Environmental Technology

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WAGENINGEN UNIVERSITY
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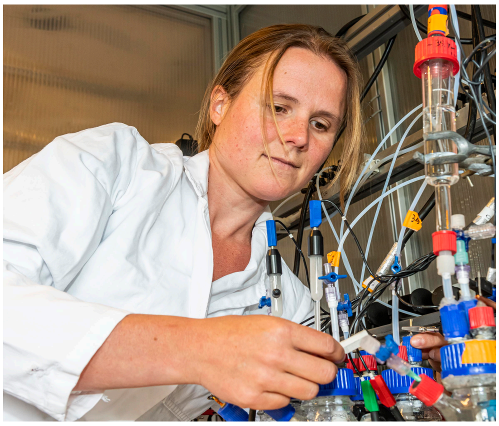
Picture: NASA

News

VIDI grant for Annemiek ter Heijne

Annemiek ter Heijne, assistant professor at ETE, was awarded the prestigious NWO VIDI grant through the Domain Applied and Engineering Science (TTW) for her project on improving resource recovery technologies. The VIDI grant offers a five-year personal budget of € 800.000 for mid-career scientists to develop their own innovative research line.



To receive a VIDI grant, applicants must be talented, creative scientists. The grant aims to boost innovation by supporting researchers to set-up their own group, carrying out original and groundbreaking research with impact. Only about 20 percent of all applicants have been awarded the grant. At Wageningen UR, five scientists received the grant.

Ter Heijne's project involves developing more efficient methods to recover resources and energy from waste streams. 'To establish a circular economy, we need new technologies to recover valuable compounds from waste', ter Heijne explains. 'During this process, bacteria play a central role. My research focuses on the use of electrodes to influence these biological conversions.' Bacteria gain energy from transporting electrons from one compound to the other. Ter Heijne focuses on understanding the electron flows to eventually design more efficient recovery technologies.

Column

Guest writer Paul O'Callaghan, CEO of BlueTech Research

Why do we use energy to treat wastewater, when it contains energy, why do we take potable water to flush a toilet, why do we produce drinking water, that so many people do not drink? The paradoxical nature of water was something that fascinated Leonardo Da Vinci over 500 years ago. He described water as the vehicle of nature, *vetturale di natura*, believing that water was to the world what blood is to our bodies. Today we need minds like that of Leonardo Da Vinci, a scientist and engineer, who stood at the crossroads between science and the humanities, an artist and inventor and someone who was imaginative, at times heretical not afraid to think differently. What conventional wisdom would he have challenged if he looked at our current systems today?

In my current PhD research at ETE, I study the process of Water Innovation. This synergizes with my work as CEO of BlueTech Research. It adds a theoretical aspect that underpins our work to analyze the future of water technology markets. In water, we only make radical changes, when faced with a crisis. Today we are facing such a crisis: a changing climate, population increases and economic growth, which collectively create a perfect storm for water.

I am fortunate at the moment to be working on a water documentary project, Brave Blue World. When we interviewed actor Matt Damon and founder of Water.org, he ended his remarks by saying: 'How exciting is it that we can be the generation that solved water. That in a hundred years, people will wish they were alive at a time when they could have solved a problem this big'. I think this is an inspiring message and perhaps even Leonardo Da Vinci might have had the same wish!

Arnoud de Wilt receives the Jaap van der Graaf prize

Former ETE PhD researcher Arnoud de Wilt receives the 2019 Jaap van der Graaf prize for his article on removing pharmaceutical residues from wastewater. The prize is awarded to a student or researcher who wrote the best English-language article on the urban water cycle in the previous year. The award was set by consultancy firm Witteveen + Bos to further raise the profile of Dutch expertise in the field of water technology in this field.

Important criteria

The winning paper of De Wilt and his colleagues, '*Enhanced pharmaceutical removal from water in a three-step bio-ozone-bio process*', was published in Water Research in 2018 and based on his PhD research at ETE. Around 60 papers competed, all had 'a very high scientific level'. But de Wilt's research met all the important criteria the best: social relevance, practical approach and applicability. According to the jury, de Wilt's research offers a pragmatic and well-developed solution to the ever-growing concentration of medicine residues in waste and surface water: one of the biggest challenges facing the water boards at the moment.

