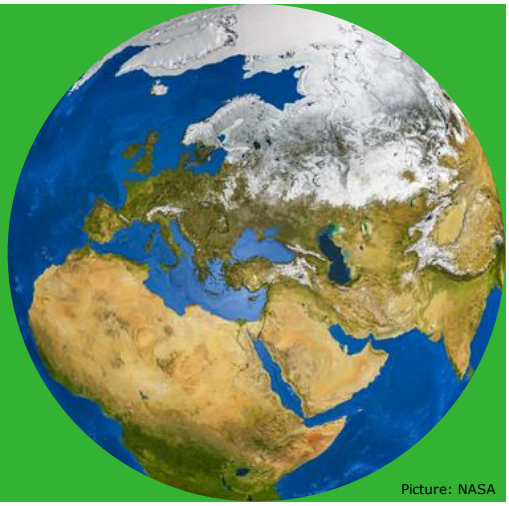
Environmental Technology

Newsletter | December 2022



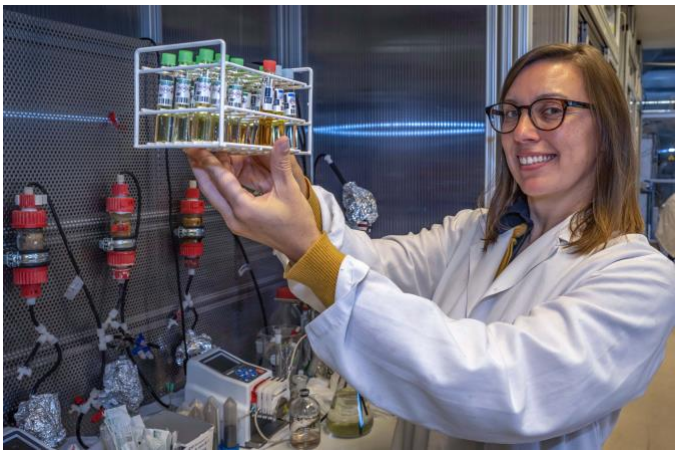
Picture: NASA

WAGENINGEN UNIVERSITY
WAGENINGEN UR

News

Making hospitals more sustainable by reducing waste and treating waste water

ETE is participating in the recently launched 'Circular Safe Hospital Initiative', introduced by EWUU Circular Society, a collaboration between Eindhoven University of Technology, Wageningen University & Research, Utrecht University and University Medical Centre Utrecht. Together with Wageningen Food and Safety Research, Nora Sutton, Associate Professor at ETE, will contribute with a project to remove pharmaceutical residues from hospital's waste water.



Nora Sutton in the ETE lab.

Increase sustainability

In The Netherlands, the healthcare sector is responsible for 13 percent of the national use of raw materials and in addition a large contributor to the pollution of air and water. Every year, more than 8000 tons of hospital waste is produced in The Netherlands alone, while most of it is not recycled. Furthermore, hospitals are responsible for discharging waste water containing a wide range of pharmaceutical residues in relatively high concentrations. The 'Circular Safe Hospital Initiative' aims to increase the sustainability and circularity of hospitals by developing cleaning and recycling technologies in combination with strategies to minimize use of materials and production of waste. Since the establishment for the alliance

Column

Prof. Cees Buisman, Chair ETE

Next year will be a very special year for me, since I will stop as chair at ETE after 20 years. Also, my colleague, Professor Huub Rijnaarts, will retire within 18 months. Therefore, two chair positions are vacant now in ETE and the search and selection for the new chairs is going on at this moment. It will be very exciting to know who will take over the leadership and responsibility of ETE.

The last 20 years, ETE has grown steadily and has continuously renewed itself. Many students did their MSc or PhD at our department, we welcomed many new colleagues and developed a completely new research program. I believe all former chairs since 1965 can be satisfied with the current department! Our program has expanded with many topics with currently more than 50 projects running simultaneously.

