprint. This can be achieved by reusing industrial waste water streams for industrial or agricultural purposes. Challenges for the reuse of this water are the salinity and the presence of industrial additives.

Green infrastructure as constructed wetlands (CWs) have shown to be able to remove harmful components from waste water streams prior to reuse. Within this PhD-research, the optimal CW systems design for the removal of industrial additives from saline industrial waste water will be studied.

Various contaminant removal mechanisms as biodegradation, photodegradation, plant uptake and adsorption occur in CWs simultaneously. The dominating removal mechanism in a CW is determined by the CW design (Fig. 1). Different pilot scale CWs are available outside our laboratories (Fig. 2). In this research, I will start with lab scale removal tests, followed by designing the optimal CW configuration in the outside CWs.

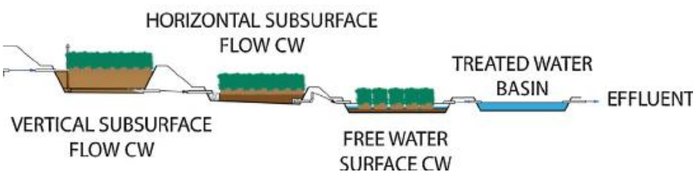
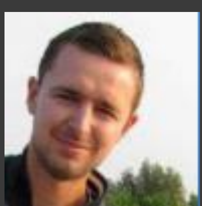


Figure 1. Hybrid CW (Avila et al., 2015)

Figure 2. Pilot scale CW facilities

My future experiments

- Perform various lab scale tests to determine the removal processes for a set of industrial additives
  - Biodegradation
  - Photodegradation
  - Adsorption
- Scale up lab scale tests to bench scale (aquarium) constructed wetland systems.
- Implement obtained knowledge on removal processes into pilot scale constructed wetland configurations (outside, next to the ETE laboratory (Fig. 2)



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WATER NEXUS

WAGENINGEN UNIVERSITY & RESEARCH

Recovery of valuable polymeric solutions by lowering the salinity using electrodialysis

Sub-department of Environmental Technology

Mar 2016 - 2020

Researcher	Supervisor	Promotor
MSc. Paulina Sosa	Dr. ir. J. Post Dr. ir. H. Bruning	Prof. dr. ir. H. Rijnaarts Prof. dr. ir. J. v. d. Gucht

Motivation

Desalination technologies that extract water seem prohibited when polymers and/or surfactants are present. Electrodialysis (ED), a technology that extract salts from the treated solution, is often proposed as a cost effective method to desalinate organic-rich waste streams. An promising application of ED is the treatment of produced water from enhanced oil recovery (EOR) (Figure 1).

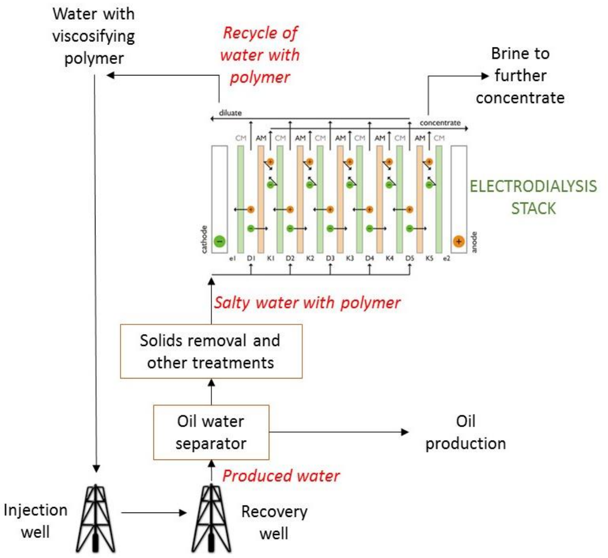


Fig.1 Electrodialysis application in the EOR process

EOR produced water still contains the viscosifying polymer, usually anionic polyacrylamide (APAM), but also a high amount of salts, solids and oil, which limit its reuse. Even after removing the oil and solids, the high salt content makes the mixture unsuitable for reinjection. This is because the salts interact with the polymer and change its morphology, consequently lowering the solution's viscosity. Therefore, the use of ED to reduce the salinity of the stream would help to restore the properties of the APAM molecules, increasing the viscosity and reducing the consumption of fresh polymer.

Similar combinations of water, salts and charged organic compounds can be found in the dairy industry (organics being mainly fats and proteins) and in the drinking water production, among others. Thus, the study of the desalination of solutions containing diverse organic material will yield results of interest for many applications.

Technological challenge

The main challenge of this research is the to understand the membrane fouling mechanism in the electrodialysis process, especially the one due to anionic polymers, and to control it (Figure 2). This will contribute to water reuse and minimization of water discharge in the oil and the water treatment industries, as well as to the improvement of processes in the dairy industry.

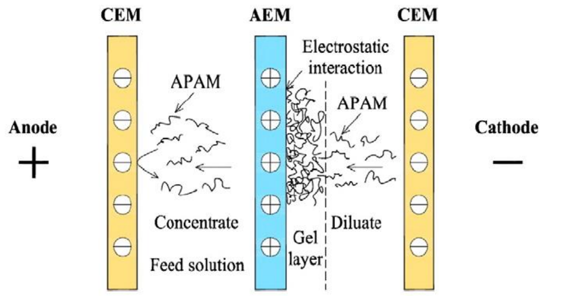
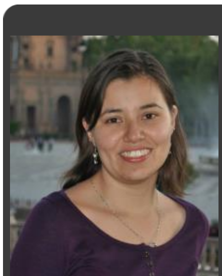


Fig.2 Proposed fouling mechanism of AEM by APAM
(Taken from Guo et al. (2014). Desalination 346(0): 46-53.)



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WAGENINGEN UNIVERSITY & RESEARCH

Biological flocculants from and for saline (waste) water

March 2016 - 2020

Researcher	Supervisor	Promotor
Victor O. Ajao	Dr. ir. Hardy Temmink Dr. ir. Harry Bruning	Prof. dr. ir. Huub Rijnaarts

Sub-department of Environmental Technology

Motivation

Large amounts of saline wastewater are generated by industries such as food, petrochemical and tannery. This has adverse effects on aquatic life, water potability and agriculture when discharged into the environment untreated. Currently, wastewater particle removal is widely achieved with the use of inorganic coagulants or/and oil-based organic polymeric flocculants. Both have non-negligible drawbacks: the former leaves residual metal particles in treated water and the latter leads to formation of toxic degradation products/monomer residues. Hence, the use of synthetic coagulants/flocculants can hardly be considered a sustainable wastewater treatment approach.

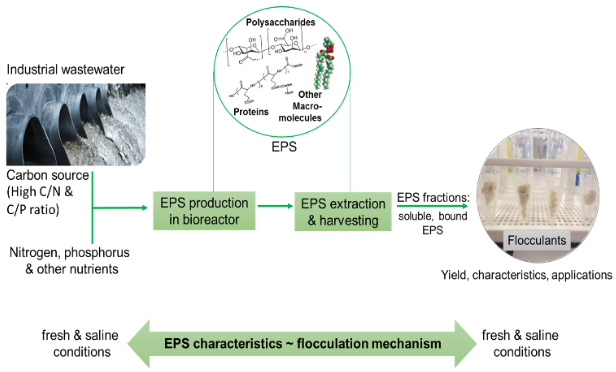
Technological challenge

Microorganisms responsible for the biological degradation of organic pollutants in (waste) water excrete biopolymers, generally referred to as extracellular polymeric substances (EPS). These EPS provide attractive and non-toxic flocculating properties.

More often than not, single-type EPS (usually polysaccharides) are obtained by the enrichment of isolated microbial strain. Although this strategy yields biodegradable polymers, the disadvantage is that pure cultures need to be fed with expensive and unsustainable carbon sources as well as valuable nutrients.

Our approach is to utilise a mixed microbial population used in wastewater treatment to concurrently produce EPS as flocculants. Hence, the advantage of combining biological removal of organic pollutants with the production of natural flocculants in a single process.

The technological challenge is therefore to develop strategies on how (saline) industrial wastewater treatment can be combined with maximum EPS production, and further studies on the biopolymer characterization and flocculation mechanisms.



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WAGENINGEN UNIVERSITY & RESEARCH

Anaerobic Granular Sludge Formation Under Saline Conditions

Oct 2015 - 2019

Researcher	Supervisor	Promotor
Dainis Sudmalis	Dr. ir. Hardy Temmink	Prof. dr. ir. Grietje Zeeman Prof. dr. ir. Huub Rijnaarts

Sub-department of Environmental Technology

Motivation

Disposal of untreated wastewater streams into receiving water bodies without prior treatment can cause detrimental effects, such as eutrophication, toxicity to aquaculture and decrease in oxygen levels. Around 5% of (waste)water generated globally is saline or highly saline.

Anaerobic biological treatment of saline wastewater streams has been reported to be a cost-effective and environmentally friendly alternative compared to physical and chemical treatment, because anaerobic wastewater treatment allows to combine removal of organic matter with recovery of energy in the form of biogas.

Technological challenge

Microorganisms in conventional treatment are unable to efficiently function under high (fluctuating) salt stress conditions as they occur in the effluent streams. This forces industries to dilute their wastewater with freshwater, herewith increasing global water stress.

The most widely applied anaerobic (waste)water treatment system to remove dissolved organic matter and produce biogas is upflow anaerobic sludge blanket (UASB). A core to successful functioning of compact anaerobic bioreactors is formation of bio-aggregates (granules), because granular sludge allows for the capacity of treatment systems to deal with high organic loading rates (decouple hydraulic and sludge retention times).

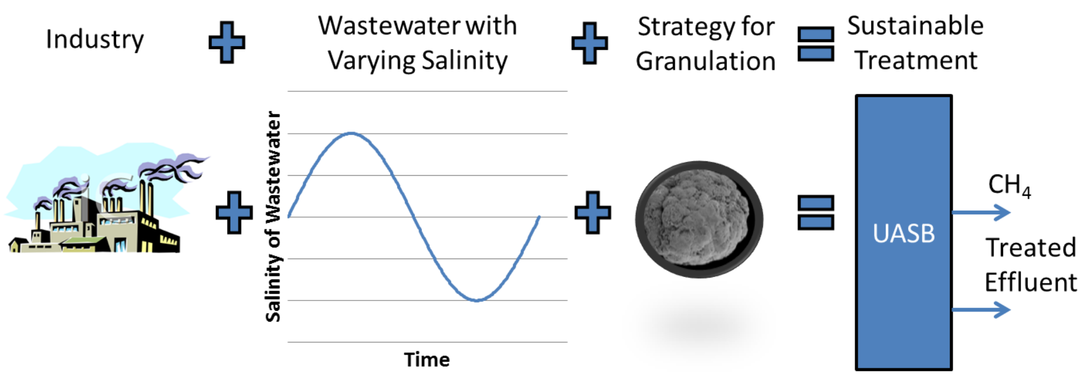
Saline wastewaters inhibit the process due to loss of microbial activity, cell lysis and disintegration of microbial granules.

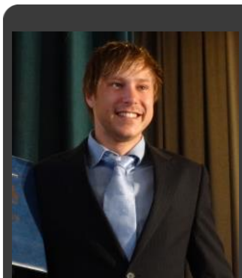
Even though several microbial strategies to deal with osmotic stress (uptake of potassium, uptake/production of osmolites) as well as conditions for successful granulation under non-saline conditions have been reported, there is no research focusing on mechanisms of granules formation under saline conditions.

Therefore the two technological challenges of this project are:

1) Development of strategies for anaerobic granular sludge formation under saline conditions;

2) Development of strategies for reactors operation under fluctuating salinity conditions





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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.

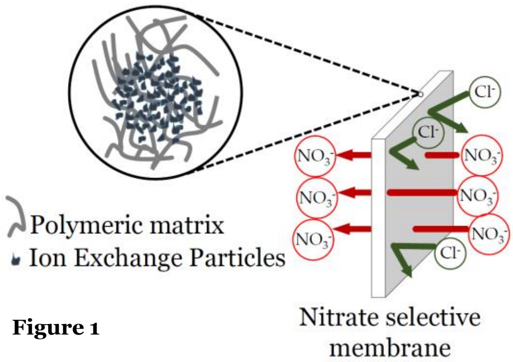

Figure 1

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.

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.

