Editorial

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To recover valuable resources of higher quality than recovered resources from conventional sewage, we must make use of source separated sanitation. As you can separate the household wastewater streams – blackwater (toilet discharges) and greywater (discharges from sinks, showers, laundry, etc), you can use the higher concentrations to reclaim the most out of each flow. A wonderful idea, that unfortunately is still lacking in 99% of new households.

I first heard of the concept in 2003 in Hamburg, where my curiosity on the topic and anaerobic treatment quickly led me to the articles of Grietje Zeeman, then associate professor at Wageningen UR. The rest is history, I came to Wetsus in 2005, to do my PhD within the theme source separated sanitation (which was called Decentraal at that time). Since then, we have had several PhD projects working on black, greywater and urine treatment addressing the recovery of N, P and C and removal of pathogens, antibiotic resistance and micropollutants. There have been more demonstrations at larger scale within the Netherlands but also abroad, in Germany, Belgium and most notably in Helsingborg, Sweden.

In this newsletter, you can get a flavor of our current research around source separated sanitation. Black water treatment could be more effective at higher temperatures and Melissa Mativo will dedicate her PhD to it. The production of high-quality reuse water can be achieved with nanofiltration as Sam Rutten has demonstrated, preparing the ground for Shuoguang Yang to further utilize the heat of greywater and study its microbiological safety. Lastly, Wydia Prihesti Iswarani works on the electrochemical recovery of nitrogen which, if applied on blackwater effluent, will bring the recovery of resources to the next level.

Happy reading.

European Water Technology Week (EWTW) 2024

Join us at EWTW 2024: science, innovation, talent, and business in the water technology sector. This event will include the Wetsus Congress and Water Alliance activities, providing a platform for experts, researchers, entrepreneurs, and policymakers to discuss the latest advancements and explore new opportunities.

Event highlights:

Monday, September 23: Focus on "New Entrepreneurship for Knowledge Valorization." Keynotes from Cees Buisman and Michael Scheffer, followed by the Marcel Mulder Award Ceremony.

Tuesday, September 24: “Accelerating Science, Innovation, and Business in Water Technology.”

Parallel Sessions:

- Optimizing drinking water systems
- Change the lens: reimagining Water Innovations in the perspective of social sciences
- Sustainable desulfurization
- Process control for N recovery from wastewater
- Circular biopolymers: unveiling the routes from innovation to application
- Plasma vortex water treatment technologies
- The ecology of micropollutant biodegradation in soils
- From MACRO to MICRO challenges and opportunities in a world of water and plastics
- Innovations to address emerging contaminants in wastewater
- Electricity-driven carbon capture and utilization
- Innovative technology to restore the natural water cycle
- Innovative monitoring of water quality
- (Microbiological) metal recovery
- Applied Science TBA
- Circular water usage in the neighborhood
- Funding and support opportunities for EU watertech SMEs – WINNing Days

Wednesday, September 25: Themed "Accelerating Talent, Technology, and International Business," featuring the WIS-Award 2024 with 8 competitors.

Thursday, September 26: Conclude with a guided tour of innovative water tech locations.

For updates and more details: Visit www.europeanwatertechweek.eu will be available soon. EWTW 2024 is an essential event for anyone engaged in the global water tech community!

EUROPEAN WATER TECH WEEK LEEUWARDEN 2024 September 23 - 26

Saving Water, Energy, and Resources with the Power of the People

Dutch founder and Emerita Professor of New Sanitation Grietje Zeeman on the advantages of source-separated sanitation.

Vacuum toilets, local waste treatment, and grey and blackwater separation – now familiar new sanitation was brought to the Netherlands by proud pioneer emerita professor Grietje Zeeman. Starting in the late 90s in Wageningen at WUR-Environmental Technology she paved the path for DeSaH, Wetsus, and many more. And if there is one innovation that showcases the abilities of water technology and the effort it takes to implement it in society, it is new sanitation. Simultaneously, people and cooperating communities are the key to new sanitation. "Especially now, as the research grows bigger. We can save more water, more energy, and more resources. The Netherlands has to go large scale. Not only should the technology work, but every stakeholder involved has to be happy to help, too," Zeeman says.

