Environmental Technology

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Picture: NASA

News

Zilveren Zandloper award for former ETE scientist Bert Hamelers

Photo: NBV

In April 2016, scientist Bert Hamelers was awarded the Zilveren Zandloper Innovation Award. This prize is made available every other year by the Dutch Biotechnology Society (NBV) to one or more persons, or an organization, that has successfully turned biotechnology science into a business. During his previous scientific work at ETE Hamelers was the driving force behind the foundation of several spin-off companies. His ideas and research have resulted in 22 internationally filed patents and three highly successful spin-off companies. The jury mentioned his impressive track record in biotechnology as a group leader at ETE and currently as a program director at Wetsus, European Centre of Excellence for Sustainable Water Technology. According to the Jury, Hamelers' outstanding achievement in applied research has led to ground breaking innovations and the establishment of successful companies that contribute to solving the biggest global challenges the world faces today.

Dedicated students

Hameler's sees his contribution to science mainly as generator of ideas. 'Together with a team of dedicated PhD-students, we managed to put those ideas into practice and establish several companies', the prize winner says.' Famous examples of these spin-off firms are **Plant-e**, where plants play a key role to generate electricity, **ChainCraft** operating a pilot plant to synthesize valuable components from organic waste, and last but not least **REDSTACK** aiming at generating **Blue Energy**. In the blue energy pilot plant at the Afsluitdijk electricity is generated by mixing salt and fresh water. The 'waste' product is brackish water. This will be utilized to develop a natural transition area between the Wadden Sea and the freshwater IJsselmeer.

Column ***Huub Rijnaarts***

Environmental Technology is booming. With over 60 M.Sc. and more than 8 Ph.D. graduates every year, we deliver well-trained people to establish the Environmental Solutions needed in our societies world-wide.

Four new programs enabled us to appoint 17 new Ph.D. candidates in 2016. The first program, ENTIRE, focuses on industrial water reuse in Ho Chi Minh City. In WATER NEXUS, water recirculation and technologies for the use of brackish water in industrial processes will be studied, for companies like Dow and Shell. WATER SEED is a program that focuses on the application of organic polymers in biological, electro and membrane water treatment technologies. Finally, Evides supports a project that focuses on technologies for removing micro pollutants and harmful bacteria.

Also ETE's international program is booming. A team of dedicated Ph.D. students and postdocs submitted and won a dialogue seminar NWO proposal (CHINED-4D)! CHINED-4D is about establishing collaborations with the Chinese Academy of Sciences and associated Chinese Top Universities, on sustainable environmental technologies and development and biobased economy. This seminar will be held in Beijing, June 4-8, with 25 participants of Wageningen, and 25 Chinese scientists. This event is part of the ETE Ph.D. trip to China, in which universities and companies in Beijing, Xi.'An, and Shanghai will be visited.

With these initiatives, we are ready for the coming decade.

Disappointment
But success doesn't come easy. For example, in these case of ChainCraft it was preceded by disappointment. 'We were trying to produce ethanol from volatile fatty acids, formed by fermenting organic waste', Hamelers says. 'We succeeded, but then we noticed to our disappointment that these alcohols were disappearing again. More or less by coincidence we found out they were converted in valuable compounds, which now form the basis of ChainCraft.'

Rachel Carson Prize for Rosanne Wielemaker

Photo: VVM. **Left: Rosanne Wielmaker, right: Casper Borsje (currently ETE PhD student), who was also nominated for the prize.**

ETE student Rosanne Wielemaker was awarded the 13th Rachel Carson Environmental Thesis Prize, last November 2015 for her M.Sc. thesis '*Harvest to harvest*'. This prize is awarded annually by VVM, a network organization of environmental professionals. Only outstanding theses on environmental and sustainability research may compete. In her thesis, Wielemaker aims to close nutrient cycles in urban agriculture by using nutrients recovered from household waste via 'new sanitation' systems. The jury evaluated her thesis as 'very good'. They particularly appreciated the originality and integral approach, and its valuable contribution to urban agriculture.