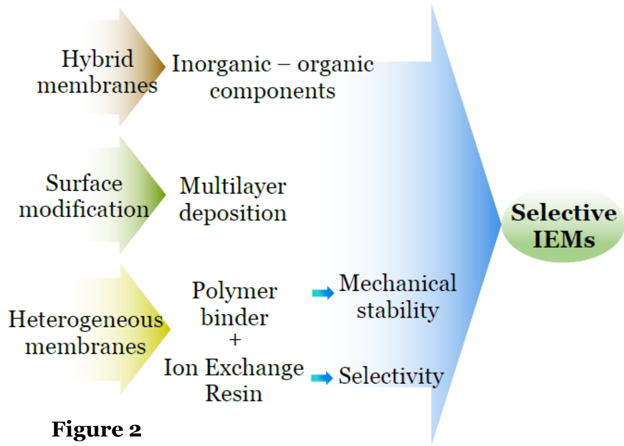

Figure 2

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Biodegradation of micropollutants in groundwater systems

Sub-department of Environmental Technology

Apr 2017 - 2021

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

Motivation

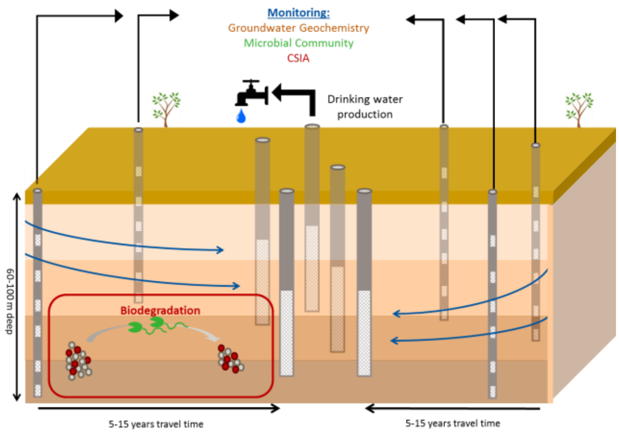
The increasing presence of organic micropollutants in different segments of the water cycle threatens future water resources. These micropollutants are currently being detected at low concentrations in groundwater and surface water used for drinking water intake. While current monitoring (chemical analyses) 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.



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WAGENINGEN UNIVERSITY & RESEARCH

Technology integration for removal of organic pollutants from saline water

Sub-department of Environmental Technology

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 the EO process.

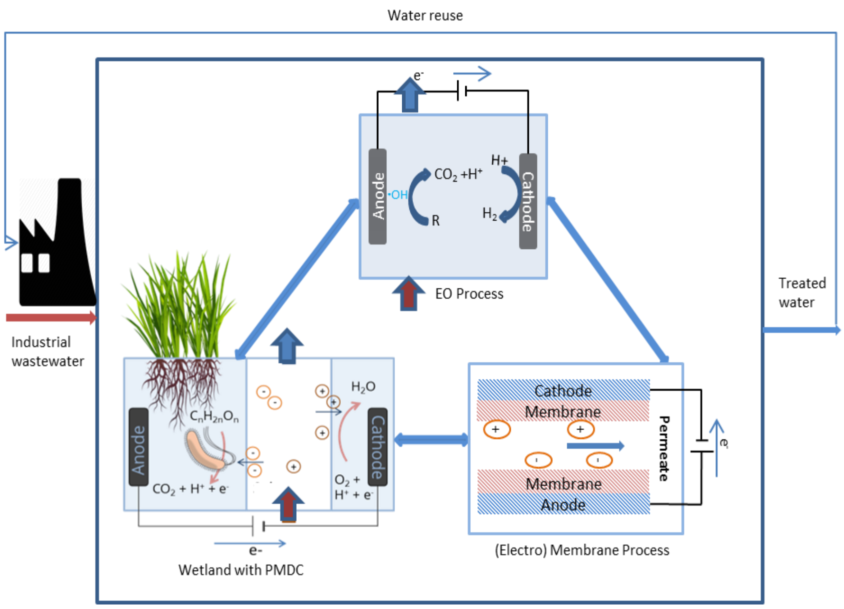

Figure: Approach for technology integration for wastewater treatment

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Sub-department of Environmental Technology

Adsorption and biodegradation of organic micropollutants in activated carbon filters

Jun 2016 - 2020

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. 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 develop a technology to remove organic micropollutants from drinking water by using the synergistic effects of adsorption to activated carbon combined with biodegradation, promoting the so called bioregeneration of AC.

Technological challenge

- Hydrophobic compounds adsorb to AC to a larger extent than hydrophilic compounds. Therefore, the latter are still present in drinking water after treatment. Conditions to promote **adsorption of hydrophilic compounds** will be studied.
- **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.
- Generally, adsorbed compounds are not available for biodegradation because bacteria cells cannot access the pores where adsorption occurs. Thus, compounds have first to desorb before they can be biodegraded. **Reversibility of adsorption** will be studied.
- The potential for **bioregeneration of AC** will be assessed by combining a suitable adsorptive material and appropriate conditions for biodegradation. A **reactor concept technology** will be proposed.

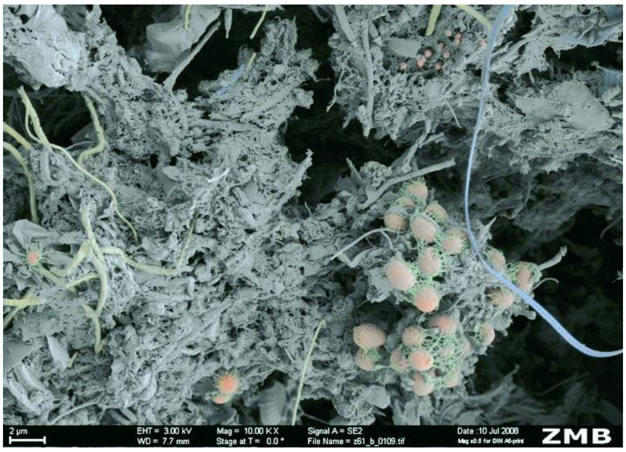

Figure 1: Biofilm on a granular activated carbon, from Eawag (Publ.) 2009: Wave21 final report – Drinking Water for the 21st Century. Schriftenreihe Nr. 20.

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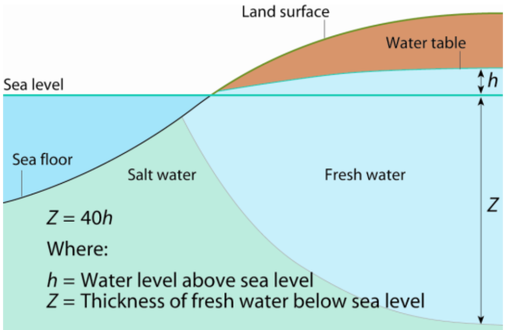
Sub-department of Environmental Technology

Electro-kinetic Fences against Sea Water Intrusion

2017 - 2021

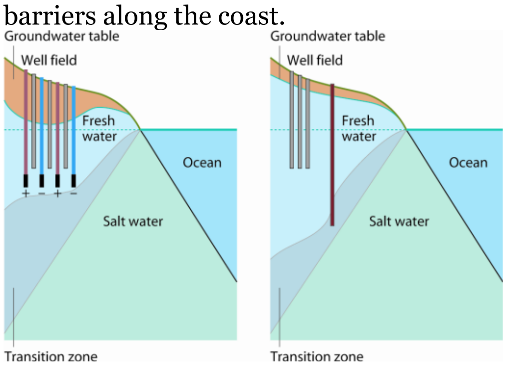
Dr. ir. Harry Bruning

Motivation

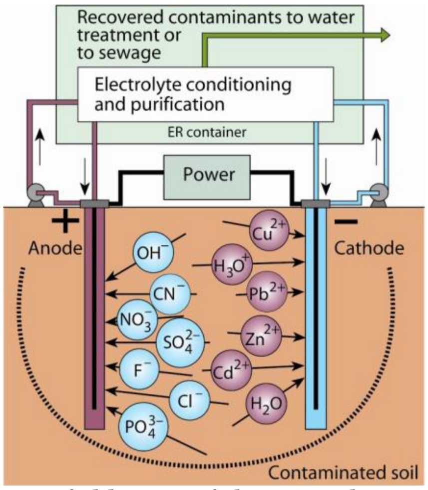


The Ghyben-Herzberg Relation

One of the major concerns today in fresh water supply along coastal areas is seawater intrusion into fresh water aquifers mainly as a result of over pumping or salt-water intrusion from the sea. There are several more or less effective methods to overcome this problem, such as recharge basins, or barrier wells to pump out salt water and recharge a fresh water gradient towards the sea. Rising cost of water and maintenance and uncertainty of long-term potable water availability force authorities to find other ways to deal with this problem. An innovative solution is the creation of electro-kinetic barriers along the coast.



Horizontal/vertical electro-kinetic fence stops sea water intrusion by capturing and removing chloride (© Lambda Consult, 2013)



Schematic field setup of electro-reclamation (© Lambda Consult, 2013)

Technological challenge

Computer simulations, assuming different boundary conditions, indicate that electro-kinetic fencing can be a viable and interesting alternative, especially when the electricity to activate the fence comes from sustainable energy sources such as wind energy and solar power. The objective of this study is to validate the computer simulations and to assess the ecological and economic feasibility of electro-kinetic fences to abate salt water intrusion fresh water aquafers.

This study is carried out in cooperation with Lambda Consult

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https://scholar.google.nl/citations?user=S241dYAAAAAJ&hl=nl

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.

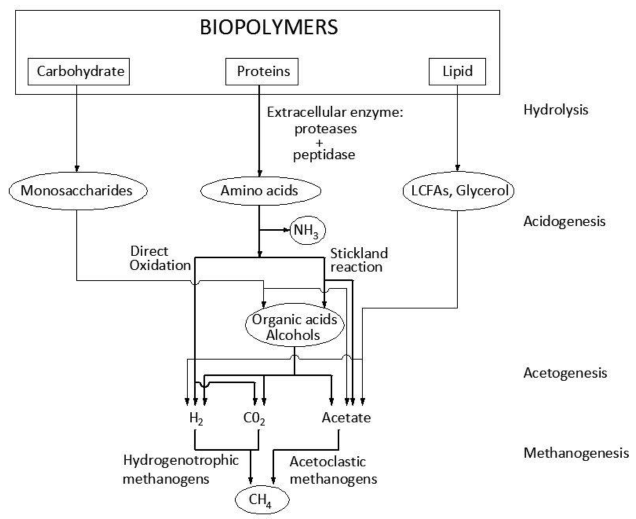
Anaerobic digestion has been widely used for the treatment of wastewater since it combines pollution control and energy recovery (as biogas). The tropical climate in Vietnam especially favors anaerobic treatment, which makes this project very relevant for sustainable development in Vietnam and other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



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Sub-department of Environmental Technology

WAGENINGEN UNIVERSITY & RESEARCH

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

Sub-department of Environmental Technology

April 2017 – 2022

Researcher	Supervisor	Promotor
Viola Bennink	Dr. ir. Tim Grotenhuis	Prof. dr. ir. Huub Rijnaarts Prof. dr. ir. Rob Comans

Motivation

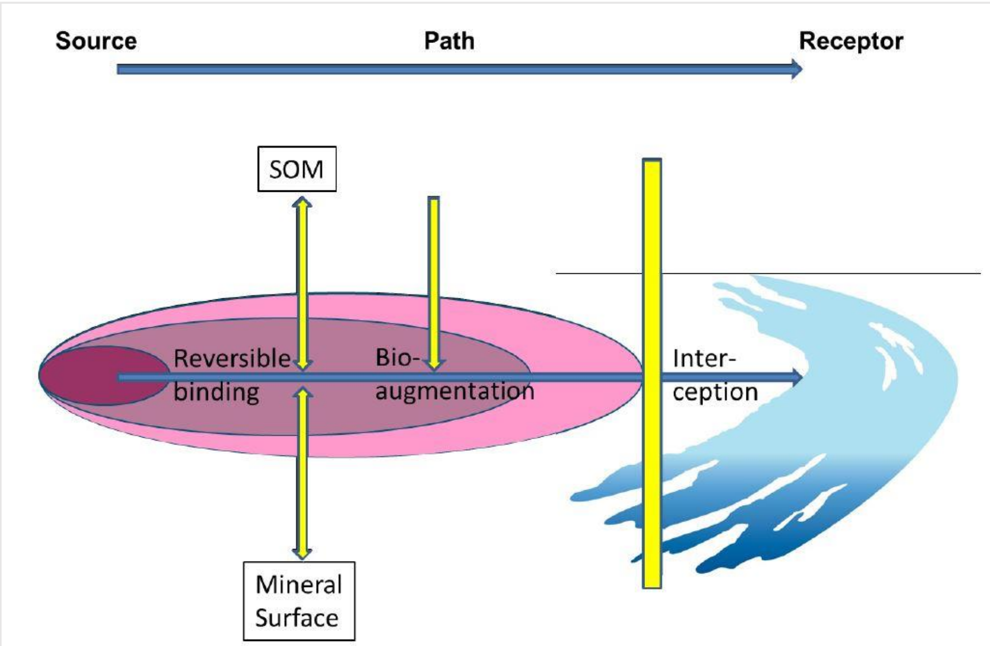
At large-scale industrial sites, a number of spills of hydrophilic and hydrophobic compounds can be present in the local groundwater. The interaction between pollution and abiotic and biotic processes can be optimized for establishing purifying activities of the local soil ecosystem. Through this, the groundwater can be remediated in an eco-friendly, cost effective way. However, the subsurface of many sites is often sub-optimal for such natural bioremediation, i.e. that residence time of the groundwater with contaminants is shorter than the time needed for biological conversion of these compounds. Furthermore, the redox conditions for natural attenuation of various compounds may not be favorable. How to create optimal conditions for full remediation of a variety of contaminants with use of the local ecosystem, is poorly understood.