“Concentrating is the key to resource reuse. If you can locally treat separate streams of blackwater – i.e., toilet water, and greywater – i.e., shower water, not only is it easier to separate your water from your resources, but it allows for local reuse too,” the emerita professor states.

New sanitation is the way to go on multiple fronts. “Source-separated sanitation can bring the average water use per person per day in the Netherlands down from 130 liters to maybe even less than 100 liters – new vacuum toilets can flush with only a liter instead of four to five. This way of sanitation allows for an energy-neutral system and even makes resource recovery easier. That is, if we can get farmers and regulators to cooperate too.”

Power by the People

Because people are key in such local systems. “When we first started in the late 90s, the municipality of Wageningen did not want to cooperate with a pilot for new sanitation. The number of people involved, from builders to governance – the many stakeholders involved- all had to cooperate on this challenge.” The town of Sneek, though, was up for that challenge and has always been a leading example.

“There, too, it was not easy to get people in line. I remember the remarks of a certain project manager well as we told him about the use of vacuum toilets. At the time, we knew it would work well in households, as they were used on cruise ships for months on end – and those are places that do not allow sanitation like this to break down.” It did mean that it was more specified, and not as many choices for the type of toilets were commercially available. For instance, in Wageningen, the project manager was rather displeased, as he stated: ‘What if people want a pink or purple toilet?’”

But at the same time, inhabitants make the technology work too. It was in Sneek that this group of people wanted to be the ones trailing a new sanitation system. They stood up unprompted at the pilot’s opening and held a speech on the honor of being involved. One man , working in the project, had the central treatment and recovery system for the street in his garage. He was the savior who fixed many small issues that inevitably arose from the pilot. And, he would later even become the director of DeSaH – the company that pleads at municipalities to build new sanitation facilities in new housing estates.

Hot topic

As bigger pilots have been built and technologies keep improving, we can do more. “At that time, we could not still involve farmers for resource reuse, but it is great that Wetsus is taking major steps in that direction with the new Leeuwarder neighborhood Spoordok. The research into fermenters in the local treatment plants, thermophilic anaerobic treatment for pathogen control, the use of nanofiltration for treated water, removing micropollutants from blackwater, ánd into the social aspects of New Sanitation, are promising steps forward.”

Challenges remain. How do you get farmers and regulators to cooperate? How should concentrate and sludge streams be processed to be reused? “In Gent, Belgium, they already reuse water for a neighboring soap factory. In Helsingborg, Sweden, they just built a great neighborhood with new sanitation; now the Netherlands must move on too – on a bigger scale.”

Emerita Professor Zeeman knows we can do it. “I have seen the embraced cooperation from Wetsus and WUR-Environmental Technology from day zero. The theme is hot topic. And I have 200% trust in my successors.”

Read more:
Grensverleggend Spoordok - Gemeente Leeuwarden

Blackwater? Nutrients are all I see

PhD researcher, Melissa Mativo is driving progress towards circularity in wastewater management. By treating toilet contents and water not as waste but as a valuable resource, her research offers an approach to tackle both eutrophication and nutrient recovery. Her work unlocks the potential of turning wastewater into organic fertilizers, promising a greener future for agriculture and a sustainable solution to nutrient loss.

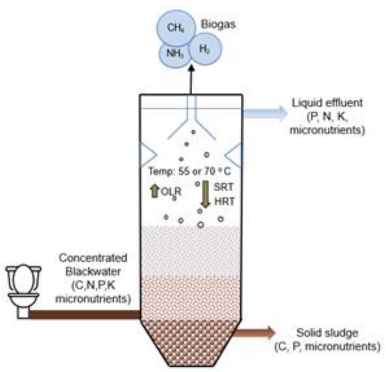
“When I learned about biological systems in wastewater treatment plants, they were hailed for their innovation in removing excess nitrogen and other plant essential nutrients. Using these biological processes, we could make our ‘waste’water ‘safe’ for discharge into our waterbodies. It sounded like a win for the environment, but there were strings attached…” explains PhD researcher Melissa Mativo.

