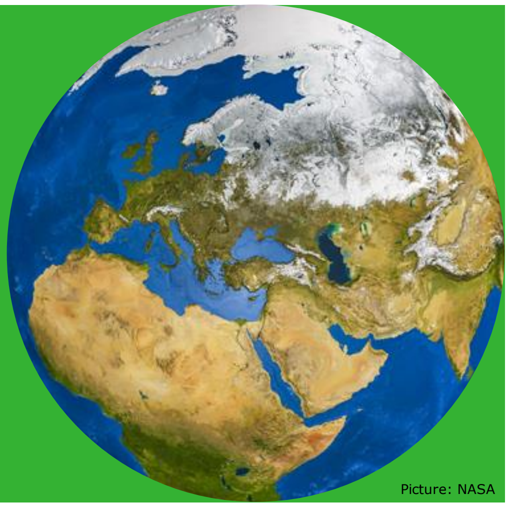
Environmental Technology



Picture: NASA

Newsletter | June 2023

WAGENINGEN UNIVERSITY
WAGENINGEN UR

News

Change of leadership at ETE

Annemiek ter Heijne succeeds Cees Buisman as new Chair Holder

On July 1st, Annemiek ter Heijne, Associate Professor at ETE, has replaced Cees Buisman as Chair Holder (Bio)recovery Technology for Circular Economy. Buisman has been Chair for over 20 years. He will continue as personal Professor at ETE for one day a week.

Ter Heijne has been employed by ETE for almost 17 years. After her PhD at ETE in 2006-2010, where she developed the microbial fuel cell as an innovative technology to recover electricity from wastewater, she continued to focus on Microbial Electrochemical Technologies, where microorganisms interact with electrodes. These systems can be used to recover valuable resources, like nutrients, metals, and energy, from wastewater.

New leadership role

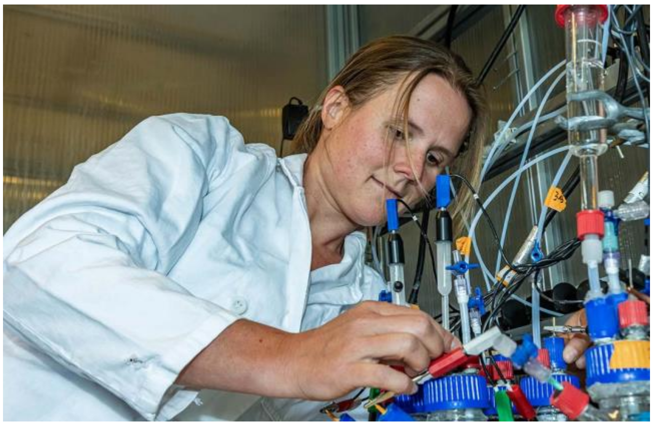
In her new role as Chair Holder, ter Heijne will face quite some changes in her activities: together with the other chair at ETE, she will function as some kind of general manager of the group, she will be responsible for the research activities in the field of biorecovery technologies at the department and co-responsible for the education program of ETE. In addition, she will also oversee the functioning of the laboratories, as well as personnel management. Ter Heijne: 'I will continue to supervise PhD students in my own expertise area, but will also become involved in new research topics in the field of biorecovery technologies.' In due time, she hopes to have support from a new colleague, who will replace retiring Professor Huub Rijnaarts, the other chair holder of ETE.

Overall research vision

ETE has grown enormously the last 10 years. Ter Heijne believes that consolidation of the large group of researchers and support staff is the first priority. In her new position, ter Heijne aims to increase her contribution to different research fields. 'Currently, I have a strong focus on resource recovery and and pollutant removal from wastewater using a combination of microorganisms and electricity', she explains. 'As the new chair, I would like to contribute more to other excellent and relevant research lines we already have at ETE. Together with the researchers in my group, I will develop an overall research vision of our chair, aimed at nutrient recovery, pollutant removal, degradation of plastics, recycling of bio-plastics, and using CO2 as a raw material for fuel or chemicals.' In all these research topics, micro-organisms often play a central and crucial role.

Boost collaboration

For most of ETE's research, the smooth operation of the laboratories is of paramount importance. Therefore, ter Heijne wants to boost collaboration and communication between the lab team, that is responsible for all lab operations, and the researchers. 'We could for example work more together to develop new methods', she explains. 'This way we benefit from the specific knowledge of both the lab team and the researchers, resulting in more efficient and optimal results.'



Good working environment

Although the new position is an important step in her career, she is down to earth and puts it all into perspective. Crucial to her is being healthy and happy, while having a good balance between work and private life. In that context, she highly values a good working environment for all employees. 'Our group should be a place where people feel safe and where all employees feel heard and appreciated', she says. 'To achieve this, it is very important for me to lead by example.'
But her main drive is to make the world a better place. Ter Heijne: 'I try to do that partly through my work, by motivating people, while putting the right person at the right place. But also, environmental technologies are important tools to contribute to a more sustainable society. For example, by developing techniques to recover materials, we can avoid depleting the earth and move towards a circular society.'