Technological challenge

The technological challenge is the design of interception area's in which local soil ecosystems are actively remediating the subsurface at contaminated sites. This PhD project is generating a proof of principle for a suitable mechanism as input for such a design. Research is focused on the combination of sorption/desorption and stimulated biodegradation.

Main principles to be tested:

- Effectiveness of organic sorbents and/or environmental factors that allow sorption, but also desorption of a variety of sorbates to ensure their bioavailability.
- Ability of local biomes at polluted sites to degrade target components with irregular substrate loads
- Effect of additional micro-organisms, electron donors, electron acceptors and/or nutrients on biodegradation rate.



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Reusable Water

Sub-department of Environmental Technology

Biopolymer based membranes for (waste) water filtration.

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?

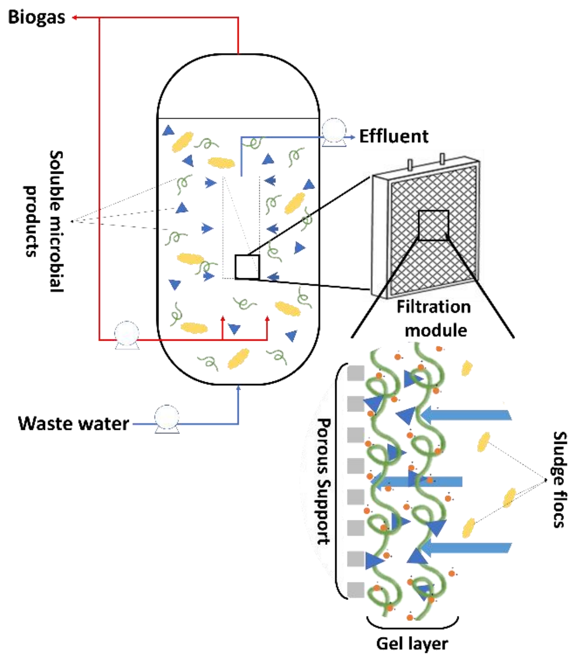

Fig. 1 – Illustration of a gel membrane in an anaerobic bioreactor

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.

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UNIVERSITY OF TWENTE.

WAGENINGEN UNIVERSITY & RESEARCH

Sub-department of
Environmental Technology

Removal of micropollutants from wastewater using a hybrid 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 large and ever expanding 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 micropollutants into the environment. Cooperating with Royal Haskoning DHV, our study aims to contribute by further developing hybrid tertiary treatment technology that can remove organic micropollutants form (waste)water towards full scale implementation.

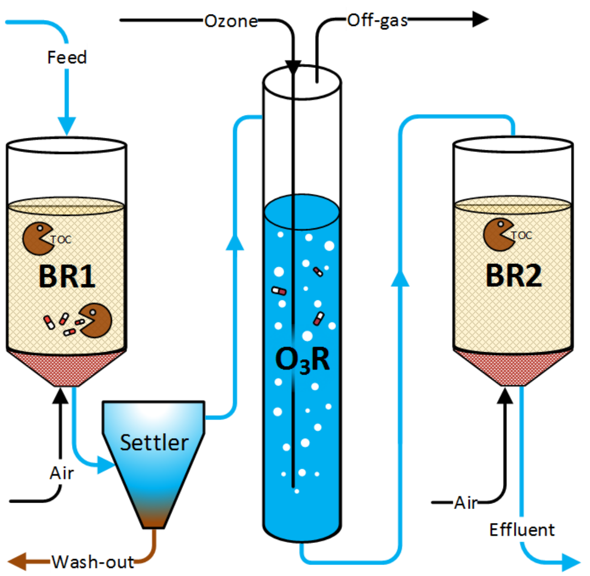


Figure 2 *Schematic overview of the BO$_3$B (bio ozone bio) lab reactor*

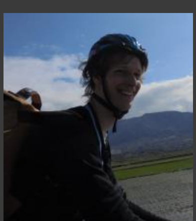
The technology

This hybrid technology (Figure 1) combines the efficiency of biological removal and the power of ozonation to remove a broad range of micropollutants, while also being a sustainable and cost effective technology. Wastewater treatment plant (WWTP) effluent is fed into the first reactor (bio), where DOC is removed to reduce the required ozone dose in the second reactor (ozone). In the third reactor (bio), potentially toxic ozonized transformation products are further broken down by microorganisms.

Technological challenge

We want to focus on understanding the ongoing processes (mainly for process optimization) and upscaling of this hybrid technology:

- Matching reality; include various types of micropollutants at realistic concentrations
- Optimizing the reactor configuration; create a design that can be implemented and operated easily as a tertiary treatment step behind conventional WWTPs
- Conversion processes inside the reactors; identify the formation and further break down of transformation products using both chemical and toxicological analyses
- Organisms present in the two biological reactors, e.g. using community analysis
- The stability of the technology for different types of effluents; test the effect of different types and concentrations of DOC on the ozonation efficiency
- Upscaling the technology; perform pilot and full scale studies



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

Aug 2017 - 2021

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

Sub-department of Environmental Technology

Motivation

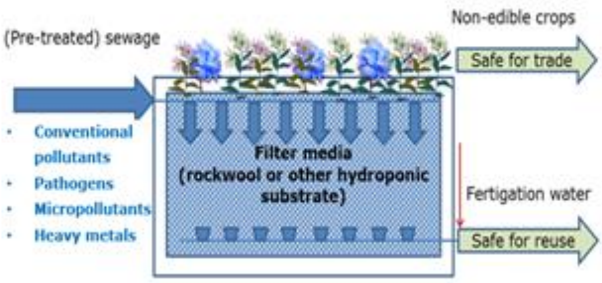
Rapid urbanization results in the production of huge amounts of wastewater, usually not paired with adequate treatment facilities. Together with the overexploitation of freshwater resources, this puts a huge stress on freshwater supply, especially in urban environments. Implementation of new conventional sewage treatment plants (STPs) in dense urban environments may not be possible due to lack of space. Therefore, a novel approach to treat urban wastewater efficiently is urgently needed. This research project aims at developing a novel (post) and compact wastewater treatment system, called Vital Urban Filter (VUF) that can recover and utilise water and nutrients from urban wastewater in a safe manner.

Technological challenge

The envisioned 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 media that can intensify biomass growth and thus degradation and sorption processes. The filter consists of a flat bed of hydroponic substrate (e.g. rockwool, etc.) planted with ornamental plants enhancing the treatment process and providing economic benefits from harvesting and selling the flowers. (Pre-treated) influent with (remaining) conventional pollutants, heavy metals, pathogens and organic micropollutants percolates down through the filter bed and undergoes various physical, chemical and biological transformation and removal mechanisms. The interplay of different components present in VUF, such as microbes, plants and specific filter properties results in the removal of a range of pollutants. Finally, the treated effluent is collected and aimed primarily for irrigation or other reuse options. The major aimed advantages of VUF above the conventional systems are compactness, flexibility, adaptability, simple construction, low investment and operational costs, good effluent quality with low energy requirements and an added economic and aesthetic value.

However, it is challenging to intensify biomass growth in VUF while avoiding clogging. Therefore, we investigate the use of different filter media in order to achieve high biomass without much clogging. The filter media we use needs 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, during the (post) treatment, VUF system will be optimized to enhance the removal of pathogens and micropollutants along with the conventional pollutants. We are also challenged with discovering sustainable ways of handling plant residues and exhausted filter media.

Since VUF is novel system, these technological challenges will be critically investigated throughout the development and validation of it.



Vital Urban Filter (VUF)

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Enhanced biodegradation of mobile aromatic hydrocarbons by an engineered reversed redox zonation barrier.

Sub-department of Environmental Technology

Oct 2017 - 2021

Researcher	Supervisor	Promotor
Ir. L. M. Keijzer	Dr. Ir. T. Grotenhuis, Prof. Dr. Ir. N. B. Sutton	Dr. Ir. T. Grotenhuis, Prof. Dr. Ir. H. H. M. Rijnaarts

Problem Definition

Before electricity was widespread in the Netherlands, households used gas to cook and heat their homes. This gas was produced locally from oil and/or coal in large factories near cities. When electricity became the most prominent power source, the factories, now in urban areas, were closed down and demolished. During demolition, it became apparent that large quantities of BTEXN, PAHs and other oil-related products remained deep

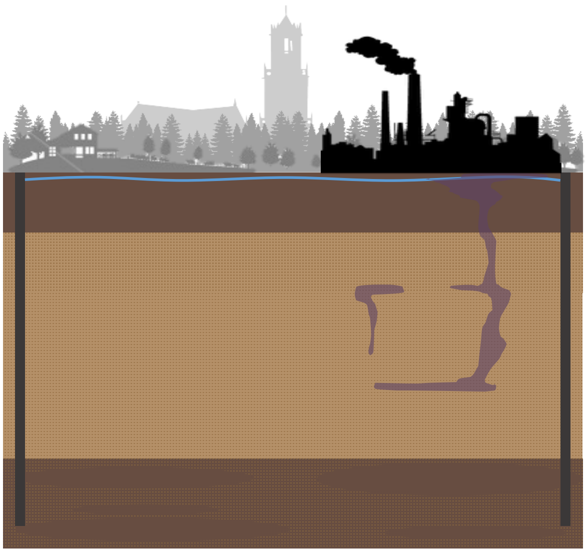

Figure 3. Conceptual site model of old gasworks pollution.

in the soil and groundwater at high concentrations. Due to the large variety of compounds and the heterogeneous of these contaminants in soil, the sites are highly complex and difficult to treat with conventional remediation techniques, thus engineered bioremediation is an interesting option.

Site Challenges

Typical gas works contaminants such as BTEXN and PAHs are somewhat recalcitrant. They are not easily biodegraded due to the internal ring structure present in all of these aromatic compounds. However, bacteria are able to use these contaminants as electron donor for respiration. There are several electron acceptors naturally available in the soil. Oxygen, being the most energy rich electron acceptor, is depleted first when going deeper in the soil. Replenishment is scarce, because the amount of oxygen that can be dissolved in water is limited. In Figure 2, the natural redox zonation with their respective reaction is presented.

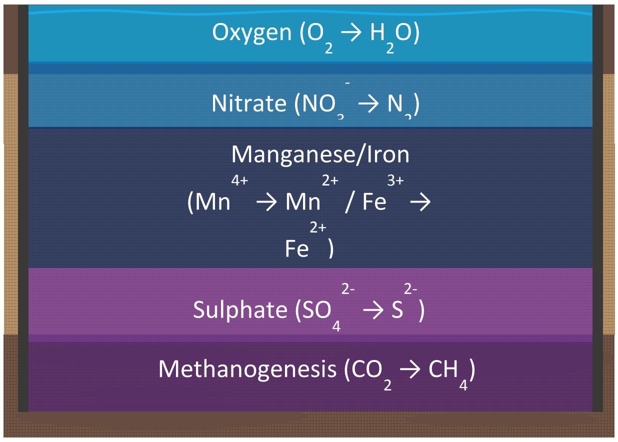

Figure 4. Natural redox zonation in pristine soils

This natural zonation can locally be disturbed when pollutants are present. The most energy rich electron acceptors, like oxygen or nitrate, will be used for degradation first, leaving the source zone of the contamination anaerobic. With each redox zone, from aerobic to eventually methanogenic, fewer oil related-contamination are broken down by bacteria with the respective electron acceptor.

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WAGENINGEN UNIVERSITY & RESEARCH

Treatment of micropollutants contaminated wastewater effluent by constructed wetlands

Sub-department of Environmental Technology

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 mciropollutants 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.