Widya Prihesti Iswarani explains that shortcutting the nitrogen cycle is one thing, but many more nutrients float around in our blackwaters. We’re talking carbon, nitrogen, phosphorus, and potassium, to name a few. Mativo: “And we can’t forget about all the micronutrients – like iron or manganese.”

Currently, in water conserving source-separated sanitation systems such as the one in Noordehoek, concentrated blackwater is collected and treated in anaerobic tank at moderate temperatures. In this stage, bacteria break down organic matter to simpler components. The decomposition of the big particles – for instance, large organic molecules that capture charged phosphates – makes the nutrients easily accessibility for plants.

“My PhD is about optimizing anaerobic biological blackwater treatment processes at higher temperature to recover organic fertilizer,” Mativo explains. “We started by characterizing what’s in Wetsus and Sneek blackwater streams. We are now building our own anaerobic reactors to tweak parameters and get the best out of the inputs. First, we want to increase the organic loading rate and reduce the hydraulic retention time – how much blackwater our reactor can treat and the time it takes to process ‘waste’, respectively – while ensuring long-term process stability.”

A balancing act



It is a balancing act too. “We want to recover nutrients and sludge for soil application. On the other hand, we want to produce methane as an energy source; and we aim to generate product streams from blackwater that are abundant in specific nutrients.”

When you add the occurrence of micropollutants and pathogens, there is quite a way to go. Mativo also recognizes a societal challenge. Convincing various stakeholders that their toilet contents are not waste, but a precious fertilizer continues to be tough. Regulators and farmers will need to collaborate to allow the use of blackwater sludge as soil amender and recovered nutrients as fertilizers. Perhaps we can aid the process along by carrying out soil tests that showcase the practical ways in which application of our sludge improves soils. “Currently, people look at blackwater as waste, but all I see are nutrients that should not simply go down the drain,” Mativo says.

Read more:

Moerland, M.J., Castañares Pérez, L., Ruiz Velasco Sobrino, M.E., Chatzopoulos, P., Meulman, B., de Wilde, V., Zeeman, G., Buisman, C.J.N., van Eekert, M.H.A.: Thermophilic (55 °C) and hyper-thermophilic (70 °C) anaerobic digestion as novel treatment technologies for concentrated black water. Bioresour Technol. 340, 125705 (2021). https://doi.org/https://doi.org/10.1016/j.biortech.2021.125705

Zhang, L., Mou, A., Guo, B., Sun, H., Anwar, M.N., Liu, Y.: Simultaneous phosphorus recovery in energy generation reactor (SPRING): High rate thermophilic blackwater treatment. Resour Conserv Recycl. 164, 105163 (2021). https://doi.org/10.1016/j.resconrec.2020.105163

Fail-safe Membranes for Grey Water Reuse

With new sanitation many resources can be recycled, but few require as many regulations as reused water. A challenge? Sure. But recycling purified greywater may be just possible with nanofiltration. Dr. Sam Rutten has spent the past four years testing the efficacy of hollow-fiber membranes discovering great potential for water reuse in irrigation, and with some attention beyond.

Ever since the start of source-separated sanitation in the Netherlands, the goals have been clear – obtain safe water and recover resources. Conventional biological reactors do a wonderful job removing all sorts of organics that end up in greywater streams, yet some pesky, persistent molecules, such as fragrances, sunscreens, and pharmaceuticals, make recycling water quite hard. “My research aimed at removing these micropollutants, by using promising newly developed hollow fiber nanofiltration membranes,” says Rutten, “and we tested how to monitor the system on leakages in order to keep it safe for reuse.”