Closing nutrient cycles
Cities import high quantities of water, energy, and food, while producing waste flows containing disposed and excreted nutrients. These nutrients are mostly not recovered for reuse. However, according to Wielemaker, more and more cities produce food within their city boundaries. 'These urban agriculture systems offer the possibilities to utilize recovered nutrients from the city's sanitation and kitchen waste, thereby closing nutrient cycles', she states. 'But for effective resource management and an efficient reuse of recovered nutrients, such as nitrogen (N) and phosphorous (P), supply and demand should be matched.'

Balance nutrient flows
Nutrient demand from urban agriculture remains unquantified and unmanaged. Similarly, nutrient supply from sanitation systems is also largely unknown. Therefore, Wielemaker calculated both nutrient supply from waste and demand from urban agriculture systems to balance nutrient flows for a virtual situation in the city of Rotterdam. Her results showed that nutrient demand from Rotterdam's urban agriculture was relatively high. 'Current use of P exceeds the actual need by a factor three to seven', Wielemaker explains. 'So the demand for this nutrient can be reduced dramatically.' The results further showed that for 1 ha of urban agriculture, household wastewater and kitchen waste collected from 25-45 individuals could supply 100 % of P and about 50% of N by recovering nutrients.
Wielemaker's study shows that recovering nutrients from urban waste can match nutrient demand by urban agriculture in Rotterdam to a large extent, increasing self-sufficiency of the city, while closing nutrient cycles.

UFW-KLV prize Shengle Huang

ETE student Shengle Huang received the UFW-KLV thesis prize within the domain of environmental sciences for his M.Sc. thesis '*Optimization of Methanol-based Mixed Culture Chain Elongation*'. This yearly prize is awarded to the best thesis or publication written by students in their M.Sc. phase. According to the jury the content of Huang´s thesis was ´impressive´. The thesis was clear and well-written with excellent tables and figures. In addition, the jury appreciated the practical applications of the thesis, which describes how low-grade organic waste is converted into valuable biochemicals.

Photo: UFW-KLV

Science: Storing energy using microorganisms

By combining existing technologies, ETE Ph.D. scientist at Wetsus, Sam Molenaar, developed a rechargeable battery, where microorganisms play a key role. The concept combines the principles of the microbial fuel cell with microbial electrosynthesis. Recent experiments have confirmed that the system is working. Molenaar: 'It may form a stable, environmental friendly and inexpensive alternative to store energy.'

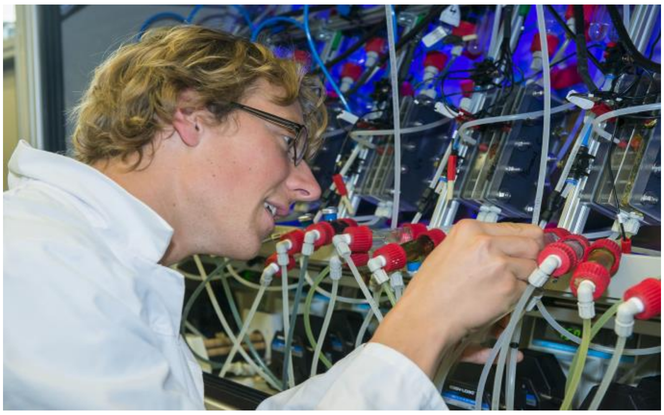


Photo: Wild Frontiers

Renewable energy sources like sun or wind don't deliver a continuous and steady amount of energy that is matched with consumer demands. During peak production, an excess of energy is delivered, while during periods without sun or wind, they provide too little energy. Therefore, to implement these green energy sources on a larger scale, storing energy to match supply and demand is essential. However, current energy storing systems have several issues, such as safety, the presence of toxic substances or the need for scarce and non-renewable substances. According to Molenaar, there is an environmental friendly alternative. 'Microorganisms may play an important role in storing electrical energy', says Molenaar. 'They are able to use electricity to generate certain compounds; these substances can subsequently be transformed back into electricity by other species of microorganisms.'

Rechargeable bio-battery

For the rechargeable bio-battery, Molenaar was inspired by two different technologies: the *microbial fuel cell* and *microbial electrosynthesis*. In the microbial fuel cell, microorganisms produce electricity. They grow on the anode while extracting electrons from organic matter present in for example wastewater or urine. These electrons are subsequently transferred to the anode, generating an electron flow: electricity. So, in this system, chemical energy is converted into electrical energy.