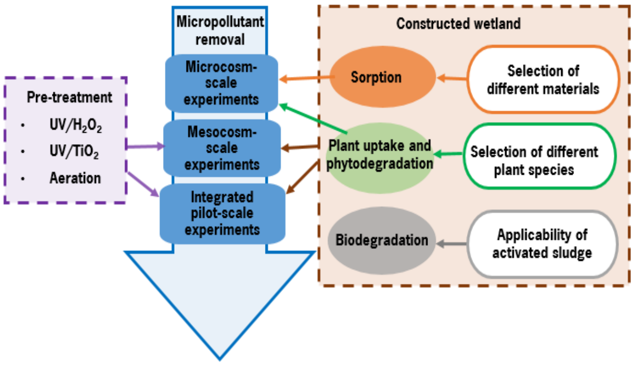

Figure 1. Scheme of this research

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Urban Systems Engineering

Sub-department of Environmental Technology

Urban Systems Engineering and Reusable Water

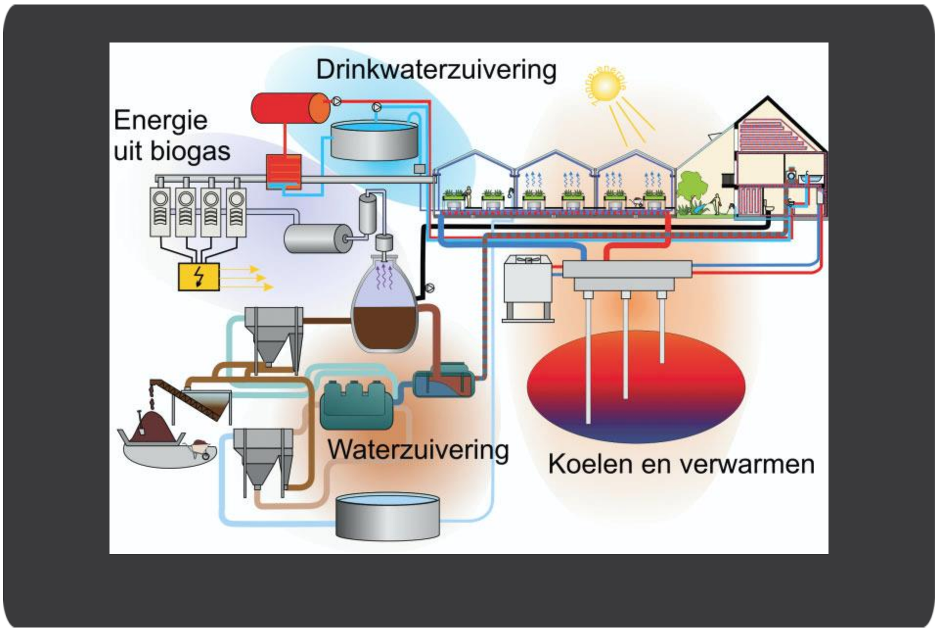
Urban & Industrial Modelling & Design

Urban Infrastructure Management

Sustainable and Healthy reuse of Urban Resources

Urban Systems Engineering and Reusable Water

Sub-department of
Environmental Technology



Environmental Issues

The intensity and scale of urbanization worldwide pose major challenges to cities' authorities in providing basic urban services such as water and energy supply, sanitation, and management of solid waste. A growing demand mainly occurring in urban areas for renewable energy, clean water, materials and minerals results in an increasing worldwide recognition that new approaches and paradigm shifts - away from the current linear thinking to manage our resources - are needed. Here, depletion of resources such as fossil fuels and phosphorus demands a rethinking of our urban areas. A further motivation is that we are still unable to provide basic services to everyone. As an 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].

Our Research

The vision of our research is to reduce environmental impact and mitigate resource depletion by closing resource cycles and achieving a circular (urban) metabolism. Our research focuses on development of concepts and integration of technologies for sustainable urban water, materials and energy cycles. We develop and evaluate new concepts for collection, transport, treatment, supply and use of energy, water and materials, which we consider as valuable resources and which qualities have to be preserved. Furthermore, we select appropriate technologies for these concepts in accordance with the local circumstances, needs and habits. Our research includes (peri-) urban areas and industrial sites, for which we aim at an optimal, sustainable and highly effective balance between supply and demand of water, energy and resources. Here, we include the effect of different urban typologies and urban agriculture on the resource cycles. 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, so as to facilitate recovery and reuse of water and other resources such as energy, nutrients and compost. Moreover we have extended this to closing Industrial and Metropolitan Water Cycles, including multi-sourcing brackish and rain water, and reclaimed purified water from large domestic waste water treatment plant effluents, as alternative water resources.

Our Approach

Cities and their challenges are addressed in accordance with the principle of cyclic, rather than linear analysis, engineering and design. Furthermore, concepts and approaches are developed in cooperation with stakeholders on a practically relevant scale (Living Lab Approach). In our research, the non-technological, socio-economic and spatial planning contexts, in which we want to integrate our concepts, receive due attention. Due to the broader inter- and transdisciplinary approach of our research, cooperation with other WUR departments takes place in various larger research programs, such as Water Nexus, Entire, LotusHR, and WUR knowledge investment programs (Metropolitan Solutions, Resilience, and Resource Efficiency).

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

Urban metabolic dynamics – Identifying spatial and temporal variability

Sub-department of Environmental Technology

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.

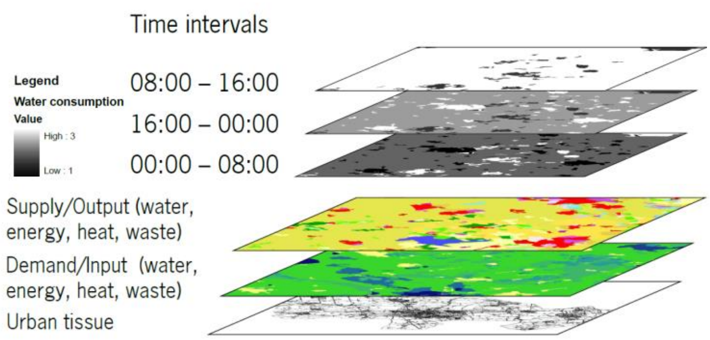

Figure 1: Spatial and temporal variability of urban metabolism.

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AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

WAGENINGEN UNIVERSITY & RESEARCH

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

Sub-department of Environmental Technology

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

Motivation

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

Objective

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

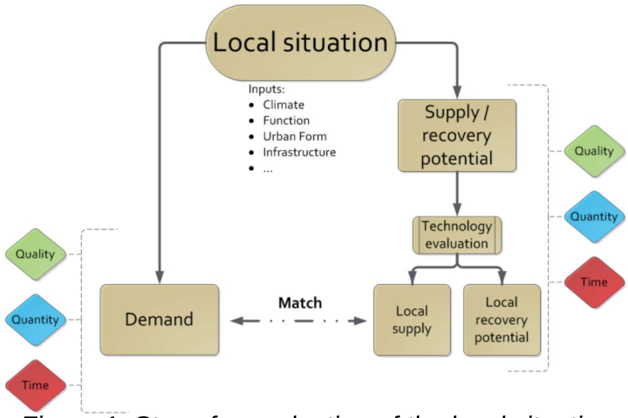

Figure 1: Steps for evaluation of the local situation and technology selection

Points of Interest

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

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

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WAGENINGEN UNIVERSITY & RESEARCH

Sub-department of
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Modeling and Prediction of Energy Demand

July 2014 - 2018

Researcher	Supervisor	Promoter
Delaram Azari	Dr. Karel Keesman Dr. Hans Cappon	Prof. dr. ir. Huub Rijnaarts

Motivation

Transition in the traditional energy system:

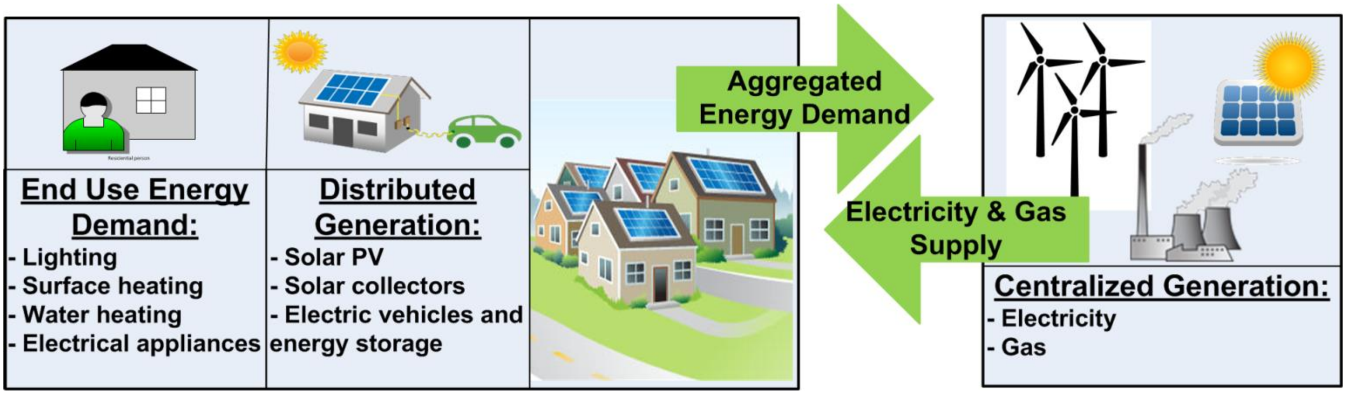
1. Integration of renewable energy sources on centralized and distributed scale.
2. Increase in the energy demand and changes in demand profile due to fast-pace growth of population and urbanization

→ Challenge: efficient and effective use of various energy sources to match the supply and demand

- Detailed knowledge about energy demand profile and predicting its future variations is useful for energy managers and urban planners.

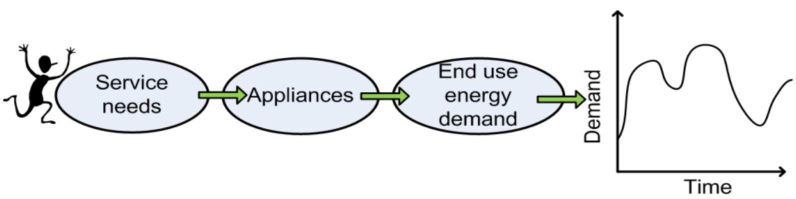
Approach

- Bottom-up approach: starting from the individual buildings, and scaling up to larger clusters of buildings, up to a district and city level.
- Characterizing energy demand, considering:
  1. Temporal variations: daily, weekly, seasonal, and yearly patterns
  2. Building characteristics, number of inhabitants and socio-economic conditions of the inhabitants
- Disaggregating electricity and gas demand based on various service needs of different consumers
- Forecasting energy demand profile based on different usage categories.



Objective

We aim to develop a model for characterizing and forecasting energy demand in the urban environment in detailed spatial and temporal resolution, including the service needs and the resulting end use energy demand.



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WAGENINGEN UNIVERSITY & RESEARCH

Amsterdam's metabolism throughout time – lessons to be learned?

Sub-department of
Environmental Technology

March 2015-2019

Researcher
Ilse Voskamp

Supervisors
Dr.ing Sven Stremke
Dr. Nora Sutton

Promotor
Prof. dr. ir. Huub Rijnaarts

Motivation

Current environmental concerns relate to scarcity and shortage of resource (e.g. peak oil, depletion of phosphorous). To address this problem a transition to renewable energy use, circular material and nutrient flows is advocated. Cities of the world are at the forefront of this transition, yet at present there are no cities that achieve this ideal of circular resources flows and independence from fossil fuels.

In order to be able to decide upon where to intervene in a city so that its metabolism becomes more circular, one needs to know which factors are key drivers for the current state of the metabolism. It is known that a close relationship exists between resource management, urbanization and technological development (Agudelo-Vera et al., 2010). But what does this relation look like for the case of Amsterdam? Which technological, socio-economic or ecological processes were the key drivers that shaped the city's metabolism? And what lessons can we learn from history for today's urbanization?

Aims and Objectives

This research project aims to investigate more closely the relationship between resource management, urban planning and design and technological development in Amsterdam from a long-term perspective. This investigation should reveal how Amsterdam's resource management system has evolved over time and how this has been affected by urban, technological and socio-economic developments. Preferably water and energy flows are studied.

Focal points of study include: changes in socio-economic circumstances, spatial organization (urban form), quantity and quality of the resources

used, size and distance to resource supply areas and technologies applied. By focusing on these aspects lessons for sustainable urban planning and design are expected.

Methods and requirements on candidate

The research will mainly consist of desktop study in which various method can be applied, depending on the student's interest and capacities. Potentially relevant activities include literature review, data gathering in the city archives, map study and expert interviews. It is also possible to make use of methods such as material flow analysis, to illustrate long-term changes in the city's resource flows quantitatively.

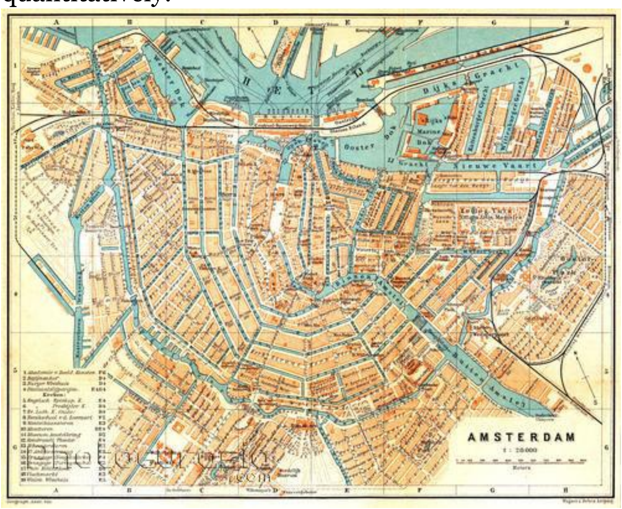

Figure 1: Historical map of Amsterdam

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Developing a Water Technology Diffusion model as a framework for analysis of innovation in water technologies

Sub-department of Environmental Technology

Jan '16 – Oct '18

Researcher
Paul O'Callaghan

Supervisor
Prof. dr. ir. Cees Buisman

Promotor
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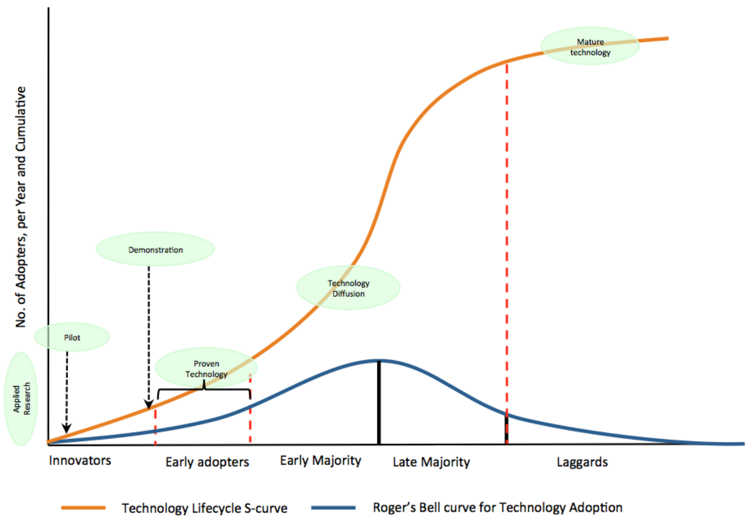
Motivation

The motivation for this thesis can be summarized with the following key points:

- Challenges in relation to water quality and availability exist and will be further exacerbated in the decades ahead due to multiple macro level drivers.
- Water Technology innovation can help to address issues relating to water quality, availability and efficient energy and resource management.
- There is a high level of research and development activity and investment in developing innovative water technologies.
- Currently the level of productive outputs and return on capital from this research and development work is poor based on metrics including percentage of technologies that make it through the technology diffusion process.