Straw-like fibers

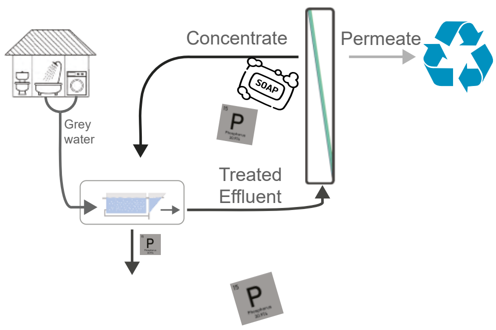
The configuration of the membranes allows for more effective cleaning strategies. Rutten: “You can see hollow-fiber membranes as a bundle of straws packed together. Water flows through these straws, and water and salts permeate through the walls of the fibers due to pressure. Meanwhile, pollutants remain in the fiber due to their size and charge.” Since these membranes have only recently become commercially available, the potential of applying the technology has just become substantially easier and attractive. That is, given that these filters can withstand various hardships they might encounter in the real world.

As the greywater stream never follows a set-in-stone recipe, challenges like changes in salt concentrations and foulants pose a risk to any filtration set-up, as do faults in the system. ”When it comes to fouling, the effects on micropollutant removal are minimal, though. Regardless of the fouling type present, the removal of micropollutants remains stable and effective. But foulants do impact the water flux through the membrane. The dirty layer on top leads to increased resistance for water molecules to pass through the membrane. Therefore, fouling is mostly something to worry about when it comes to the speed at which clean water is produced.

Ensuring water safety

“There is another threat, though, that can’t be taken lightly when it comes to water reuse,” the young doctor mentions: damage to the system. Bacteria could slip through the membrane when it is compromised, and these new membranes, even a single fiber could snap and leak into the produced clean water. Since there are so many fibers, you would not even notice that one is broken when looking at the water flux. So how would you check it?

“We tested both plating, in other words growing, bacteria, and the detection of DNA using qPCR of samples where a single fiber was deliberately broken. Here we saw that growing bacteria gives the clearest results when a leak is present. For qPCR, the results could be trickier, as sometimes you will find DNA in the clean water stream while the membrane is functioning properly. This most likely occurs due to free-floating DNA that can wiggle through the tiny pores in the membrane. And we were able to detect antibiotic-resistant genes in the greywater, which is something that deserves attention in the future.”

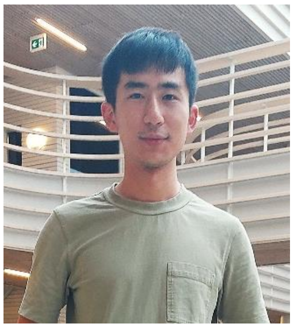


In the end, 80% micropollutant removal in large scale systems seems quite doable, even when testing the limitations Rutten tried. Hollow fiber nanofiltration look like an excellent method to treat greywater effluent. Though it is not yet usable for drinking water yet, the water should be viable for irrigation purpose. “I do think we need long-term investigation and further advancements to unlock the *entire* potential of advanced greywater treatment for water reuse,” Rutten states.

Read more:

Samuel B. Rutten. 2024. “Nanofiltration of Greywater to Remove Micropollutants.” Membrane Science and Technology, MESA+ Institute. https://doi.org/10.3990/1.9789036559508

Creating a Warm Water Web



Nutrients and water seem logical targets when it comes to recycling our household's outputs. But there is more. PhD candidate Shuoguang Yang investigates the energy and recycling ability of grey water – creating a communal warmth battery that is safe and circular is his ultimate goal. And now it seems that regaining hot shower water is entirely feasible.