Three-step treatment

To remove medicine residues from wastewater, de Wilt focused on using ozone in combination with bacteria. Just ozone treatment to degrade pharmaceutical residues is not cost-effective, among others due to high amounts of background organic matter in wastewater: a lot of ozone is consumed by degrading this fraction. 'In my research, conducted at ETE, we used wastewater from a nearby plant, so a very practical and realistic approach', says de Wilt. 'We removed pharmaceutical residues in a three-step follow-up treatment: bacteria, ozone and again bacteria.' The first bacterial step removed organic matter. As a result, less ozone was required during the second step, where this gas effectively degrades pharmaceuticals. Due to the first bacterial treatment, ozone demand dropped by more than a third. After the ozone step, a final bacterial step removed the remaining ozone products. This 3-step method targets different pharmaceuticals, and results in a cost-effective pharmaceutical removal of more than 85 %, while the average treatment costs increase by no more than five to ten euros per person per year.

Full scale implementation

De Wilt's current employer, Royal HaskoningDHV, is involved in the follow-up study. 'We examine what needs to be done to bring this three-step wastewater treatment method from the lab to practice', says the Wilt. 'Then we aim to start a pilot in 2019, together with a water board. When this pilot is successful, full-scale implementation is the next step.'

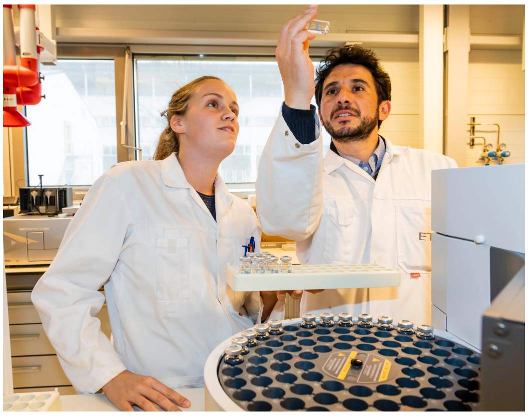
Selected publication

de Wilt, A., van Gijn K., Verhoek T., Vergnes A., Hoek M., Rijnaarts H.m, & Langenhoff A. 2018. Enhanced pharmaceutical removal from water in a three-step bio-ozone-bio process. Water Res. 138, 97-105.

Sulfy: a new GC for analyzing sulphur compounds

A state-of-the-art gas chromatograph, with autosampler and photodetector, is the brand-new addition to ETE's already impressive collection of analytical machinery. Sulfy, as the machine is called by its users, is specialized in measuring sulphur compounds like mercaptans and hydrogen sulphide (H_2S). 'With this machine we can analyze a wide range of sulphur compounds more accurately', PhD scientist Margo Elzinga says.

Mercaptans, for example methanethiol (CH_3SH), are organic sulphur compounds, that are present in, among others, natural gas. Burning these smelly substances results in sulphur dioxide (SO_2), an important air pollutant and one of the causes of acid rain. Therefore, mercaptans have to be removed before the gas can be used. One known method is to 'wash' the gas by bubbling it through a highly alkalic fluid: the mercaptans will stay in the fluid, where after they can be further treated. In the past, one of ETE's research projects was aimed at degrading mercaptans using anaerobic fermentation in a so-called UASB reactor. This resulted in the formation of hydrogen



sulphide (H_2S). This smelly substance can theoretically be converted into commercially valuable sulphur particles. 'But this UASB method was very slow and the microorganisms could not deal with the higher mercaptans', Elzinga says. 'Therefore, together with company Paqell, ETE is now focusing on a more efficient method to degrade these compounds.'

More accurate measurements

For a proper development and understanding of such a degrading process, the scientists need to measure not only the H_2S formed, but also other sulphur compound that can possibly be formed during these reactions. Elzinga: 'We need more accurate measurements of a wide range of sulphur compounds. Not only the mercaptans should be measured, but also the in-between products as well as the end products. This way, we can make an accurate balance about which compounds go where and eventually get a thorough understanding of the whole breakdown process.'