Technological challenge

- Current models to analyse Water Technology Diffusion exist, but they are incomplete and not designed for the water sector.
- The development of a Water Technology Diffusion model as a framework to analyse the process of water technology can help increase the efficiency in the use of capital to develop water technologies to address issues relating to water quality and availability and efficient use of resources and energy in water and wastewater management.



- We will describe the development of a Water Technology Diffusion model to cover the complete cycle of technology development from applied research through to technology maturity. The model combines and adapts elements from other technology innovation models to create a framework that can be used to analyse the process of water technology development and technology diffusion.

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Dynamic model of aquaculture-horticulture systems, INAPRO.

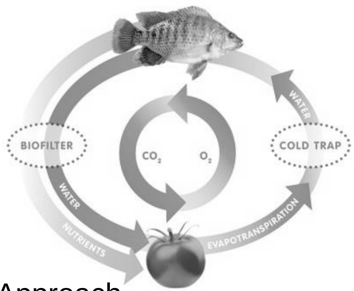
Sub-department of Environmental Technology

Jun 2014 - 2018

Researcher	Supervisors	Promotor
Daniel Reyes Lastiri	Dr. ir. Karel J. Keesman, BCT Dr. ir. Hans J. Cappon	Prof. dr. ir. Huub Rijnaarts

Motivation

We are a very high-maintenance society. About 70% of the fresh water used worldwide is destined to agriculture, largely for animal feed production; simultaneously, near to 75% of the global fish stocks are overfished.
Aquaponics is a technique that combines farming of aquatic species (**aqua**culture) with soilless plant production (hydro**ponics**). It tackles both wastewater treatment and nutrient recovery by reusing the fish waste for plant growth in a single water cycle.
Developing aquaponics to a commercial scale can thus help reducing our water demand and impact on biodiversity.



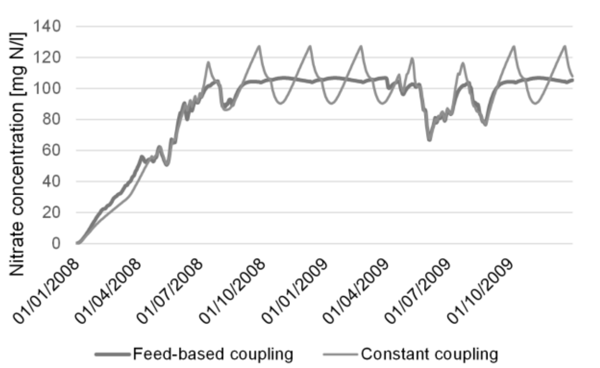
Approach

Fish and plants have different growth cycles and nutrient requirements. Their production systems are not mutually optimal.
It is necessary to understand the dynamics of each system and their interactions in order to reach a balance between both cycles, with minimal water, nutrient and energy consumption.
For this purpose, we develop a mathematical model that improves our understanding of aquaponics.
Together with partners in Europe and China, the INAPRO project combines the model basis with a demonstration-based approach. Our model supports the design of demo systems and their operation provides us with validation data.

Technological challenge

Drawing lines
The model must be simple enough to provide system-level solutions, yet detailed enough to include all relevant physical, chemical and biological phenomena affecting the production.
Additionally, it must have a modular construction to simulate different system components and locations in the world.

Coupling
The individual production cycles are not in synchronicity. We must devise and test strategies to couple the water between fish and plants to achieve a resilient and sustainable system.



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Sub-department of
Environmental Technology

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

Mar 2016 - 2020

Researcher	Supervisor	Promotor
Joeri Willet	Dr.ir. Koen Wetser	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. Even in a “wet” country such as the Netherlands extreme weather events, sea level rise, and overexploitation threaten existing fresh water resources. Increased salt water intrusion, due to sea level rise, threatens to turn fresh water resources saline in the low lying areas of the Netherlands. A paradigm shift in the way water is used is required to assure continued abundance for domestic, agriculture, and industrial purposes.

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.

The main challenge of this research is to match environmental renewable water supply with industrial water demand.

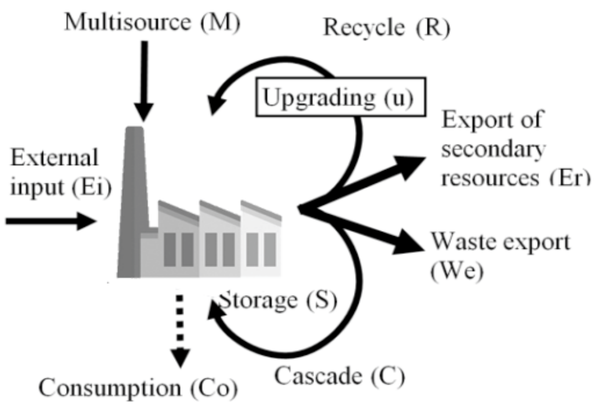
Possible thesis topics

1. Hotspot identification of industrial resource use through Material Flow Analysis (MFA)

Utilize MFA techniques in order to map the resource flows of an industrial case study. Attention to interactions between energy and water flows is required to identify possible locations in which resource use can be reduced.

2. From Urban Harvest to Industrial Harvest

Apply the Urban Harvest Approach (UHA) to an industrial case (IHA) to identify the possibilities of (re)using local available resources.



Adapted from: Agudelo-Vera, Claudia M. 2012. “Dynamic Water Resource Management for Achieving Self-Sufficiency of Cities of Tomorrow. Ph.D. Thesis, Wageningen University, Wageningen, Netherlands.”

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WATER NEXUS

WAGENINGEN UNIVERSITY & RESEARCH

Developing an Integrated Wastewater Management Plan for Coastal Bangladesh

March 2017 - 2021

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

Sub-department of Environmental Technology

Background

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

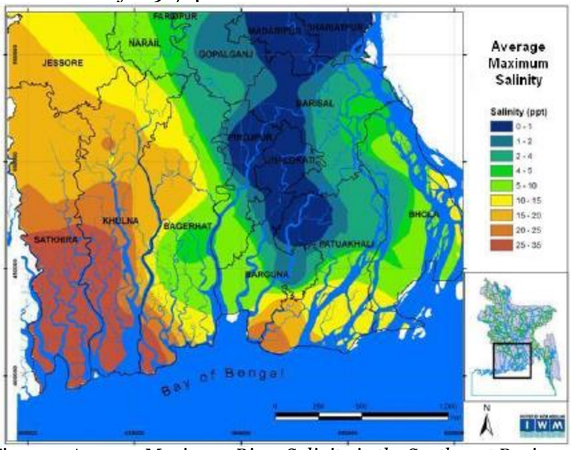


Figure 1: Average Maximum River Salinity in the Southwest Region of Bangladesh (World Bank, 2015)

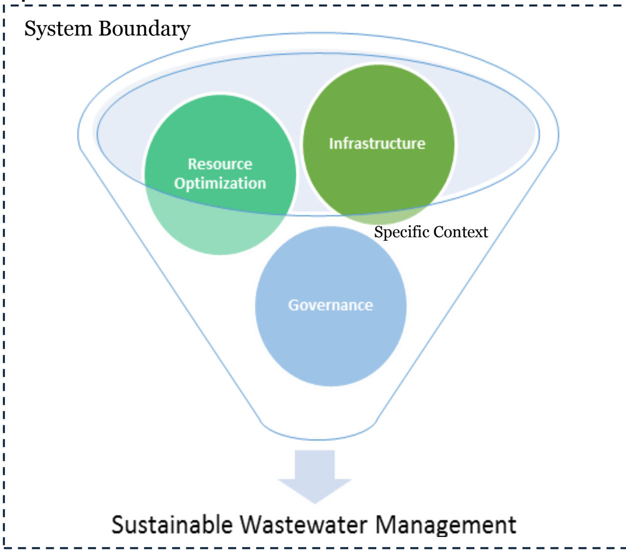
Motivation

- 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 resulting poor quality wastewater, 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 plan integrating risk mitigation strategies for safe re-use in agriculture.

Operational Framework

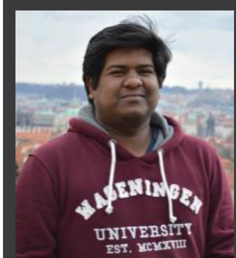


Methods

- Wastewater quality/quantity analysis
- QMRA-Monte Carlo Simulation
- Stakeholder mapping and perception analysis
- Spatial Analysis
- Scenario Planning and MCA

Expected Outcome

- Seasonal variation in wastewater quantity/ quality and associated health risk for reuse
- Framing stakeholders perception towards planned wastewater re-use in agriculture
- Understanding of spatial and temporal dynamics of wastewater flows facilitating better urban-rural infrastructure linkage
- Scenarios for wastewater treatment options facilitating re-use in agriculture



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Research Interest: Water re-use, urban-rural linkage, spatial planning

Enhancing biological stability of drinking water by membrane treatment

Apr 2016 - 2020

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

Motivation

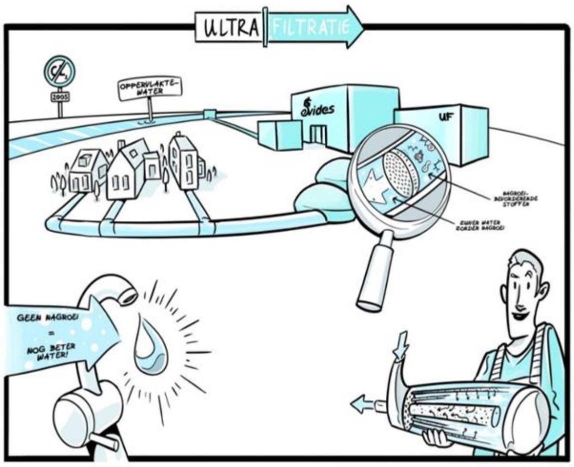
Distribution of potable water without any residual disinfectant eliminates DBP (disinfectant-byproduct formation) and maximizes consumer satisfaction in terms of taste and odor. However, biological stability, i.e. unobjectionable levels of microbial and invertebrate organisms, is to be maintained in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

Technological challenge

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

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

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



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Sub-department of Environmental Technology

Technology and Infrastructure Innovations for Water Supply in Industrial Zones

Aug 2016 - 2020

Researcher
Le Minh Truong

Supervisor
Dr.ir. Katarzyna Kujawa

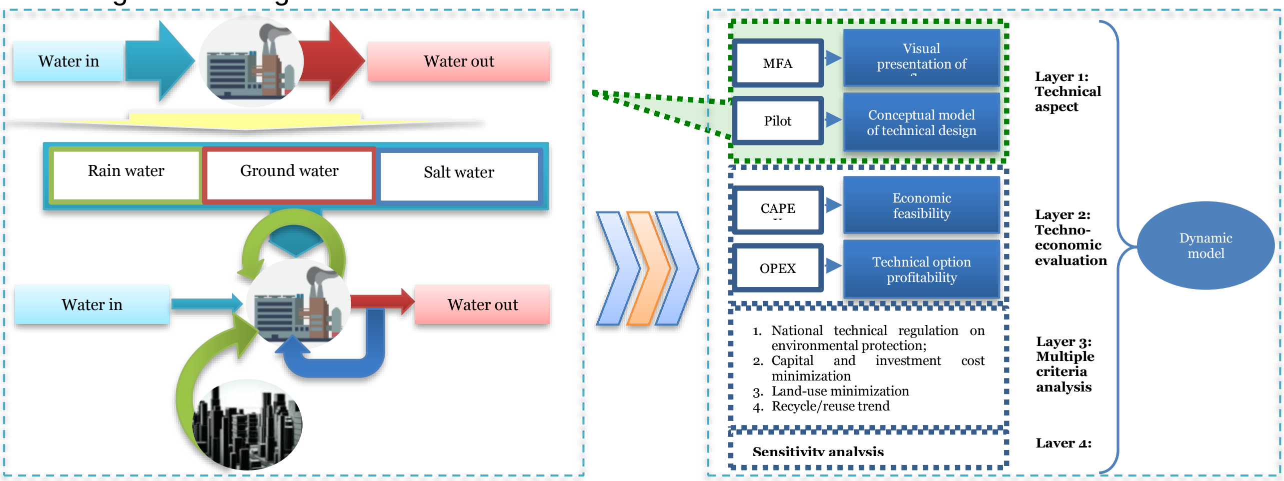
Promotor
Prof. Huub Rijnaarts
Assoc. Prof. Tran Thi My Dieu

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.