I am proud of our achievements. We continued to work in this difficult but very meaningful and important field. We have found solutions to a variety of existing environmental problems. We succeeded in many innovations, spin offs and high- quality research. I wish the new leaders inspiration for the next 20 years.

between the four universities in 2019, ETE professor Huub Rijnaarts has been a member of the working group 'Circular Society'. Now ETE is expanding their contribution by the participation of Associate Professor Nora Sutton in the 'Circular Safe Hospital Initiative' with a project on removing pharmaceutical residues from hospital's wastewater.

Prof. Huub Rijnaarts

Hotspots of discharge

'Making hospitals more sustainable is a real challenge', Sutton says. 'Large amounts of materials are used, many of which cannot be easily recycled, while hospitals are hotpots for the discharge of pharmaceutical residues in waste water as well.'
In her recently funded project within the 'Circular Safe Hospital Initiative', Sutton will focus on human hospitals, while Wageningen Food and Safety Research will run a similar project, aimed at veterinary hospitals, like the one at the Faculty of Veterinary Medicine in Utrecht. Since there are a lot of similarities in how to tackle the sustainability problem between human and animal hospitals, a collaboration is time and money efficient. Nevertheless, the distinction between human and veterinary hospitals is important since the waste streams, as well as types and amounts of pharmaceuticals used, differ fundamentally. 'Waste streams of pharmaceuticals in veterinary hospitals are mostly associated with manure and urine **streams**, while in human hospitals, these pollutants mainly end up in waste water', Sutton explains. 'Also, different pharmaceuticals are used in people and animals, while prescribed quantities may differ greatly: there is a big difference treating a mouse of 20 grams or a horse of 600 kilograms.'

Biggest problem

As a first step, Sutton's, together with MSc student Toby Schadenberg, made a map of pharmaceutical use in hospitals: where and which pharmaceuticals are mostly used, and in which waste streams do these end up (fig. 1)? Also, she needed more information about the different medications: the quantities used, their toxicity and the behavior in the body. Sutton: 'Some compounds are almost completely metabolized, resulting in breakdown products that might pose a problem as well, while others are excreted mostly unchanged.' Based on this information, she made a list of high-risk compounds that should be prioritized. She concluded that antibiotics pose the biggest problem, due to their extensive use and the risk of increased antibiotic-resistance when these compounds enter the environment.

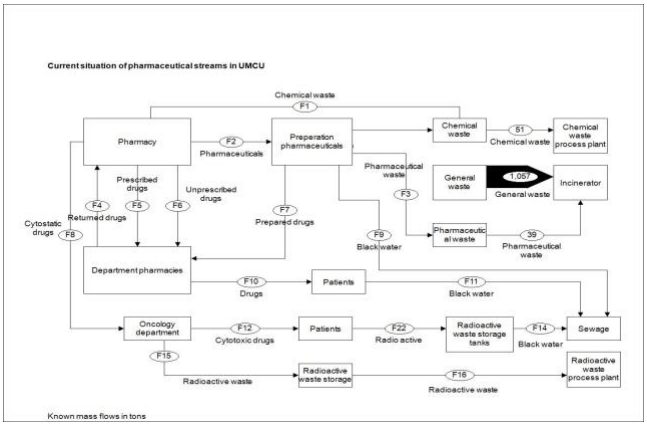


Fig. 1. Flow analysis of pharmaceuticals within hospitals, by Toby Schadenberg

Solutions

In her project, she is now focusing on removal of these compounds from waste water, or prevent them from entering the waste stream at all. 'We are looking how we can implement technology in hospitals to deal with these antibiotics', Sutton says. 'Radioactive substances are already separated from the hospital's waste water streams, so, this should be possible for other medication too. Possibly, absorption in toilets or biological degradation on site are solutions, but such technologies are still in their infancy. We will have quite a few challenges waiting for us in the coming years.'