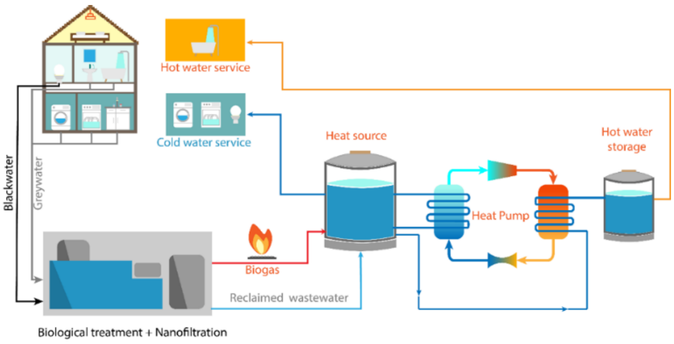
A watched kettle never boils – or so it seems. It takes rather large quantities of energy to heat a container of water, it has a high heat capacity. All good and well if you can burn any fuel on demand to warm your shower, but much more challenging for our environment. That has to change.

And not unlike the nutrients and water we now see disappear down the drain, we flush our warm shower water too. "We could recover a lot of warmth from grey water like shower water, in a source separated system, and likely reuse the water for non-potable solutions like washing too," says Yang. But only once we can make sure that no malicious microbes attach to the heat exchanger. And also, the high-quality treated greywater could be reused if the microbiological safety is guaranteed. That investigation is the other half of the work of this engineer turned microbiologist.

A network of hot streams
The viability of the plan relies on two points: a network of hot streams, and the safety of the reused grey water. "We started by modeling the thermodynamics of a new sanitation system that would regain energy in this way – using a heat pump. The recovery system we design goes over different scenarios, including desired temperatures to reach."

The two variables are vital in their own way. Yang: "A district-level heat recovery system could be more energy- and economy-efficient compared to the single house energy recovery" The researcher thinks that the system can meet the energy demand for household showering. But that will have to be tested in practice yet.

Bacteria sneaking in



The required energy differs based on the heat of the reservoir. "We could heat to 60 degrees centigrade to be effective against more bacterial growth, but if we can ensure safe water at lower temperatures, that would be better."

Therefore, Yang is now testing the outflows from the New Sanitation Site in Sneek, to see if any bacteria sneak through the nanofiltration filters. "We do not expect any but have found some bacteria now. We will test in a newer part of the facility whether bacteria truly pass through the filters, and if so, if they will be harmful."

He will mimic different heat pump temperatures and residence times to see the effects of bacteria. The investigation is focused on where these bacteria come from, how many there are and how the community if built up.

If all goes well, both his thermodynamic modeling and bacterial testing can be combined in a lab-scale setup to further show the viability of grey water energy harvesting.

Read more:
Nagpal, H., Spriet, J., Murali, M. K., & McNabola, A. (2021). Heat recovery from wastewater—A review of available resource. *Water*, *13*(9), 1274. https://doi.org/10.3390/w13091274

A Positive Change to the Nitrogen Cycle

Through the wonders of modern chemistry, we can extract nitrogen fertilizer from thin air and feed millions. On the flip side, this process costs enormous amounts of energy and we are over-enriching our planet with plant nourishment. By source-separating urine though, you can shortcut the nitrogen cycle and let it not go to waste. Better yet, says PhD candidate Widya Prihesti Iswarani, there are even more resources to be gained from this liquid gold.

Nitrogen fertilizers have changed the world as we know it. It has secured food availability for a large population by pulling the much-needed resource out of thin air. The Haber-Bosch process has done good for the world population, making ammonia from nitrogen and hydrogen gas. Though the molecules involved sound simple enough, the process to transform them is not straightforward. It requires about two hundred atmospheres of pressure and needs a temperature that would melt zinc.