Teaching: more attractive and appealing

Another important goal of ter Heijne's is to make the BSc program of the Department of Environmental Sciences more attractive and appealing for students. She feels there should be more focus on the student's motivation and personal development, and a change in the current BSc program is needed. Therefore, she is already part of a committee that aims to redesign this BSc program of Environmental Sciences. 'Currently, the first year of the BSc is dominated by a lot of basic courses, where the context of the course often is lost', she explains. 'That may discourage and demotivate students. Therefore, we'd like to include more applied courses in the program, starting already during the first year. This puts the basic courses more in a context and illustrates how to incorporate and apply that fundamental knowledge into practice.'

Artificial Intelligence

But ter Heijne also keeps a close eye to new developments in the scientific field, while she is particularly fascinated by the rise of artificial Intelligence (AI): how to deal with that powerful development in science and education? 'I think AI can be a great contribution if used properly, especially in writing. For example, Chat GPT can be great writing tool, since it can supply the student with a basis, a general starting point for a writing assignment', she states. 'It may also help to structure texts, and help to write a coherent piece with good connections between the different paragraphs.' To what extent these tools can be used in research, is still a topic to be explored. As a group, but also as WUR, we need to develop a vision and strategy on how to use the benefits of AI, while being aware of the setbacks.

Honorary doctorate for a special microbiologist

On March 9th 2023, microbiologist Willy Verstraete received an honorary doctorate from Wageningen UR. Every DIES lustrum, Wageningen awards this special honor to a few outstanding scientists, that have an international reputation for contributions to a scientific field relevant for Wageningen UR.

Foto: Guy Ackermans

Together with more than 10 colleagues from different universities, ETE Professor Huub Rijnaarts took the initiative for the nomination of Willy Verstraete for an honorary doctorate, for his contributions to Environmental Biotechnology oriented on resource recovery. According to Rijnaarts and the initiators for the award, Professor Verstraete has been a major inspiration for many students and scientists active in this field. He showed that microorganisms are important allies to solve many societal problems related to health, waste management, reuse of raw materials and closing cycles for a circular economy.

Microorganisms to recycle

'Willy was far ahead of his time, and saw the potential of microorganisms to recycle carbon, nitrogen and phosphorous from waste', Rijnaarts says. 'Being a student in soil quality and waste water management and microbiology back in the 1980's, I met him during the frequent courses and lectures he gave in Wageningen and he inspired me with his vision to apply microorganisms in circularity and sustainability. Without any doubt, these lectures strongly contributed to the basis of my later career.'

Better reuse of resources

During most of his working life, Verstraete' s vision influenced Rijnaarts and colleagues to change traditional treatment methods for wastewater. These methods are still predominantly oriented on removal of carbon (C), nitrogen (N) and phosphorous (P) from water, using high amounts of oxygen and energy, and losing these as chemical waste (P) and to the atmosphere (C and N). This was and is not sustainable', Rijnaarts explains. 'At ETE we all applied and further developed Willy's philosophy, to close cycles in waste management by smartly using microorganisms, to recover C, N and P as reusable products, and remove harmful chemicals such as pharmaceuticals and salts. This will lead to a much better reuse of these resources, i.e. carbon in biogas or organic polymers and N and P as fertilizers for sustainable agriculture'.

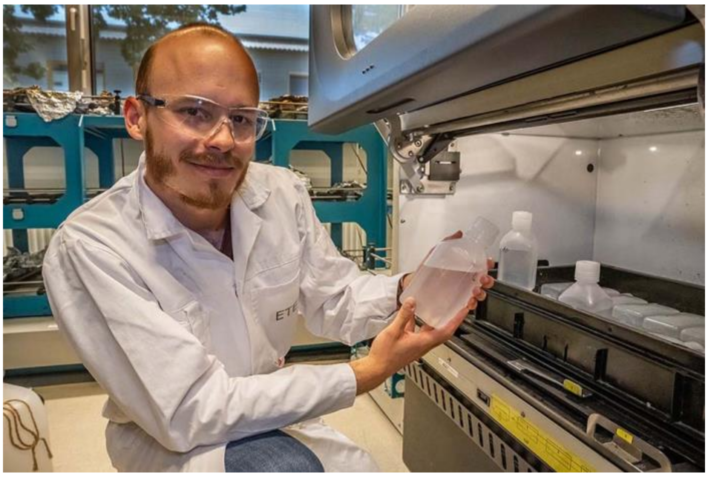
Lasting impact

Verstraete' s continuing collaboration with different Universities, including Wageningen UR and Delft University, made a lasting impact on the achievements in the environmental sciences and technology. Rijnaarts: 'The idea to award him the honorary doctorate was, not surprisingly, quickly embraced by all colleagues and resulted in a joint application.' Even today, Verstraete' s vision still influences many scientists. 'The two currently most urgent grand societal challenges, like reducing carbon emissions and reducing nitrogen emissions, can much better be solved if society would include environmental biotechnologies that work with the help of microorganisms', Rijnaarts says. 'Willy's vision he introduced 40 years ago is becoming more relevant for society and science day by day.'