Annemiek ter Heijne nominee for Excellent Education Award

© Guy Ackermans

Associate ETE professor Annemiek ter Heijne (2nd from the right) has been nominated for the Excellent Education Award of Wageningen UR, in the category Basic Courses. Together with 4 other nominees, she was in the race for the final nomination. And although she eventually didn't win the competition, it shows the appreciation of her course *Renewable Energy Technologies* by the students. Obviously, a theoretical part combined with applying the theory in a real-life case study, together with the enthusiasm of the lecturer, appealed to the students.

Basics of energy

'Energy is a hot topic nowadays, and this course teaches students the important basics of energy: energy saving and harvesting sustainable energy sources, like solar, wind and biomass', Ter Heijne says. 'During the course students will also focus on how different technologies, like solar panels and heat pumps work, while they also learn to calculate the efficiency of different energy conversions.' Heat transport, energy loss from a house, electricity and possibilities to store energy are covered in detail. In addition, guest lecturers provide detailed knowledge on solar cells and wind turbines.

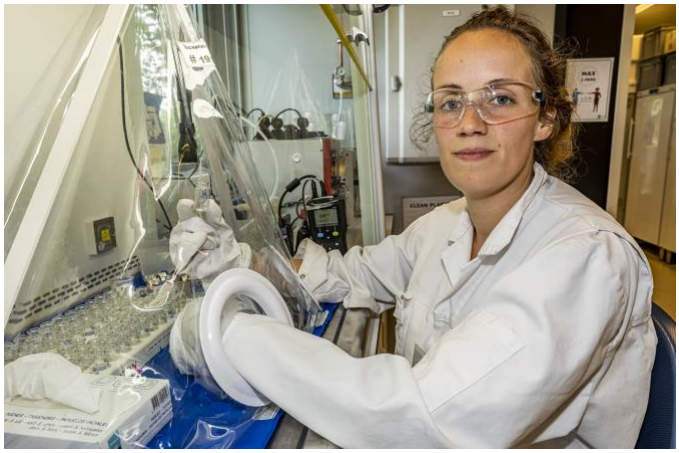
Self-sufficient house

The theory learned in this first part of the course is applied in the second part of the course in a case study, where students have to design an energy self-sufficient house on a specific geographical location. 'They need to consider the location's different weather conditions and be aware of the solar radiation reaching the house, wind and temperature', Ter Heijne explains. 'The house has 1 hectare of land, and this may be used to place solar panels, or when there is an altitude difference and a creek, to generate electricity using hydropower.

Even during Covid, when part of the lectures was given online, the course worked out. Ter Heijne: 'We had a really nice crew of teachers that could easily join in using Teams to help out students. This course really worked well online too.'

Two 'Best Presentation' awards for ETE PhD scientists

Margo Elzinga won the second 'Best Presentation Award' at the ISMET8 Conference, held in Greece. This three-yearly conference is considered as the most important meeting on bio electrochemistry. 'This was my first live congress', Elzinga says enthusiastically. 'Due to Corona, previous sessions were held on line. But this live conference was super cool, since I really like meeting people in person and having more in-depth discussions!'



Proof of principle

Elzinga won her award with her oral presentation on the removal of highly toxic thiols from natural gas, using microorganisms and electricity. The new method convincingly shows the proof of principle for a safe and efficient thiol removal. Elzinga is more than enthusiastic about her research. 'It is a real pleasure to work with sulfur compounds, since there are so many different reactions possible, you can really go in all directions, and potentially discover other reactions', she says. 'We still don't really understand in detail which biological processes are taking place, but the experiments have clearly shown that our thiol removal method works.' Her enthusiasm clearly reflected in her presentation, which was highly appreciated by the audience. 'There were so many other interesting topics showcasing important and relevant research that deserved this award', she says. 'But I guess that my clear and animated presentation style helped a lot to win this award.'