Special coating

Assistant researcher Julian Zamudio is an expert on the new GC and his appreciation for the new lab addition is more than clear. He points to a stainless-steel tube-shaped part of the machine. 'Here the liquid sample, containing the sulphur compounds we want to measure, is heated up and the resulting gas is led into the machine', he explains enthusiastically. 'Every part of the machine, that comes in contact with this gas has a special coating to prevent any interaction with the sulphur components. This way, all different

compounds present remain intact and unchanged.' The coming months Elzinga and Zamudio will work on developing their new method to degrade mercaptans and thanks to Sulfy, they hope to get a full understanding of the whole process involved.

ETE for Impact Conference

Next year, from June 3-5 2020, the 5-yearly *Environmental Technology for impact* conference will be held in Wageningen.

During this conference the 55th anniversary of the ETE group will be celebrated with inspiring lectures, poster presentations and social events. After the conference, on Friday, June 5 in the afternoon, the ETE alumni day will be held.

'Unique to this conference is the diversity of themes', says Jouke Dykstra, scientists at ETE and member of the organizing committee. 'Examples of these themes are bio-recovery of valuable components from waste streams, desalination, removal of micropollutants from wastewater, industrial wastewater management and urban system engineering'. Another selling point of the conference is the knowledge exchange and networking possibilities, not only between scientists, but also between ETE researchers and their partner companies, governments, and institutes.

For more information on registration and submission of abstracts as well as key note speakers, please visit https://www.wur.nl/en/activity/Environmental-Technology-for-Impact.htm

Science: Nature's cleaning power. Using constructed wetlands to purify industrial wastewater

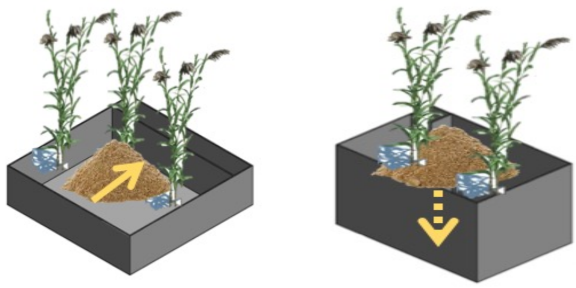
As part of Water Nexus, a NWO-TTW program that aims to find solutions for fresh water shortage, PhD researcher Thomas Wagner investigates the use of constructed wetlands to remove chemicals from industrial wastewater. Wagner: 'By creating such a nature-based water-cleaning system, industry and nature could go hand in hand, while recycling precious fresh water resources.'

'Look at the difference in color between the ingoing and the outgoing water', Thomas Wagner says. He holds two Erlenmeyers, containing water samples before and after they passed through his constructed wetlands. One Erlenmeyer holds a brownish fluid, while the liquid in the other one is clear. 'The bottom sediments filter the brown humic acids out, while microorganisms together with the plants and the sediment, also remove chemicals like the corrosion inhibitor benzotriazole as well as nitrate and phosphate.'

Wagner studies how constructed wetlands may remove chemicals from industrial waste water. He specifically focuses on cleaning water from industrial cooling towers. 'Many industries use fresh water for cooling purposes', he explains. The salinity of that water increases during the cooling process as result of evaporation and the water has to be discharged when the salinity becomes too high. Reusing this discharged water in the cooling tower itself would lower the fresh water footprint of the cooling tower, but requires desalination. 'However, to prevent corrosion, excessive bacterial growth and deposition of calcium salts (scaling) in the cooling system, they add corrosion inhibitors, but also biocides, like glutaraldehyde and phosphonates as anti-scalants.' Desalinating this cooling water for reuse therefore requires a pre-treatment, where these chemicals are removed first. Constructed wetlands may play a key role here.