Reducing PFAS concentrations in drinking water

PFAS is a group of industrial chemicals that have dispersed in the environment, including drinking water. ETE PhD student Marko Pranić is developing tools to help drinking water companies to remove these substances during the water purification process.

Polyfluoralkyl substances, PFAS, are industrial, persistent chemicals that are dirt-, water-, and fat-repellant. They are used in many consumer products, for example lubricants, water-proof clothing, anti-stick cookware and fire fighter foam. However, their properties also make them spread and accumulate in the environment, and they easily find their way into our food and drinking water.



Activated carbon

There are thousands of different types of PFAS, of which a few dozen are regulated. Exposure to PFAS occurs for about 80% through food and 20% through drinking water. Drinking water companies use activated carbon to remove contaminants from water. This porous material has a huge surface to volume area and many of these substances efficiently stick to the surface of the many pores inside activated carbon. 'But for PFAS this is not very effective, and removal is very slow', Pranić says. 'In addition, activated carbon appears to become saturated for PFAS quite quickly, and costly reactivation of the carbon is needed.'

Slow removal

To solve the problems to remove PFAS from drinking water, Pranić tries to understand what exactly happens with PFAS during drinking water treatment, particularly, inside the carbon filters. 'Maybe there is competition with other substances to stick to the coal, like organic substances or ions in the water' Pranić hypothesizes. But even in pure water, without any other components, PFAS removal is very slow, his experiments show. 'The models we use to describe the removal process, suggested that the PFAS mobility along the internal carbon surface is very slow, and it consequently takes time for PFAS to adsorb, Pranić explains. 'During drinking water treatment, the water flow through the carbon filter could easily drag the PFAS from the coal surface before it is adsorbed, so it isn't removed effectively.'

Eventually, Pranić hopes to better understand what's happening exactly during the purification process and supply tools for a more effective PFAS removal from drinking water. For example, by changing temperature, using a different kind of active carbon, or by pre-treating the water to achieve a better ion composition for removal.

Science: Using bio-sulfur as fertilizer in agriculture

Sulfur can be recovered from wastewater as well as gas streams using microorganisms, resulting in elemental sulfur. However, the reuse of this biologically produced sulfur is not always easy. However, sulfur is an essential nutrient for plants, and may therefore have great potential as a fertilizer in agriculture. Annemerel Mol, Assistant Professor at ETE, is investigating how to efficiently apply recovered bio-sulfur as fertilizer in agriculture to encourage sulfur reuse and close cycles.

The lights in the greenhouse of 'Nergena', Wageningen UR's plant experimental facility, shrouds everything in a yellowish glow. Annemerel Mol and MSc student Ángel Cimas Quero, are harvesting plants from their experiment that just ended. They collect the leaves and roots and weigh the different plant parts. 'In this plant experiment, we are investigating if this cabbage species grows well if we replace sulfate (SO_4^{2-}), present in artificial fertilizer, with bio-sulfur, recovered from natural gas', Annemerel Mol says. 'We measure the plant's size, but also check it's health by quantifying the pigments present, for example chlorophylls. We also look at the size and color of the flowers.' If the plant receives too little nutrients, like sulfur for example, some pigments may decrease, the roots will grow relatively big, trying to absorb more nutrients, while also the flowers will suffer: they remain smaller and often are white instead of yellow. If the experiment is successful, recovered bio-sulfur may have a future application as fertilizer in the agricultural industry, increasing its value, while making recycling easier.

Reduction of emissions

Sulfur recovery with microorganism from fuels, like natural gas, is a well-established technology, that has been developed by Professor Cees Buisman in the 1990's.

After the removal of sulfur, fuels are cleaner, resulting in a strong reduction of sulfur oxide (SO_2) emissions when these fuels are burnt. Excessive atmospheric SO_2 was once one of the causes of acid rain, due to its conversion into sulfuric acid (H_2SO_4). 'During the last 20 years, sulfur emissions have reduced substantially, due to these cleaner fuels', Mol explains. 'As a result, acid rain is largely a thing of the past, while deposition of sulfur-compounds has decreased as well.' However, the success of clean fuels results in a sulfur shortage in some areas; these sulfur depositions from burning fuels were important to grow crops in the intensive agricultural industry. Consequently, in the Eastern United States, but recently also in The Netherlands, sulfur has to be supplemented to successfully grow crops.