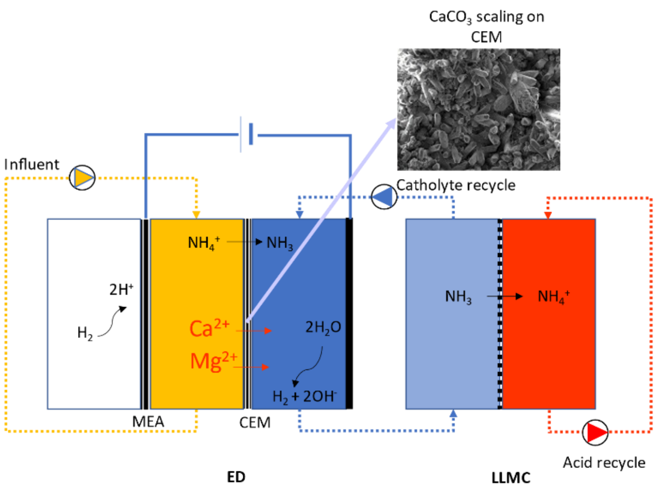
It's odd to think we don't give the generated material a second thought. "Nitrogen feels unlimited as it is everywhere," says Widya Prihesti Iswarani, "but it's a shame we think about it that way, since it's hard to get. And we use it everywhere – from fertilizer to cleaning agents, to industrial processes and more." We have to use biological processes to break the nitrogen down in our wastewater treatment plants, release it back into the atmosphere as nitrogen gas, and regain it from there again. Moreover, this breakdown means that plenty of greenhouse gasses are released.

A new light

So, it's been hot topic at Wetsus to shortcut that cycle. Widya is not the first researcher to approach the challenge but is shining a new light on the circularity of it. "By now, there has been a pilot that can extract ammonia from urine and other streams. Of course, with that new challenges arose, like the issue of scaling. Salts collect over time on the surface of the membrane." And the generation of acid from water in one part, could be used elsewhere where acid is needed.

As of now, ammonium can be extracted from urine, but it still requires some chemical addition to do so. Iswarani: "Once you protonate the ammonia from the influent, it can be transported over the membrane together with other positive ions. The other side of the reactor is alkaline, which then converts the protonated ammonium back to ammonia gas. To recover just this ammonia, it has to be transported over a gas permeable membrane, where it can be captured with sulfuric or nitric acid to make a fertilizer product."

The Gold Standard



This ammonium-ammonia proton trading is not quite circular. That's where Iswarani's research comes in. She has a couple of ideas where to reuse the generated acid. One of which is to prevent or treat the scaling that currently poses a challenge to the pilot at work. We're trying two approaches – cleaning the membranes with acid or using it to regenerate ion-exchange resins that filters out bivalent cations in the pretreatment. Now, both usually are treated by acidic solutions, but the question is just how concentrated acidic solution must be, and can a surplus of protons be used in finale of the process too. As there, ammonia has to be in contact with acid once again, this time to be recovered in directly applicable ammonium-based fertilizers.

And even the ammonia-depleted concentrate that remains can have its uses in a fertilizer context. This salt-laden water could pose the basis from a liquid plant supplement. Given the plant-toxic sodium concentrations can be dealt with, the potassium-rich medium would be an interesting fertilizer product.

Wetsus first nitrogen recovery project stated it well – titled value from urine, Philipp Kunte showed the potential a ‘waste stream’ could have. The valorization makes a great case for the destiny of source separation as the go-to route for sustainable household water and resource reuse. Though it’s not quite liquid gold they’re dealing with, the researchers are on their way to make it a gold standard for sustainable water technology.

Read more:

Rodrigues, Mariana, Aishwarya Paradkar, Tom Sleutels, Annemiek Ter Heijne, Cees J. N. Buisman, Hubertus V. M. Hamelers, and Philipp Kuntke. 2021. “Donnan Dialysis for Scaling Mitigation during Electrochemical Ammonium Recovery from Complex Wastewater.” Water Research 201 (117260): 117260. https://doi.org/10.1016/j.watres.2021.117260.

Ferrari, Federico, Maite Pijuan, Sam Molenaar, Nick Duinslaeger, Tom Sleutels, Philipp Kuntke, and Jelena Radjenovic. 2022. “Ammonia Recovery from Anaerobic Digester Centrate Using Onsite Pilot Scale Bipolar Membrane Electrodialysis Coupled to Membrane Stripping.” Water Research 218 (118504): 118504. https://doi.org/10.1016/j.watres.2022.118504.