The opposite is essentially happening during microbial electrosynthesis. Microorganisms grow at the cathode, while using electricity (electrons) and a carbon source like CO_2. These bacteria take up electrons generated at the anode and produce biomass and acetate at the cathode. 'Acetate is a perfect substrate for microorganisms in the microbial fuel cell to produce energy', Molenaar explains. 'So, when you combine these two systems, you have in fact a rechargeable bio-battery.' He further developed this concept into his so-called Microbial Rechargeable Battery, briefly MRB, where he connected the two different systems. In the MRB microorganisms at the bio-cathode use electricity and CO_2 to produce acetate, while at the bio-anode different microbiota use acetate to produce electricity.

Mimicking solar panels

Subsequent experiments provided solid proof that the concept was working. 'We successfully operated the two systems in turn during a 24 hour period, with acetate production during the night at the cathode and electricity production during the day at the anode', Molenaar explains. 'We were in fact mimicking solar panels that also produce energy only during daytime.' The overall energy efficiency was about 40%, so the scientist is working to increase efficiency of his MRB: 'Although the battery will always have some losses due to the fact the bacteria have to grow and maintain themselves, this may surely be further improved'. Also regarding the energy density further improvements are required. It will most likely never be as high as in lithium batteries, but levels comparable to old-fashioned lead-acid batteries may be achieved. The system is therefore not suitable to be used in electric cars, it would simply become too big.' According to Molenaar, his finding is a promising alternative for the stationary storage of energy. The working concept has shown that MRB could become an inexpensive and environmentally friendly energy storage device in the future.

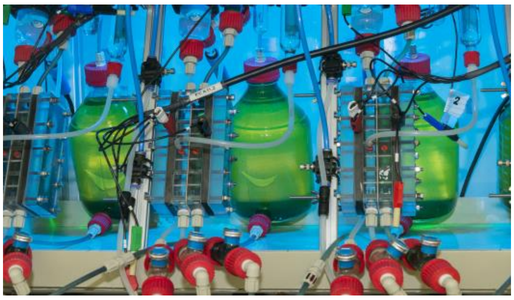


Photo: Wild Frontiers

This research was performed at Wetsus, within the theme "Resource Recovery", supported by Magneto Special Anodes BV, Mast Carbon, Desah, Kemira, Evides, Abengoa Water, Waterschap De Dommel

Published as: Molenaar et al. 2016. Microbial Rechargeable Battery: Energy Storage and Recovery through Acetate. Environmental Science and Technology Letters, 2016.

Science: Drug residue removal from wastewater

Drug residue removal from wastewater
ETE Ph.D. researcher Yujie He developed a method for more efficient removal of drug residues from wastewater. Current wastewater treatment plants are relatively ineffective to remove these pharmaceuticals resulting in a substantial environmental exposure. Yujie improved existing photo-degradation technologies and combined this method with a second cleaning step using so called constructed wetlands.

Photo: Wild Frontiers

The use of pharmaceuticals, such as the painkillers ibuprofen, diclofenac and naproxen, but also beta blockers like propranolol and metoprolol, pose an increasing threat to our environment. Most of these compounds are actually only partly taken up by the body, the rest is excreted in urine.

Consequently, many of these drugs subsequently end up in wastewater. For example, in The Netherlands, from 34 pharmaceuticals investigated, about half ended up in sewage and surface water in relatively high concentrations: from ng/l to several ug/l. However, wastewater plants are not designed for the removal of these substances; roughly, for more persistent pharmaceuticals, less than one third can be removed. The rest is released into surface waters. Due to their persistency, they may accumulate through the food chain, affecting animals at the top of the food chain. 'Many pharmaceuticals may interfere with reproduction in vertebrates', Yujie explains. 'For example, exposure of fish to 0.001–10 mg/L of diclofenac has been shown to a significant decrease in hatching success.

Constructed wetlands

Photo-degradation, where UV in solar light breaks down these compounds into smaller break-down products (metabolites), has been shown to be rather effective to remove pharmaceuticals from wastewater. However, the efficiency of this method could be improved. In addition, the metabolites might be more toxic than the parent pharmaceuticals. Her research therefore aims to increase photo-degradation efficiency and combine this method with a second degradation step to breakdown the metabolites: constructed wetlands. These man-made wetlands consist of plants growing in substrate containing a lot of microorganisms. Waste water containing pharmaceuticals and their metabolites are directed into these wetlands after pre-treatment using sunlight (fig.1). The drugs are consequently absorbed to the substrate while micro-organisms further degrade these chemicals.