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WAGENINGEN UNIVERSITY & RESEARCH

Sub-department of
Environmental Technology

Green Street:

Street as the basic building block for constructing circular city of the future

Nov 2016 – Dec 2017

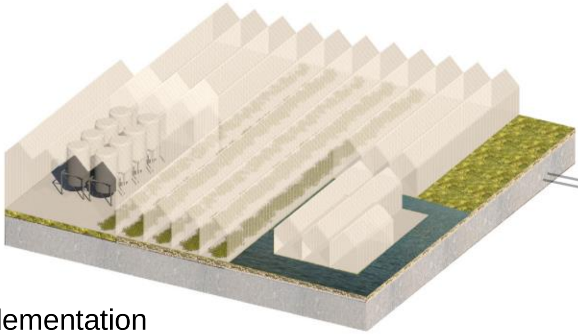
Researcher	Supervisor	Project leader
Dr. Wei-Shan Chen	Dr. ir. Jan Weijma	Prof. dr. ir. Huub Rijnaarts

Motivation

Street is an ideal building block for constructing a circular city of the future. Infrastructures are intensively clustered in streets to provide essential urban services like several types of traffics (vehicular, bicycle & pedestrian) and waste(water) & rainfall discharge. Moreover, street level is more attractive, than the household level, for implementing renewable energy production & storage as well as reuse of nutrient from waste in urban farming, due to its larger supply and demand. Streets also catalyse the social interactions within the neighborhood. The path towards a sustainable city should, therefore, start at a sustainable street, which we called "Green Street".

Technological Principle

The core idea is to re-design the street functionality and morphology. A co-creation with multiple stakeholders is emphasized. Involving multiple stakeholders from the beginning of this revolutionary project will guarantee the impact and sustainability of Green Street concept.



Implementation

The city of Almere is preparing for the up-coming Floriade 2022, the biggest horticultural exhibition in the world, with the theme "the feeding city". Together with Amsterdam Metropolitan Solutions (AMS), ETE will design and build a prototype of "Green Street" that is tailor-made for the city of Almere. The Green Street prototype aims to demonstrate the potential of integrating existing/emerging environmental technologies for a circular "street" metabolism and the impact of co-creation. The experience we learn during this prototype will be applied to other cities that also strive for a sustainable urban development.

Research challenges

- Review emerging & existing technological/ social approaches for achieving circular use of water, energy & nutrient in urban street level
- Design by selecting & integrating the reviewed technological/social approaches (case study in several cities available)
- Develop indicators & applicability assessment for supporting evaluation & implementation of the generated designs
- Identify potential stakeholders to be involved for implementation of Green Street (in Almere and potentially other cities in the world)

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AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

WAGENINGEN UNIVERSITY & RESEARCH

Sub-department of
Environmental Technology

Water out, shit in:

Innovating & phasing the resource-recovery based sanitation system

Nov 2016 – Dec 2017

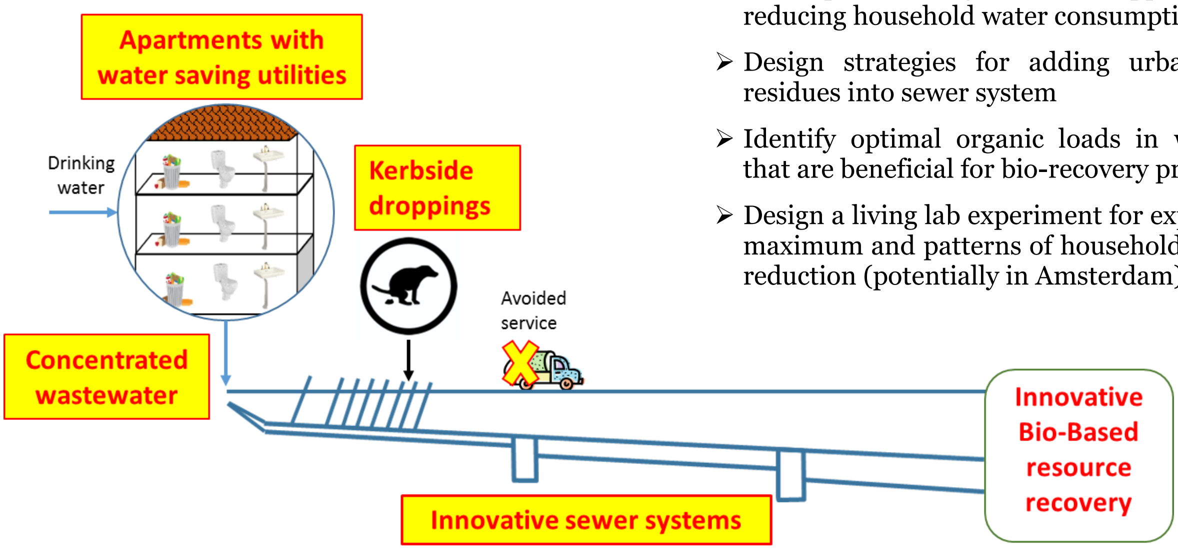
Researcher	Supervisor	Project leader
Dr. Wei-Shan Chen	Dr. ir. Jan Weijma	Prof. dr. ir. Huub Rijnaarts

Motivation

Large quantity of resources will flow through urban area to support the living, and most of them end up in urban waste streams. Current sanitation system could not effectively recover resources from urban waste, as it was designed with an aim to remove waste(water) as far away and as fast as possible. Moreover, urban waste streams are often highly heterogeneous, making the recovery difficult. Novel sanitation system that is designed for maximizing resource recovery from urban waste streams is required and envisioned.

Technological Principle

The core idea is to maximise the organic concentration in wastewater, which is beneficial for emerging bio-recovery processes. This can be done by minimizing the water and maximsing the organic waste entering the sewer system, namely water out and shit in.



Water out- Minimising water consumption
Numerous water-saving home utility has been invented and commercialized. A preliminary investigation indicates that up to 67% of household water consumption can be reduced by applying water-saving utilities. Moreover, social-ecological approaches can be applied to influence water-using behaviors of end-users, i.e. citizen in this case.

Shit in- Maximising organic waste into sewer
Organic waste can be dumped into sewer, instead of trach bin, by employing kitchen or toilet grinders. Transportation needed for kerbside collection of organic waste is avoided. A preliminary experiment showed that smaller sewer pipe may be beneficial for transporting wastewater with a high solid content.

Research challenges

- Develop technological/social approaches for reducing household water consumption
- Design strategies for adding urban organic residues into sewer system
- Identify optimal organic loads in wastewater that are beneficial for bio-recovery processes
- Design a living lab experiment for exploring the maximum and patterns of household water-use reduction (potentially in Amsterdam)

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AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

WAGENINGEN UNIVERSITY & RESEARCH

Sub-department of Environmental Technology

Dynamic modelling of freshwater supply and industrial demand for delta regions

June 2016 - 2021

Researcher	Supervisor	Promotor
Jess Wreyford	Dr. ir. Koen Wetser Dr.ir. Jouke Dykstra Dr. ir. Hans Cappon	Prof. dr. ir. Huub Rijnaarts

Motivation

Water scarcity is a growing global issue, especially for delta regions which are susceptible to salt water intrusion. These locations are also known to attract residential, municipal, and industrial development which places a larger burden on the water supply. One of the largest consumers of fresh water is industry which can represent as much as 59% of total freshwater usage for a given area (WBCSD, 2009). Of this freshwater use, up to 90% is returned in the form of wastewater unable for reuse and polluting water supplies (WCW, 2000). It is therefore necessary that improvements be made to both reduce the amount of freshwater needed upstream and reduce the amount of wastewater returned downstream. In order to do so, a clear understanding of supply and demand is needed. However, present evaluations are either too focused for regional relevance or too broad for improvement recommendations.

Technological challenge

In order to improve the situation for delta regions, a clear understanding of the current situation is necessary. Specifically, a comprehensive approach is needed that can accurately capture the relationship between freshwater supply and its demand. Existing methods such as indices and benchmarking have yet to accurately achieve this in a meaningful way. Modelling could be seen as a solution. However, present modelling attempts are either too narrow (small scale) or too broad (large scale). Small scale is usually a bottom up approach which cannot consider issues outside of the set boundaries and is very site specific. Large scale, meanwhile, is a top down approach which typically cannot provide design information and is usually only relevant regionally or globally. Therefore, a hybrid method is recommended as it can connect small and large scale models. To date, this approach has only been used for analysis with no application to sustainable design problems (Hanes & Bakshi, 2015).

The technological challenge of this research is to develop a dynamic model which will:

i) depict local water availability and demand;
ii) provide matching of supply and demand;
iii) test the applicability of integral solutions.

This research will be primarily focused on (reducing) the freshwater use of the industrial sector through up- (Figure 1) and downstream modelling, case studies, and integrations of both small and large scale applications within a single model. This to allow for assessing both design improvement as well as the impacts of these decisions on a larger scale.

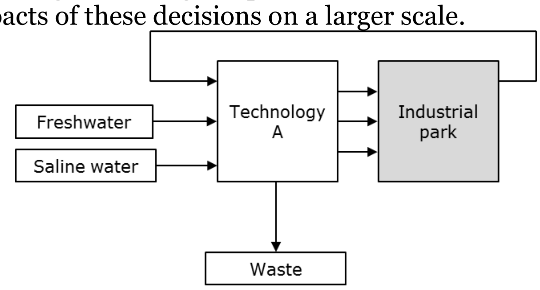

Figure 1. Upstream Technology optimization modelling scheme, aiming at minimizing fresh water intake and waste water discharged.

This research is part of the larger Water Nexus program whose aim is to use "salt water where possible, fresh water where necessary". https://teamsites.wur.nl/sites/WaterNexus/SitePages/Home.aspx

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WATER NEXUS

WAGENINGEN UNIVERSITY & RESEARCH

Water-Energy-Food Nexus – Interconnectivity between different sectors

Sub-department of Environmental Technology

Researcher
Koen Wetser

Motivation

The generation of water, energy and food are fragmented and fit within a linear economic perspective. Resources (e.g. water, nutrients and materials) are extracted, treated if necessary, and distributed for single use. The resources are pressurized by among others the growing population, climate change and pollution, which results in scarcity, inequality and limited development of industrial, agricultural and residential areas.

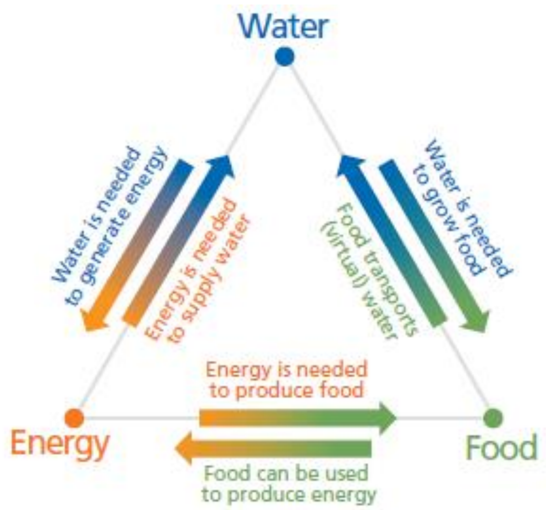
The water-energy-food nexus is a paradigm shift that considers the water, energy and food sectors as a whole, developing integral solutions for a sustainable development of an entire region. As such, the region is not dependent on non-renewable resources and resources from other regions, and thus can sustain their processes indefinitely. Present attempts for solving the water, energy and food issues are fragmented, only focussing on parts of the problem, and are often coupled with high costs and poor sustainability. The water-energy-food nexus requires good knowledge on the supply and demand of resources, effective technologies and integrating concepts and solutions. The nexus approach is successful, because it looks at the entire system with collaboration both across sectors (e.g. water, energy, agriculture, economy, policy, environment, science etc.) and scales (i.e. internationals, nationals, regional, local). Water, energy and food related challenges might be similar for different locations, like securing adequate food availability. The solutions to the challenges differ regionally, due to for example differences in climate, regulations and culture. A solution that works in the Netherlands might not work somewhere else. Therefore, a context-specific adaptation of the water-energy-food nexus approach is needed.

Objective

The objective of this research is to investigate the interconnectivity between water, energy and food. The focus of the research is to show that technology investments in one of the sectors can stimulate the other sectors. For example, investments in renewable energy could increase the water and/or food security. Suitable investments are different per region as each region has their own climate, policies, culture and budget. This research is therefore targeting at a specific region.