Different designs

Wagner focuses on different removal mechanisms of chemicals present in his lab-made industrial water mix, mimicking the real industrial cooling water. It contains a mixture of different salts, nitrate, phosphate and the corrosion inhibitor benzotriazole. Removal of chemicals may be due to adsorption to the sediment, microbiological breakdown in the sediment, or uptake and degradation by the plants. In addition, he looks at different constructed wetland designs (Fig. 1a,b) to find out the most optimal system for cleaning his water mix. 'We study both horizontal and vertical water flows through the sediments', he explains. 'With the vertical flow design, water moves from the surface through the sediment and absorbs more oxygen than with the horizontal flow design.'



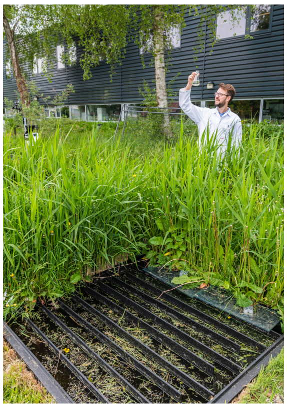
(a) **(b)**

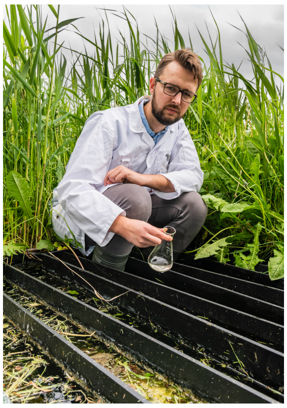
Fig. 1. Wetland design with a horizontal (a) and vertical (b) water-flow through the sediment.

This difference in oxygen content also influences the activity of different bacteria and consequently the breakdown of different chemicals. For example, adsorption to the sediment is the most important removal mechanism for benzotriazole. But due to the oxygen present in a vertical flow system, aerobic bacteria add to the removal of this compound, resulting in an overall better performance to remove benzotriazole. In contrast, nitrate is more efficiently removed in the more anaerobic horizontal system, where anaerobic bacteria are active.
Another important factor for efficient chemical removal is the temperature. Wagner: 'Lower temperatures may result in lower removal rates as result of lower microbial activity. In addition, when plants die in late-autumn, they do not take up contaminants and don't provide oxygen to the constructed wetland anymore.

Complicating factor

In addition to oxygen present and the ambient temperature, also biocides present in cooling water, like glutaraldehyde, a compound resembling formaldehyde, may impact the cleaning effectivity of the constructed wetland. An extra complicating factor here is the partial breakdown of such biocides, resulting in the formation of completely new compounds with different toxic properties. This might have implications for the proper cleaning function of the system. Therefore, Wagner also focuses on the impact of these biocides on chemical removal rates. 'In theory, these toxic compounds may slow down biodegradation, but our experiments showed that the lowest concentrations used in cooling towers, 5 micrograms per liter, didn't reveal any effects', Wagner says. 'If we find an impact at higher concentrations, we may have to include an extra biocide removal step or find a biocide with less impact on our constructed wetlands.'





Natural look

Despite some challenges, Wagner is convinced that constructed wetlands can play an important role in thepre-treatment of industrial cooling water, before the final desalination step. Depending on the compounds to be removed, it is possible to make a custom wetland design, favoring the breakdown of specific compounds. For example, phosphate could be more efficiently removed by mixing the sediment with better absorbing substances. Aluminum sludge, rest materials from the drinking water industry, is a potentially good candidate. But also, the bacterial populations, responsible for the breakdown of different compounds can be manipulated: aerobic bacteria can be favored by aeration of the system using air pumps. This may result in a better breakdown of, for example, benzotriazole. In addition to their effective removal of a wide variety of contaminants, constructed wetlands are appealing. Wagner: 'By using them as natural waste water cleaners, nature and industry can go hand in hand.'

Selected publication

Wagner, T.V., Parsons, J.R., Rijnaarts, H.H.M., de Voogt, P., Langenhoff, A.A.M. 2018. A review on the removal of conditioning chemicals from cooling tower water in constructed wetlands. Crit. Rev. in Environ. Sci.& Technol.48, 1094-1125

Spin-off: Combining a business and a PhD: a win-win situation

BlueTech Research is a company specialized in providing clients with crucial water technology information. Founder and CEO Paul O'Callaghan successfully combines his business with a PhD on water technology at ETE. 'Both jobs are intertwined. They complement and reinforce each other, thus improving the quality of both.'