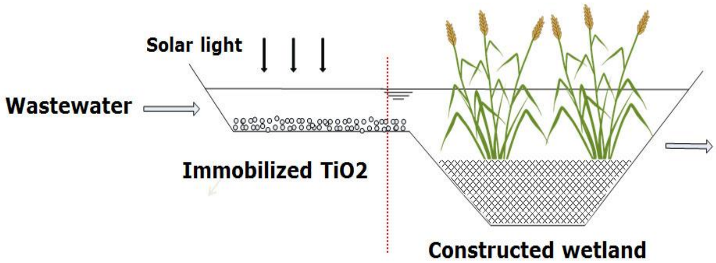


Fig. 1. Schematic overview of drug removal by photodegradation combined with constructed wetlands.

Effective catalyst

Yujie started her research by improving the photo-degradation pre-treatment step. 'I added titanium dioxide as a catalyst, so the residues are broken down more quickly and completely', she explains. 'To make sure the titanium dioxide doesn't end up in the water, I attached it to the sand in the substrate so it was immobilized.' The immobilized titanium dioxide proved to be a very effective catalyst. Within 3 days of treatment, beta-blocker propranolol and painkiller diclofenac were removed completely (Fig. 2). Other components, like carbamazepine and ibuprofen were more resistant towards photo-degradation, but were still reduced for about 93 % within 4 days (Fig. 2).

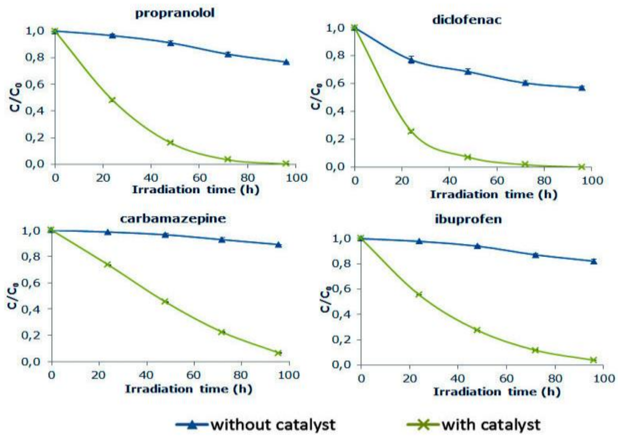


Fig. 2. Photodegradation of different pharmaceuticals with titanium oxide (green lines) and without titanium oxide (blue lines).

Valuable addition

To break-down the remaining pharmaceuticals and their metabolites resulting from photo-degradation, Yujie is now performing experiments where she uses constructed wetlands to study the potential of pharmaceutical breakdown by several pathways in wetlands, including photo-degradation, plant uptake, adsorption and biodegradation. The first results show large variation in persistence of pharmaceuticals that was also dependent on whether aerobic or anaerobic conditions were used in biodegradation. According to her, this second step could be a valuable addition to wastewater plants to improve the capacity for the removal of drug residues. But the scientist is also determined to clarify the key pathways inside the constructed wetlands.

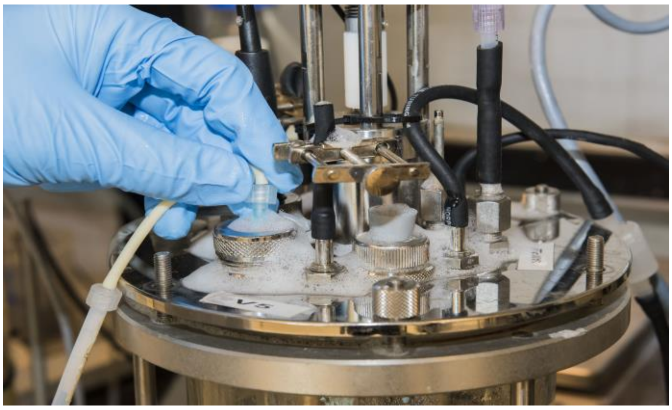
'Currently, constructed wetlands are still a black box and we have very limited knowledge of the processes taking place', she says. 'When we know more about the mechanisms of processes taking place, we can better control these processes resulting in a more efficient residue removal.'