Selectivity of membranes

ETE PhD scientist Selin Ozkul was another 'Best Presentation' winner at the 5th International PMP symposium 2022 in Wageningen. This yearly conference focuses on the physics of membrane processes (PMP) and involves fundamental understanding of physics and chemistry of the membrane processes that are used in industrial production, energy as well as environmental technologies. Ozkul's oral presentation 'Effects of ion composition on ion-selectivity in electrodialysis: towards mechanical understanding' was awarded 'Best presentation' out of a total of 28 talks.

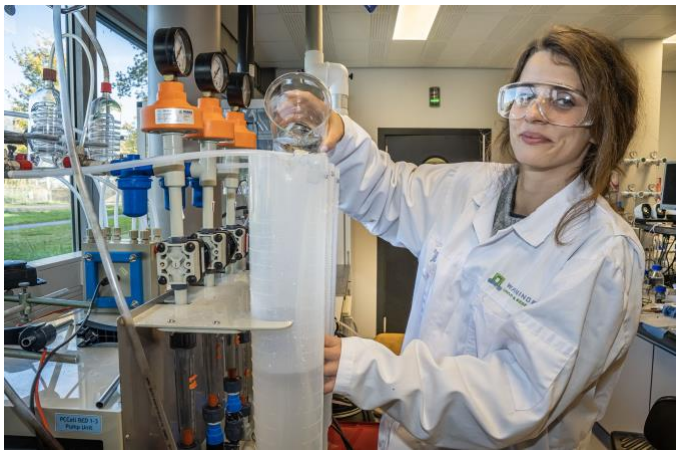
Undesired removal

Desalination of water for reuse, for example in agriculture can be real challenge. Electrodialysis, where a combination of electrical force and ion exchange membranes is used, can be an effective method to selectively remove undesirable ions, like sodium. Electrical force is used to transport ions

through the pores of an ion-exchange membrane. ‘A problem we encounter is that different ions may influence each other, especially their preferential transport through the membrane’, Ozkul explain. ‘Also, these ions may change the membrane properties and selectivity. For example, a high salt concentration may cause shrinking of the membrane, resulting in smaller pores and a different ion selectivity. This may eventually result in the undesired removal of the smaller potassium ion, instead of sodium.’

Interesting scientific content

Ozkul’s presentation focused on both experiments and theoretical models. She used experiments to study the selectivity changes that occurred at different ion compositions. Based on these results, she designed a model that could predict how a certain ion concentration and composition could change the membrane selectivity. Besides the interesting scientific content, Ozkul believes she was awarded the prize because of the clarity of the presentation. ‘Often, models can be extremely complicated, with lots of equations that are difficult to explain’, she says. ‘I wanted to avoid that and focused on only the most important parameters. In addition, I also showed the model’s application in real-life situations and made sure that the presentation could also be understood by people outside my field.’



Two new lecturers at ETE

Starting in February 2023, ETE will add two new lecturers to their teaching team. Sigrid Scherrenberg and Sjoerd Kerstens, both employed at Royal HaskoningDHV, will contribute to teaching the course *Water Treatment*. The appointment is for three years, with the intention for a continuation.

Sustainable solutions

The new ETE lecturers are both working in the water technology department at Royal HaskoningDHV, an independent consultancy company that develops

sustainable technological solutions to local and global environmental problems. Scherrenberg is R&D manager and Associate Director Waste water, while Kerstens is Leading Professional wastewater treatment and resource recovery. They will contribute with their expertise on aerobic water treatment to ETE’s course *Water Treatment*, but also to the course *Biological water treatment and Recovery Technology* at Wetsus European Centre of Excellence for Sustainable Water Technology.

Solid foundation

The course provides a solid foundation of the theoretical aspects of wastewater treatment. ‘It’s about understanding the main concepts of aerobic and anaerobic processes and resource recovery’, Kerstens says. Scherrenberg adds: ‘The theory of aerobic wastewater treatment is the main core of our lectures, but we will illustrate the concepts with technological applications in the wastewater industry. Our background at Royal HaskoningDHV really helps to illustrate how the theory works out in the real world.’