Potential research topics

- Renewable energy investments to increase food security in Sub-Saharan Africa
- Renewable energy investments to improve water security in the Middle East
- Investments in water security to increase food security in Northern Africa



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WAGENINGEN UNIVERSITY & RESEARCH

Publication List Environmental Technology 2017

Refereed article in a journal

- In-situ carboxylate recovery and simultaneous pH control with tailor-configured bipolar membrane electrodialysis during continuous mixed culture fermentation
  Arslan, D. ; Zhang, Y. ; Steinbusch, K.J.J. ; Diels, L. ; Hamelers, Hubertus V.M. ; Buisman, C.J.N. ; Wever, H. de (2017)
  Separation and Purification Technology 175 . - p. 27 - 35.
- Effect of humic acid on anaerobic digestion of cellulose and xylan in completely stirred tank reactors : inhibitory effect, mitigation of the inhibition and the dynamics of the microbial communities
  Azman, Samet ; Khadem, Ahmad F. ; Plugge, Caroline M. ; Stams, Fons ; Bec, Sabina ; Zeeman, Grietje (2017)
  Applied Microbiology and Biotechnology 101 (2). - p. 889 - 901.
- Bioelectrochemical conversion of CO2 to chemicals : CO2 as a next generation feedstock for electricity-driven bioproduction in batch and continuous modes
  Bajracharya, Suman ; Vanbroekhoven, Karolien ; Buisman, Cees J.N. ; Strik, David P.B.T.B. ; Pant, Deepak (2017)
  Faraday Discussions 202 . - p. 433 - 449.
- Biotransformation of carbon dioxide in bioelectrochemical systems: State of the art and future prospects
  Bajracharya, Suman ; Srikanth, Sandipam ; Mohanakrishna, Gunda ; Zacharia, Renju ; Strik, David P.B.T.B. ; Pant, Deepak (2017)
  Journal of Power Sources 356 . - p. 256 - 273.
- In situ acetate separation in microbial electrosynthesis from CO₂ using ion-exchange resin
  Bajracharya, Suman ; Burg, Bart van den; Vanbroekhoven, Karolien ; Wever, Heleen De; Buisman, Cees J.N. ; Pant, Deepak ; Strik, David P.B.T.B. (2017)
  Electrochimica Acta 237 . - p. 267 - 275.
- Long-term operation of microbial electrosynthesis cell reducing CO₂ to multi-carbon chemicals with a mixed culture avoiding methanogenesis
  Bajracharya, Suman ; Yuliasni, Rustiana ; Vanbroekhoven, Karolien ; Buisman, Cees J.N. ; Strik, David P.B.T.B. ; Pant, Deepak (2017)
  Bioelectrochemistry 113 . - p. 26 - 34.
- Investigating bacterial community changes and organic substrate degradation in microbial fuel cells operating on real human urine
  Barbosa, S.G. ; Peixoto, L. ; Heijne, A. ter; Kuntke, P. ; Alves, M.M. ; Pereira, M.A. (2017)
  Environmental Science : Water Research & Technology 3 (5). - p. 897 - 904.
- Organic Pollutants in Shale Gas Flowback and Produced Waters : Identification, Potential Ecological Impact, and Implications for Treatment Strategies
  Butkovskyi, Andrii ; Bruning, Harry ; Kools, Stefan A.E. ; Rijnaarts, Huub H.M. ; Wezel, Annemarie P. van (2017)
  Environmental Science and Technology 51 (9). - p. 4740 - 4754.
- Micropollutants in source separated wastewater streams and recovered resources of source separated sanitation
  Butkovskyi, A. ; Hernandez Leal, L. ; Zeeman, G. ; Rijnaarts, H.H.M. (2017)
  Environmental Research 156 . - p. 434 - 442.
- Role of microbial accumulation in biological sulphate reduction using lactate as electron donor in an inversed fluidized bed bioreactor : Operation and dynamic mathematical modelling
  Cassidy, J. ; Frunzo, L. ; Lubberding, H.J. ; Villa-Gomez, D.K. ; Esposito, G. ; Keesman, K.J. ; Lens, P.N.L. (2017)
  International Biodeterioration and Biodegradation 121 . - p. 1 - 10.
- Production of Caproic Acid from Mixed Organic Waste : An Environmental Life Cycle Perspective
  Chen, Wei Shan ; Strik, David P.B.T.B. ; Buisman, Cees J.N. ; Kroeze, Carolien (2017)
  Environmental Science and Technology 51 (12). - p. 7159 - 7168.
- Isobutyrate biosynthesis via methanol chain elongation: converting organic wastes to platform chemicals
  Chen, W.S. ; Huang, Shengle ; Strik, D.P.B.T.B. ; Buisman, C.J.N. (2017)
  Journal of Chemical Technology and Biotechnology 92 (6). - p. 1370 - 1379.

- Simultaneous recovery of calcium phosphate granules and methane in anaerobic treatment of black water : Effect of bicarbonate and calcium fluctuations
  Cunha Costa, J.M.R. da; Tervahauta, T. ; Weijden, R.D. van der; Hernández Leal, L. ; Zeeman, G. ; Buisman, C.J.N. (2017)
  Journal of Environmental Management .
- Association between DNA methylation profiles in leukocytes and serum levels of persistent organic pollutants in Dutch men
  Dungen, Myrthe van den; Murk, A.J. ; Kampman, Ellen ; Steegenga, Wilma T. ; Gils-Kok, Dieuwertje van (2017)
  Environmental Epigenetics 3 (1). - 11 p.
- Persistent organic pollutants alter DNA methylation during human adipocyte differentiation
  Dungen, Myrthe W. van den; Murk, Albertinka J. ; Gils-Kok, Dieuwertje van; Steegenga, Wilma T. (2017)
  Toxicology in Vitro 40 . - p. 79 - 87.
- Theory of pH changes in water desalination by capacitive deionization
  Dykstra, J.E. ; Keesman, K.J. ; Biesheuvel, P.M. ; Wal, A. van der (2017)
  Water Research 119 . - p. 178 - 186.
- Energy efficiency of a concentration gradient flow battery at elevated temperatures
  Egmond, W.J. van; Starke, U.K. ; Saakes, M. ; Buisman, C.J.N. ; Hamelers, H.V.M. (2017)
  Journal of Power Sources 340 . - p. 71 - 79.
- Impact of compost and manure on the ripening of dredged sediments
  Figueiredo Oliveira, Bruna Raquel ; Laarhoven, Bob ; Smit, Martijn P.J. ; Rijnaarts, Huub H.M. ; Grotenhuis, Tim (2017)
  Journal of Soils and Sediments 17 (2). - p. 567 - 577.
- Functional properties of soils formed from biochemical ripening of dredged sediments—subsidence mitigation in delta areas
  Figueiredo Oliveira, Bruna Raquel ; Smit, Martijn P.J. ; Paassen, Leon A. van; Grotenhuis, Tim C. ; Rijnaarts, Huub H.M. (2017)
  Journal of Soils and Sediments 17 (1). - p. 286 - 298.
- Assessment of nitrogen and phosphorus flows in agricultural and urban systems in a small island under limited data availability
  Firmansyah, I. ; Spiller, M. ; Ruijter, F.J. De; Carsjens, G.J. ; Zeeman, G. (2017)
  Science of the Total Environment 574 . - p. 1521 - 1532.
- Biofilm formation and granule properties in anaerobic digestion at high salinity
  Gagliano, M.C. ; Ismail, S.B. ; Stams, A.J.M. ; Plugge, C.M. ; Temmink, H. ; Lier, J.B. Van (2017)
  Water Research 121 . - p. 61 - 71.
- Bio-production of selenium nanoparticles with diverse physical properties for recovery from water
  Hageman, Simon P.W. ; Weijden, Renata D. van der; Stams, Alfons J.M. ; Buisman, Cees J.N. (2017)
  International Journal of Mineral Processing 169 . - p. 7 - 15.
- Microbial selenium sulfide reduction for selenium recovery from wastewater
  Hageman, S.P.W. ; Weijden, R.D. van der; Stams, A.J.M. ; Cappellen, P. van; Buisman, C.J.N. (2017)
  Journal of Hazardous Materials 329 . - p. 110 - 119.
- Metabolism of Ibuprofen by Phragmites australis : Uptake and Phytodegradation
  He, Yujie ; Langenhoff, Alette A.M. ; Sutton, Nora B. ; Rijnaarts, Huub H.M. ; Blokland, Marco H. ; Chen, Feiran ; Huber, Christian ; Schröder, Peter (2017)
  Environmental Science and Technology 51 (8). - p. 4576 - 4584.
- Bench scale steam explosion pretreatment of acid impregnated elephant grass biomass and its impacts on biomass composition, structure and hydrolysis
  Kataria, Rashmi ; Mol, Annemerel ; Schulten, Els ; Happel, Anton ; Mussatto, Solange I. (2017)
  Industrial Crops and Products 106 . - p. 48 - 58.
- Effect of humic acids on the activity of pure and mixed methanogenic cultures
  Khadem, Ahmad F. ; Azman, Samet ; Plugge, Caroline M. ; Zeeman, Grietje ; Lier, Jules B. van; Stams, Fons (2017)
  Biomass and Bioenergy 99 . - p. 21 - 30.
- Scenario analysis of rainwater harvesting and use on a large scale–assessment of runoff, storage and economic performance for the case study Amsterdam Airport Schiphol
  Kuller, Martijn ; Dolman, N.J. ; Vreeburg, J.H.G. ; Spiller, Marc (2017)
  Urban Water Journal 14 (3). - p. 237 - 246.

- Hydrogen Gas Recycling for Energy Efficient Ammonia Recovery in Electrochemical Systems
  Kuntke, Philipp ; Rodríguez Arredondo, Mariana ; Widyakristi, Laksminarastri ; Heijne, Annemiek ter; Sleutels, Tom H.J.A. ; Hamelers, Hubertus V.M. ; Buisman, Cees J.N. (2017)
  Environmental Science and Technology 51 (5). - p. 3110 - 3116.
- Membrane Bioreactor (MBR) as Alternative to a Conventional Activated Sludge System Followed by Ultrafiltration (CAS-UF) for the Treatment of Fischer-Tropsch Reaction Water from Gas-to-Liquids Industries
  Laurinonyte, Judita ; Meulepas, Roel J.W. ; Brink, Paula van den; Temmink, Hardy (2017)
  Water Air and Soil Pollution 228 .
- Electrochemical Induced Calcium Phosphate Precipitation : Importance of Local pH
  Lei, Yang ; Song, Bingnan ; Weijden, Renata D. van der; Saakes, M. ; Buisman, Cees J.N. (2017)
  Environmental Science and Technology 51 (19). - p. 11156 - 11164.
- Heat-Treated Stainless Steel Felt as a New Cathode Material in a Methane-Producing Bioelectrochemical System
  Liu, Dandan ; Zheng, Tianye ; Buisman, Cees ; Heijne, Annemiek Ter (2017)
  ACS sustainable chemistry & engineering 5 (12). - p. 11346 - 11353.
- Structural uncertainty in air mass factor calculation for NO₂ and HCHO satellite retrievals
  Lorente Delgado, Alba ; Folkert Boersma, K. ; Yu, Huan ; Dörner, Steffen ; Hilboll, Andreas ; Richter, Andreas ; Liu, Mengyao ; Lamsal, Lok N. ; Barkley, Michael ; Smedt, Isabelle De; Roozendael, Michel Van; Wang, Yang ; Wagner, Thomas ; Beirle, Steffen ; Lin, Jin Tai ; Krotkov, Nickolay ; Stammes, Piet ; Wang, Ping ; Eskes, Henk J. ; Krol, Maarten (2017)
  Atmospheric Measurement Techniques 10 (3). - p. 759 - 782.
- Competition between methanogens and acetogens in biocathodes : A comparison between potentiostatic and galvanostatic control
  Molenaar, Sam D. ; Saha, Pradip ; Mol, Annemerel R. ; Sleutels, Tom H.J.A. ; Heijne, Annemiek ter; Buisman, Cees J.N. (2017)
  International Journal of Molecular Sciences 18 (1).
- Enhancement of methane production from 1-hexadecene by additional electron donors
  Paulo, A.M.S. ; Salvador, Andreia F. ; Alves, J.I. ; Castro, R. ; Langenhoff, A.A.M. ; Stams, A.J.M. ; Cavaleiro, Ana J. (2017)
  Microbial Biotechnology . - 10 p.
- Continuous long-term bioelectrochemical chain elongation to butyrate
  Raes, S.M.T. ; Jourdin, Ludovic ; Buisman, C.J.N. ; Strik, D.P.B.T.B. (2017)
  ChemElectroChem 4 (2). - p. 386 - 395.
- Oil biodegradation : Interactions of artificial marine snow, clay particles, oil and Corexit
  Rahsepar, Shokouhalsadat ; Langenhoff, Alette A.M. ; Smit, Martijn P.J. ; Eenennaam, Justine S. van; Murk, Tinka ; Rijnaarts, Huub H.M. (2017)
  Marine Pollution Bulletin 125 (1-2). - p. 186 - 191.
- Turbulent mixing accelerates PAH desorption due to fragmentation of sediment particle aggregates
  Rakowska, Magdalena I. ; Smit, Martijn P.J. ; Kupryianchyk, Darya ; Qin, Jinyi ; Koelmans, Bart ; Rijnaarts, Huub H.M. ; Grotenhuis, Tim (2017)
  Journal of Soils and Sediments 17 (1). - p. 277 - 285.
- Continuous versus batch production of lipids in the microalgae Acutodesmus obliquus
  Remmers, I.M. ; Hidalgo-Ulloa, A. ; Brandt, B.P. ; Evers, W.A.C. ; Wijffels, R.H. ; Lamers, P.P. (2017)
  Bioresource Technology 244 . - p. 1384 - 1392.
- Gas diffusion electrodes improve hydrogen gas mass transfer for a hydrogen oxidizing bioanode
  Rodenas, Pau ; Zhu, Fangqi ; Heijne, Annemiek ter; Sleutels, Tom ; Saakes, Michel ; Buisman, Cees (2017)
  Journal of Chemical Technology and Biotechnology 92 (12). - p. 2963 - 2968.
- Prototype of a scaled-up microbial fuel cell for copper recovery
  Rodenas Motos, Pau ; Molina, Gonzalo ; Heijne, Annemiek ter; Sleutels, Tom ; Saakes, M. ; Buisman, Cees (2017)
  Journal of Chemical Technology and Biotechnology 92 (11). - p. 2817 - 2824.
- Load ratio determines the ammonia recovery and energy input of an electrochemical system
  Rodríguez Arredondo, Mariana ; Kuntke, Philipp ; Heijne, Annemiek Ter; Hamelers, Hubertus V.M. ; Buisman, Cees J.N. (2017)
  Water Research 111 . - p. 330 - 337.