For most of his career, Paul O'Callaghan was fascinated by water technology and innovation. As part of his MSc, he optimized and redesigned a waste water processing unit for the Body Shop in the UK. 'This was the start of a fascinating journey', O'Callaghan says. 'After finishing my MSc, I worked for a pharmaceutical company to test a pilot membrane bio-reactor for wastewater treatment.' He soon noticed that water technology companies wasted a lot of time to find clients and investors. In addition, it often took a long time before a newly developed technology finally could be placed on the market. In response to the demand from these companies, O'Callaghan set up his own consultancy company in 2006, advising smaller water technology businesses to make better tactical decisions, be more efficient and avoid errors. Soon, investors and larger water technology companies from Silicon Valley in California, like Kleiner Perkins, VPVP and XPV Water Partners, asked for information to assess new technologies.

'At that point I started to think how I could develop a product out of relevant water technology information', O'Callaghan explains. 'This was a challenge because there are so many different technologies to keep track of.'

Better decisions, avoid mistakes

To keep control over the massive amount of water technology information available, O'Callaghan focused on collecting and analyzing data. In 2011, he founded BlueTech Research and moved from consultancy work to a more software-based company. The company focuses on delivering relevant and strategic information for water technology companies based on large amounts of data. 'We begin by collecting Big Data from different sources', he explains. 'Companies developing water technologies, Universities, conference papers and patents are all valuable information sources.' Using a customized taxonomy and software system, these data are then ordered and structured. Subsequently, technology experts analyze the data and search for existing patterns and trends. This results in concrete information that may help companies to make better decisions and avoid mistakes. For example, what technologies should be developed or invested in? Where is the water technology market heading to? How can a company avoid to miss crucial opportunities? How can the implementation of new technologies be speeded up?

In a rapidly changing world, with ever increasing challenges, it soon became apparent that there was a huge appetite for this kind of information-based advice. BlueTech research has now around 25 employees and clients all over the world, with offices in North America, Europe and Asia. Major clients are PepsiCo, L'Oreal, Carlsberg, and Nestle, but also big water technology companies like DOW and SUEZ are valued customers.

Marketable product

Besides his busy occupation as CEO of BlueTech research, O'Callaghan is also working on a PhD at ETE. There he studies how new water technologies make their way to the market. It's a long way from a new technological invention to a marketable product. After developing a new technology, scientists test the concept in a small pilot plant. If successful, a full-scale demonstration plant is built. O'Callaghan: 'If you understand all steps in this process well, you can speed it up, and allow technologies to be marketed quicker. That saves time and money.'

Academic lens

O'Callaghan's experience and knowledge as CEO of a water technology company boosts his PhD research, while on the other hand, the PhD strengthens his business by providing a solid scientific basis. For example, his recently published paper on a *Water Technology Adoption Model*, developed at ETE, helps to understand how long it will take for a technology to move through the different stages before it reaches the market. It was widely appraised by the industry. O'Callaghan: 'People tell me that the paper helps them to understand how to take a new innovation to the market more time-efficiently.' Apparently, O'Callaghan's PhD research at ETE underlines the practice-oriented, science-based quality of BlueTech research. At the same time, O'Callaghan thinks ETE is an inspiring environment: 'Doing my research at ETE is great fun and keeps me curious. It enables me to look at company issues through an academic lens. It also keeps me engaged and sparks new ideas.'

Selected Publication:

O'Callaghan P., Daigger G., Adapa L., and Buisman C. 2018. Development and Application of a Model to Study Water Technology Adoption. Water Environ. Res. 90(6): 563-574.

Agenda

PhD defences (Aula, Wageningen):

Leire Caizan June 14th 2019, 11.00h. Granular activated carbon in capacitive microbial fuel cells.

Mariana Rodriguez October 4th 2019, 15.00h (Leeuwarden). (Bio)-Electrochemical recovery of ammonia

Conferences

ETEi2020. June 3-5 2020. Wageningen.

ETE alumni day June 5th 2020

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