Successful fertilizer

The increasing sulfur shortage in agriculture offers a new application for recovered elemental bio-sulfur (Fig. 1) as a fertilizer. Wastewater and natural gas are currently the most important bio-sulfur sources. 'In wastewater, the organic matter present is fermented into biogas (CH_4) and hydrogen sulfide (H_2S) by microorganisms', Mol explains. 'Other microorganisms can subsequently convert 99 percent of the H_2S into pure, high-quality sulfur.'

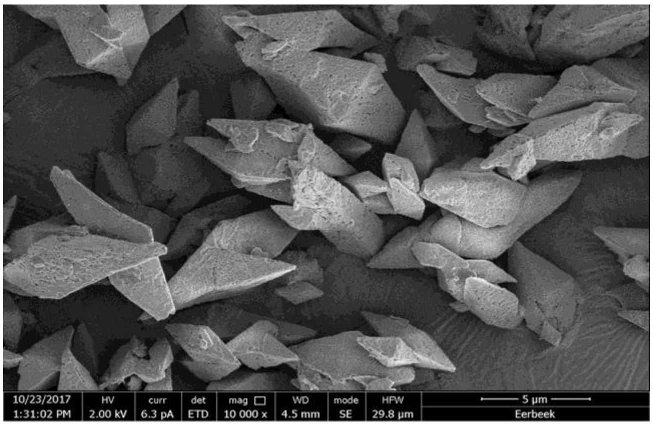


Fig. 1. Biosulfur crystals.

To find out if the bio-sulfur can be successfully applied as a fertilizer, Mol has planned different experiments. Currently, she is performing pot plant experiments in a greenhouse, but in the future, possibly also field experiments will be carried out, where sulfur fertilization can be evaluated under realistic farming conditions. 'In our pot plant experiment, we use a cabbage species, a plant with high sulfur requirements', she says. 'We want to compare growth and health of plants receiving elemental bio-sulfur with plants receiving sulfate, a sulfur source present in commercial fertilizer.' There is an important difference however, between sulfate and bio-sulfur. Sulfate can be absorbed directly and efficiently by the plant, while bio-sulfur requires microbial oxidation into sulfate, before it can be taken up. As a result, from this microbial conversion, bio-sulfur acts as a slow-release fertilizer, that could be beneficial.

But the scientists don't know yet how slow this release is, what the role is of different soil types, with their specific microorganism populations, and if it is actually beneficial for the plant. These are important questions that Mol aims to answer during her research.

Hurdles to take

Preliminary results of the plant pot experiment show that bio-sulfur is as suitable as a fertilizer as commercial sulfate, but there are some hurdles to take before the sulfur cycle can be closed effectively.
Mol: 'The main challenges of sulfur recycling are the logistics: how do you get your bio-sulfur from the place of production to the location where it can be used? If we recover large amounts of sulfur from wastewater, while the demand comes from overseas, how can we minimize transportation costs and overcome the complicated logistics?' In addition, the recovered sulfur might contain some small amounts of impurities, for example salts, that need to be removed before it can be used, adding to the costs. And minimizing total expenses is essential to effectively close the sulfur cycle. 'Economic viability is crucial for success. Landfilling recovered sulfur costs money, but if it can be used as fertilizer, the added value gives an extra incentive to recycle, despite some efforts needed', Mol states. 'With a possible decreasing fossil fuel use in the future, sulfur demand could increase due to an even more reduction in sulfur deposition, resulting in scarcity. We need to invest now in working technologies and an effective chain to recycle and reuse sulfur, so we are ready for the future.'

Contact

Annemiek ter Heijne (Environmental Technology)
E: Annemiek.terHeijne@wur.nl
www.wageningenur.nl/ete

Text and pictures by Hans Wolkers (Wild Frontiers B.V.)
E: Info@wildfrontiers.nl
www.wildfrontiers.nl

Agenda

PhD defences:

Elackiya Sithamparanathan, July 5th 2023, 16.00h. Local treatment of urban sewage streams for healthy reuse, by vertical constructed wetlands.

Joao Fontes Pereira, September 11th 2023, 11.00h. Electron flows in electro-active biofilms.

Barbara Vital, September 11th 2023, 16.00h. Enabling renewable energy generation by reverse electrodialysis: Fouling and Process Design.

Vania Chavez Rico, September 22nd 2023, 13.30h. Organic residues engineering to increase organic matter in agricultural soils.

Kaiyi Wu, November 10th 2023, 16.00h. Modelling and optimisation of scenarios for resource recovery from urban sanitation.

Meetings:

European Meeting of the International Society for Microbial Electrochemistry and Technology (EU-ISMET, www.euismet2023.eu), September 6-8, in Wageningen.