Need for innovation

The lecturers have a somewhat different, but overlapping background, and are clearly up for the task. Former ETE student Kerstens has a doctorate in sanitation planning and resource recovery, while Scherrenberg is a chemical technologist, with a PhD in phosphate removal from Delft University of Technology. In addition, she is a qualified university teacher with almost 10 years of experience. Scherrenberg currently works as a Team Leader, R&D Manager and Associate Director wastewater. ‘My main focus is to develop more sustainable wastewater treatment technologies in order to reuse water and recover resources’, she says. ‘We are developing new concepts and ideas, leading to better and smarter treatment technologies.’ Kerstens has overlapping qualifications. He is a Leading Professional, working as a Process Engineer, specialized in wastewater resource recovery. ‘In my role as Process Engineer, I’m currently developing new innovative technologies

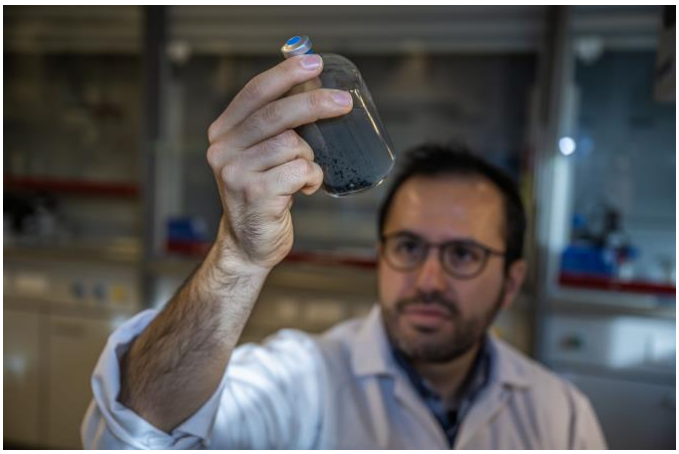
including those that produce an effluent that can be reused', he explains. 'We had some pretty dry summers, while there is a continuous supply of wastewater that - after treatment - can be used for a variety of purposes. With the right technology, this could play a role in solving future drought issues.'

Environmental challenges

Within the framework of this existing course, the lecturers plan to follow the main headlines, while further building the course, by including their own interpretation, experience and knowledge. 'With all environmental challenges, there is a lot of need for people in this discipline', they say. 'We are excited to contribute to this education, it really ties in with our inner motivation and drive.'

Science: Better metal recovery for improved yield and less mining waste

ETE scientist Adrian Hidalgo-Ulloa developed a new method to improve the retrieval of metals from mining streams. He redesigned the recovery process of commercial mining companies: by adding hydrogen sulfide (H_2S) to the mined metal-containing rocks, crystallized metal salts were formed. By manipulating the pH, he was able to precipitate the different metal salts one by one making an easy recovery possible. Hidalgo-Ulloa: 'With this method we have potentially increased the metal recovery yield, but also reduced the metal waste in mining tailings tremendously.'



Due to the increased electrification and the transition to a more electricity-based society, the demand for metals, like copper, nickel, zinc and cobalt, is growing at a high rate. For example, global copper demand is estimated to double to 50 million tons by 2035, while prices are expected to increase as well. This puts extra pressure on current mining companies to expand their activities, to meet the growing needs. However, the environmental impact of these activities will increase as well. 'One of the issues is that the currently low metal prices do not reflect the environmental costs of mining', Hidalgo-Ulloa says. 'There is no incentive to be efficient with the recovery of metals. Often it is cheaper to waste metals, than to put money and effort into a more efficient operation.'