Spin-off: From organic waste to valuable chemical building blocks

ETE's research regularly results in patents and the establishment of spin-of companies. ChainCraft was founded in 2010 as a direct result of ETE's discovery of a microbiological process where organic waste is converted into valuable chemical building blocks. The young company is now planning a demonstration factory that is economically viable and where the process is optimized.

Organic waste waiting to be processed
Photo: Wild Frontiers

A heavy, acidic smell penetrates my nose when I enter the huge factory hall of waste management concern Simadan BV in Amsterdam. Long rows of colored containers with organic waste are waiting to be processed to biogas. In a modest corner of the hall a few shiny stainless steel vessels contrast with the pungent smell. This is the pilot plant of ChainCraft. Organic waste serves a different purpose here: the manufacturing of sustainable biobased chemicals that can be used as building blocks for a variety of products. 'Our aim is to contribute to the biobased economy by converting waste into valuable raw materials without depletion of natural resources', ChainCraft director Niels van Stralen explains. 'We are working to optimize and commercialize the process of manufacturing high-value chemicals derived from waste streams.'



Lab facilities *Photo: Wild Frontiers.*

High-value chemical

ChainCraft, formerly called Waste2Chemical, was founded in 2010 as a spin-off of research carried out at ETE. In 2007 Ph.D. student Kirsten Steinbusch by coincidence discovered that microorganisms could convert volatile fatty acids (VFA's), small molecules derived from fermented organic waste, into caproate, a much larger molecule. This high-value chemical is a raw material for food, feed, pharma as well as a range of chemical materials. The caproate formation process was described in detail and subsequently patented by ETE. ChainCraft bought the patent and started the laborious process to commercialize production. Several investors, such as Dutch Greentech Fund and Horizon 3, financed the spin-off, and the young company set-up a research lab. Three years ago the small team delivered the proof of concept on lab scale and a next step to scale the process was taken. Van Stralen points at the shiny stainless steel components of their test facility. 'In 2014 this pilot plant was operational', he says. 'Here we test and optimize the process at an approximately 500 times bigger scale than in de lab.'

Economic viability

The results from the pilot plant experiments were very promising. 'The process works essentially similar as in the lab; we proved the technological feasibility of the process at this bigger scale', van Stralen states. 'But we still have to demonstrate the economic viability of the process.'

To test this, the research and development team needs to scale the process even more. For this reason, they have planned to realize a demonstration factory in 2017, where we can operate at again a 500 times bigger scale than the pilot plant.

Lasting impact

In addition to establishing a profitable demonstration factory, ChainCraft is planning more activities related to creating valuable components from waste. The technical and economic optimization of new processes will be incorporated in their research. Collaborations with ETE and other parties are part of ChainCraft's strategy. 'ETE still plays an important role in our activities and we still work closely together in some scientific areas', van Stralen explains. 'Examples are R&D of new processes and joint grant applications.' The future for ChainCraft looks bright and their team of dedicated researchers and engineers is determined to have an important contribution to manufacturing valuable components from waste. Van Stralen enjoys having a broad overview of the company's different activities: 'I feel like a spider in a web and I appreciate connecting different aspects of ChainCraft's R&D, financing, business development and team to have a lasting impact on a more sustainable society.'

Pilot plant *Photo: Chaincraft*

Agenda

PhD defences (Aula, Wageningen):

May 12 2016, 11:00: Pawel Roman. ´Biotechnological removal of H_2S and thiols from sour gas streams under haloalkaline conditions´

May 25, 2016, 11:00: Sjef van der Steen. ´"Beehold" The colony of the honeybee (Apis mellifera L) as a bio-sampler for pollutants and plant pathogens´

July 8, 2016, 16:00: Myrthe van Dungen. ´Revealing epigenetic mechanisms behind delayed adverse health effects of dioxins and PCBs in fish´

Sep 21, 2016, 11:00: Zhang Lei. ´The application of a UASB-digester system treating low temperature (10-20°C) domestic sewage´

Sep 23, 2016, 16:00: ´Microbial Electrosynthesis for chemical production from CO_2´

Oct 11, 2016, 16.00: Bruna Oliveira. ´Lift up Lowlands: The potential of organic sediments to reverse land subsidence´

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