- Centralised, decentralised or hybrid sanitation systems? Economic evaluation under urban development uncertainty and phased expansion
Roefs, Ivar ; Meulman, Brendo ; Vreeburg, Jan H.G. ; Spiller, Marc (2017)
Water Research 109 . - p. 274 - 286.
- Membrane Selectivity Determines Energetic Losses for Ion Transport in Bioelectrochemical Systems
Sleutels, Tom H.J.A. ; Heijne, Annemiek ter; Kuntke, Philipp ; Buisman, Cees J.N. ; Buisman, Cees J.N. ; Hamelers, Hubertus V.M. (2017)
ChemistrySelect 2 (12). - p. 3462 - 3470.
- Discovery of anaerobic lithoheterotrophic haloarchaea, ubiquitous in hypersaline habitats
Sorokin, Dimitry Y. ; Messina, Enzo ; Smedile, Francesco ; Roman, Pawel ; Sinninghe Damsté, J.S. ; Ciordia, Sergio ; Mena, Maria Carmen ; Ferrer, Manuel ; Golyshin, Peter N. ; Kublanov, Ilya V. (2017)
ISME Journal 11 (5). - p. 1245 - 1260.
- Red mud as secondary source for critical raw materials - purification of rare earth elements by liquid/liquid extraction
Ujaczki, Éva ; Zimmermann, Yannick ; Gasser, Christoph ; Molnár, Mónika ; Feigl, Viktória ; Lenz, Markus (2017)
Journal of Chemical Technology and Biotechnology 92 (10). - p. 2683 - 2690.
- Red mud as secondary source for critical raw materials - extraction study
Ujaczki, Éva ; Zimmermann, Yannick S. ; Gasser, Christoph A. ; Molnár, Mónika ; Feigl, Viktória ; Lenz, Markus (2017)
Journal of Chemical Technology and Biotechnology 92 (11). - p. 2835 - 2844.
- Enhanced Performance of the Eurostat Method for Comprehensive Assessment of Urban Metabolism : A Material Flow Analysis of Amsterdam
Voskamp, Ilse M. ; Stremke, Sven ; Spiller, Marc ; Perrotti, Daniela ; Hoek, Jan Peter van der; Rijnaarts, Huub H.M. (2017)
Journal of Industrial Ecology 21 (4). - p. 887 - 902.
- Electricity from wetlands : Tubular plant microbial fuels with silicone gas-diffusion biocathodes
Wetser, Koen ; Dieleman, Kim ; Buisman, Cees ; Strik, David (2017)
Applied energy 185 . - p. 642 - 649.
- Operational parameters affecting MB/Red-light photosensitized degradation of pharmaceuticals
Ye, Y. ; Luo, Y. ; Bruning, H. ; Yntema, D. ; Rijnaarts, H.H.M. (2017)
Journal of Photochemistry and Photobiology. A, Chemistry 348 . - p. 96 - 101.
- Homogeneous photosensitized degradation of pharmaceuticals by using red light LED as light source and methylene blue as photosensitizer
Ye, Y. ; Bruning, H. ; Yntema, D. ; Mayer, M. ; Rijnaarts, H. (2017)
Chemical Engineering Journal 316 . - p. 872 - 881.
- Ammonia recovery from urine in a scaled-up Microbial Electrolysis Cell
Zamora, Patricia ; Georgieva, Tanya ; Heijne, Annemiek ter; Sleutels, Tom H.J.A. ; Jeremiasse, Adriaan W. ; Saakes, Michel ; Buisman, Cees J.N. ; Kuntke, Philipp (2017)
Journal of Power Sources 356 . - p. 491 - 499.
- Long-term operation of a pilot-scale reactor for phosphorus recovery as struvite from source-separated urine
Zamora, Patricia ; Georgieva, Tanya ; Salcedo, Inmaculada ; Elzinga, Nico ; Kuntke, Philipp ; Buisman, Cees J.N. (2017)
Journal of Chemical Technology and Biotechnology 92 (5). - p. 1035 - 1045.
- Glyphosate (Ab)sorption by Shoots and Rhizomes of Native versus Hybrid Cattail (Typha)
Zheng, Tianye ; Sutton, Nora B. ; Jager, Pim de; Grosshans, Richard ; Munira, Sirajum ; Farenhorst, Annemieke (2017)
Bulletin of Environmental Contamination and Toxicology 99 (5). - p. 595 - 600.
- Development and validation of a drinking water temperature model in domestic drinking water supply systems
Zlatanovic, Ljiljana ; Moerman, Andreas ; Hoek, Jan Peter van der; Vreeburg, Jan ; Blokker, Mirjam (2017)
Urban Water Journal 14 (10). - p. 1031 - 1037.
- An experimental study on the influence of water stagnation and temperature change on water quality in a full-scale domestic drinking water system
Zlatanović, Lj ; Hoek, J.P. van der; Vreeburg, J.H.G. (2017)
Water Research 123 . - p. 761 - 772.

Refereed book chapters

- Mixed Culture Chain Elongation (MCCE) - A Novel Biotechnology for Renewable Biochemical Production from Organic Residual Streams.
  Chen, W.S. ; Roghair, M. ; Triana Mecerreyes, D. ; Strik, D.P.B.T.B. ; Kroeze, C. ; Buisman, C.J.N. (2017)
  In: Energy Engineering / Raghavan, K.V., Ghosh, P., Singapore : Springer Nature Singapore, - p. 157 - 158.
- Understanding selenium biogeochemistry in engineered ecosystems : Transformation and analytical methods
  Jain, Rohan ; Hullebusch, Eric D. Van; Lenz, Markus ; Farges, François (2017)
  In: Bioremediation of Selenium Contaminated Wastewater Springer International Publishing Switzerland, - p. 33 - 56.
- Electrodes for cathodic microbial electrosynthesis processes: Key developments and criteria for effective research and implementation
  Jourdin, Ludovic ; Strik, David (2017)
  In: Functional Electrodes for Enzymatic and Microbial Electrochemical Systems - p. 429 - 473.
- E-course: Micropollutants in water
  Langenhoff, A.A.M. ; Meric, S. (2017)
  In: Innovative Wastewater Treatment Technologies & Resource Recovery Technologies / Lema, J.M., Suarez, S.S., London : IWA Publishing, - p. 618 - 620.

PhD Theses

- Lactic acid fermentation of human excreta for agricultural application
  Andreev, Nadejda (2017)
  University. Promotor(en): Piet Lens. - Leiden : CRC Press/Balkema, - 207
- Microbial chain elongation based on methanol
  Chen, Wei-Shan (2017)
  University. Promotor(en): Cees Buisman; Carolien Kroeze, co-promotor(en): David Strik. - Wageningen : Wageningen University, - 201
- Marine snow formation during oil spills: additional ecotoxicological consequences for the benthic ecosystem
  Eenennaam, Justine S. van (2017)
  University. Promotor(en): Tinka Murk, co-promotor(en): Edwin Foekema. - Wageningen : Wageningen University, - 160
- Lift up of Lowlands : beneficial use of dredged sediments to reverse land subsidence
  Figueiredo Oliveira, Bruna Raquel (2017)
  University. Promotor(en): Huub Rijnaarts, co-promotor(en): Tim Grotenhuis. - Wageningen : Wageningen University, - 229
- Physiology and application of sulfur-reducing microorganisms from acidic environments
  Florentino, Anna Patrícya (2017)
  University. Promotor(en): Fons Stams, co-promotor(en): Irene Sanchez Andrea; Jan Weijma. - Wageningen : Wageningen University, - 264
- Removal of pharmaceutically active compounds in constructed wetlands: mechanisms and application
  He, Yujie (2017)
  University. Promotor(en): Huub Rijnaarts, co-promotor(en): Alette Langenhoff; Nora Sutton. - Wageningen : Wageningen University, - 290
- Valorisation of waste streams from by-product to worm biomass
  Laarhoven, Bob (2017)
  University. Promotor(en): Cees Buisman, co-promotor(en): Hardy Temmink; Hellen Elissen. - Wageningen : Wageningen University, - 141
- Bioelectrochemical metal recovery with microbial fuel cells
  Rodenas Motos, Pau (2017)
  University. Promotor(en): Cees Buisman, co-promotor(en): Annemiek ter Heijne; Tom Sleutels. - Wageningen : Wageningen University, - 126 p.

Refereed conference paper

- Assessing the flexibility potential of the residential load in smart electricity grids - A data-driven approach
  Azari, Delaram ; Torbaghan, Shahab Shariat ; Cappon, Hans ; Gibescu, Madeleine ; Keesman, Karel ; Rijnaarts, Huub (2017)
  In: 2017 14th International Conference on the European Energy Market, EEM 2017. - IEEE computer society, 14th International Conference on the European Energy Market, EEM 2017, Dresden, 2017-06-06/2017-06-09
- Water Out Shit In: a new paradigm for resource recovery
  Chen, W.S. ; Vreeburg, J.H.G. (2017)
  In: Proceedings of the 43rd International Symposium of CIB W062 on Water Supply and Drainage for Buildings. - CIB International Council for Research and Innovation in Building and Construction, 43rd International Symposium of CIB W062 Water Supply and Drainage for Buildings, Haarlem, 2017-08-23/2017-08-25 - p. 431 - 441.
- X-ray diffraction of iron containing samples : The importance of a suitable configuration
  Mos, Yvonne M. ; Vermeulen, Arnold C. ; Buisman, Cees J.N. ; Weijma, Jan (2017)
  In: 22nd International Biohydrometallurgy Symposium. - Trans Tech Publications Ltd, (Solid State Phenomena) 22nd International Biohydrometallurgy Symposium, 2017, Freiberg, 2017-09-24/2017-09-27 - p. 545 - 548.
- Immobilization of arsenic by a thermoacidophilic mixed culture with pyrite as energy source
  Vega, Silvia ; Weijma, Jan ; Buisman, Cees (2017)
  In: 22nd International Biohydrometallurgy Symposium. - Trans Tech Publications Ltd, (Solid State Phenomena) 22nd International Biohydrometallurgy Symposium, 2017, Freiberg, 2017-09-24/2017-09-27 - p. 656 - 659.
- Chemical vs. Biological crystals, all the same?
  Weijma, Jan ; González-Contreras, Paula ; Buisman, Cees N.J. (2017)
  In: 22nd International Biohydrometallurgy Symposium. - Trans Tech Publications Ltd, (Solid State Phenomena) 22nd International Biohydrometallurgy Symposium, 2017, Freiberg, 2017-09-24/2017-09-27 - p. 559 - 562.

Other output

- Towards combining heterogeneous electro-catalysis and bio-electro-synthesis
  Chatzipanagiotou, K.R. ; Jourdin, Ludovic ; Buisman, C.J.N. ; Strik, D.P.B.T.B. ; Bitter, J.H. (2017)
- Towards combining heterogeneous electro-catalysis and bio-electro-synthesis
  Chatzipanagiotou, K.R. ; Buisman, C.J.N. ; Strik, D.P.B.T.B. ; Bitter, J.H. (2017)
- Association between DNA methylation profiles in leukocytes and serum levels of persistent organic pollutants in Dutch men
  Dungen, Myrthe van den; Murk, Tinka ; Kampman, Ellen ; Steegenga, Wilma ; Gils-Kok, Dieuwertje van (2017)
- Van business case naar value case in de afvalwaterketen : Nieuwe selectiemethode voor toekomstbestendige en duurzame sanitatietechnologieën voor huishoudelijk afvalwater
  Merksteijn, C. van; Telkamp, P. ; Zeeman, G. (2017)
  H2O online . - 8
- Chemical phosphorus recovery from animal manure and digestate : Laboratory and pilot experiments
  Schoumans, O.F. ; Ehlert, P.A.I. ; Regelink, I.C. ; Nelemans, J.A. ; Noij, I.G.A.M. ; Tintelen, W. van; Rulkens, W.H. (2017)
  Wageningen : Wageningen Environmental Research, (Wageningen Environmental Research rapport 2849) - 113