Low efficiency

Mining operations are usually quite straightforward: metal-containing rocks are mined, and grinded to small particles for an easier metal recovery. Then, acids and water are added and the mixture is heated to dissolve the metals. Adding caustic soda (NaOH) will increase the pH, resulting in the precipitation of the target metals as salt crystals, for example copper-hydroxide, that can be recovered. Since mining companies often target only a few metals, while the mined rock often contains many different metals, there is a low efficiency of metal recovery: as much as 40-60 percent can be wasted. These waste streams, 'mine tailings' are stored on land and obviously pose an environmental hazard due to leaching of toxic compounds in to the soil and ground water. Hidalgo-Ulloa: 'In 2020, the total amount of mining waste produced equaled more than 216 cubic kilometers, just because of inefficient metal recovery.'

Highly toxic compound

During his PhD research, Hidalgo-Ulloa developed a better method for metal recovery: he used hydrogen sulfide (H_2S) to react with the metals, forming metal-sulfides. The advantage of these salts is that their solubility changes with changing pH, allowing for an efficient recovery of most metals present. 'At acidic pHs, most metal sulfides are soluble. Increasing the pH affects the solubility of most metal sulfides greatly, but individually. So, when one metal sulfide is almost insoluble, the others remain partially in solution. For example, at pH 3, copper sulfide is insoluble, while nickel-sulfide is quite soluble', Hidalgo-Ulloa explains. 'By producing H_2S into the same vessel as the acid rock mixture and slowly increasing pH step by step, different metal salts precipitate, permitting their one-by-one recovery.' However, to make this work in a cost-effective way, the H_2S production and transport should be profitable. Ideally, transporting this highly toxic compound to the recovery plant should be at low

cost, or avoided altogether. In the Dominican Republic, the Pueblo Viejo Mine developed a reactor design for the metal sulfide precipitation, with a separate compartment for H_2S generation on site (Fig. 1).

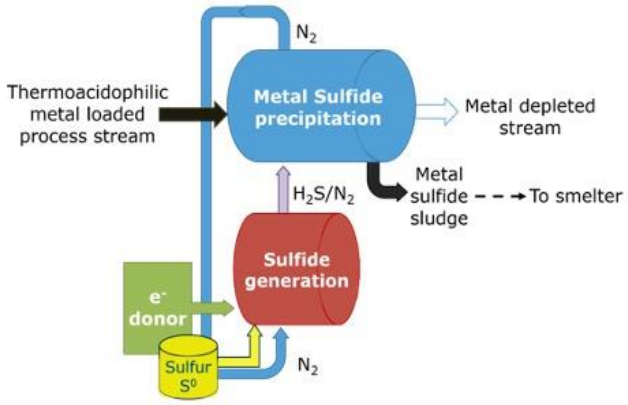


Fig. 1. Schematic overview of the Pueblo Viejo Mine reactor design

However, it would be even more cost-efficient to design a reactor where the H_2S formation and metal sulfide precipitation occurred in the same vessel. The H_2S formed could then directly react with the metals, forming metal sulfides that could subsequently be precipitated (Fig. 2).

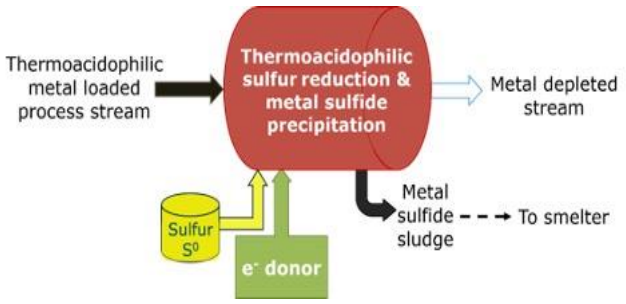


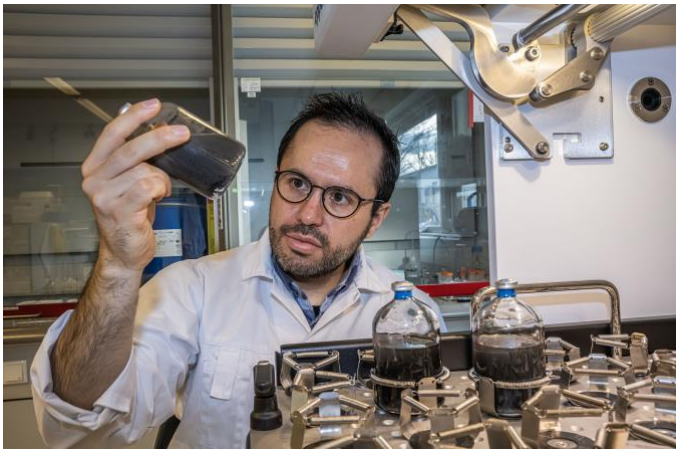
Fig. 2. Schematic overview of an improved reactor design with H_2S formation and metal sulfide precipitation occurring in the same vessel

Test reactor

For the first challenge, to make H_2S at low cost, Hidalgo-Ulloa used microorganisms to do the job. There are two possible methods to do this: the first one uses sulfate (SO_4^{2-}) and hydrogen that react to H_2S, while the second method uses elemental sulfur and hydrogen. 'The second method, based on elemental sulfur, is four times more efficient than the sulfate method, so we used this one to be as efficient as possible', Hidalgo-Ulloa explains. 'Our next focus was on making this work in a single reactor vessel, where all reactions would preferably take place in one single tank.' But this approach was challenging, because the reactor conditions with low pH, high temperature and toxic metals present are highly unfavorable for most microorganisms.

Suitable microbes

Therefore, as a first step, the scientists aimed to find suitable microbes that were up to the task. They focused on industrial reactors to find suitable microorganisms. So, they collected microorganism samples from different industrial reactors and tested their activity and H_2S production in a gas-lift reactor with a low pH, between 2 and 4 and high temperature, up to 80 °C. Eventually, Hidalgo-Ulloa found a suitable culture that originated from a reactor from a chemical plant in Emmen: the microorganisms survived the reactor conditions while producing H_2S. 'We were lucky to find those microorganisms', he says. In addition, the culture tolerated metals really well, and eventually we found the conditions to increase their activity and H_2S production! Further optimization, with lower temperature and increasing the amount of metals, resulted in a 10-fold increase in H_2S production. Nevertheless, despite the massive improvements, the H_2S yield is still on the lower limit for industrial purposes. 'There are still a lot of optimizations possible and rates might be pushed to add even more metals and fine tune parameters like temperature and reactor flow rate', Hidalgo-Ulloa says. 'The main issue however remains that the price of the environmental damage should be included in mining operations, so mining companies have a stronger incentive to be more efficient and less polluting.'



Selected publication:

Hidalgo-Ulloa A., Buisman C.J.N., and Weijma J. 2022. Metal sulfide precipitation mediated by an elemental sulfur-reducing thermoacidophilic microbial culture from a full-scale anaerobic reactor. Hydrometallurgy 213, 105950

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: Hans.Wolkers@gmail.com
www.wildfrontiers.nl, www.science-explained.nl

Agenda

PhD defences:

Koen van Gijn, January 13th, 2023, 16.00h. Upscaling the biological-ozone-biological (BO3B) treatment processes.

Suzanne van der Meulen, January 17th 2023, 13.30h. Functional quality of urban surface water.

Jinsong Wang, January 20th 2023, 11.00h. Optimizing design and operation of sand and active carbon filtration for removal of contaminants of emerging concerns (CECs) biodegradation.

Sanne de Smit, February 3rd 2023, 13.30h. Bioelectrochemical chain elongation to caproate.

Le Minh Truong, April 14th 2023, 11.00h. ENTIRE: ENabling susTainable Industrial development in Vietnamese delta's: REducing, recycling and multi-sourcing industrial water.