Newsletter Science and Technology December 2025

Editorial
by Carlos Contreras Dávila – theme coordinator Natural Flocculants

New polymers are needed in water technology to increase efficiency and sustainability. Whether it is about separation processes to remove contaminants or recover valuable molecules, biodegradable and sustainable alternatives are key to tackling the accumulation and toxicity risks associated with the widespread use of more common synthetic polymers or unsustainable processes. We have selected some publications for you, showcasing the broad reach and variety of work that we host within Wetsus to tackle these global challenges, while opening up new opportunities. Furthermore, we would like to introduce you to the new researchers that have joined us this year, and share an outlook on the ones to come.

First of all, in this newsletter, Yizhou Xing from the Biopolymers from Water theme demonstrated a single-step process to produce biodegradable polyhydroxyalkanoates (PHA) plastics directly from wastewater microbial communities. By carefully choosing fermentation feedstocks, PHA-producing bacteria thrive and accumulate biopolymers, achieving up to fourfold higher yields in just 48 hours – simplifying production.

In the Natural Flocculants theme, we showed, similarly, that the same microbial communities can be enriched with bacteria that produce high amounts of extracellular polymeric substances (EPS). This time, as an effective, biodegradable alternative to petrochemical flocculants. Continuous lab-scale and semi-pilot-scale bioreactors achieved consistent performance from simulated and industrial wastewaters. It allows the raw microbial mixture to be applied directly, thereby cutting purification costs and energy use, and moving the technology toward industrial readiness.

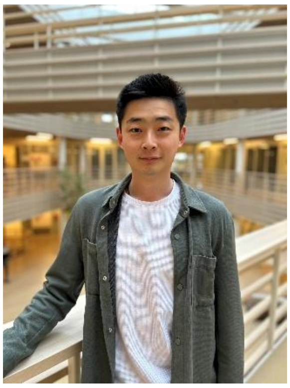
Finally, new polymers are also needed in a more classical chemistry context – to create sturdy, heavy-duty membranes. In the Desalination & Concentrates theme, Xiao Zhang developed a simple crosslinking modification for polyelectrolyte multilayer membranes, making them stable in high-salinity waters. This enables nanofiltration membranes to retain selectivity and resist swelling under conditions that previously caused failure, opening new applications for industrial brine treatment.

Together, these studies show the power of guiding biological and material systems to deliver solutions that are sustainable, efficient, and ready for real-world challenges.

I wish you a pleasant read and happy holidays.

— Carlos Contreras Dávila

Saving energy with single-step, on-site biopolymer production from waste streams



On-site and in a single step, you can selectively and effectively make biopolymers from readily available bacterial mass in municipal WWTPs. That is what PhD candidate Yizhou Xing from the Biopolymers from Water theme, and his colleagues demonstrate in a recent publication in the Chemical Engineering Journal. With simple steering of fermentation feedstocks, you can selectively grow bacteria that naturally store energy as polyhydroxyalkanoates (PHA) – a biodegradable plastic alternative.

Direct accumulation

Wastewater sludge typically contains a mixture of PHA-producing and non-producing bacteria. Traditionally, separating or enriching for the PHA producers require complex, multi-step processes. The approach highlighted by Xing's work, however, relies on one-step selective enrichment accumulation.

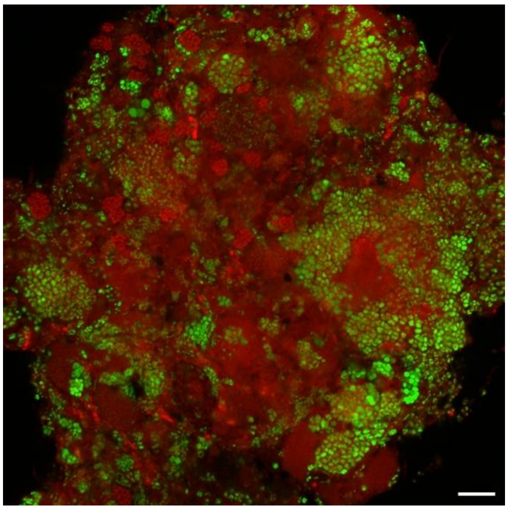
By dosing the right feedstock, for example butyrate, the PHA-producing bacteria can quickly grow while simultaneously storing these biobased biopolymers. Combined with the imposed selective bioprocess conditions, other bacteria struggle to use this substrate efficiently, giving the PHA producers a competitive edge.

Even when starting with a roughly 50/50 mixture of PHA-producing and non-producing bacteria, this strategy allows direct accumulation of PHA, turning what was previously waste into a valuable product. Up to 60% of the product biomass can become PHA as PHA producers selectively grow and convert fed substrate into biopolymers in this single-step bioprocess. Adjusting the feed composition, such as controlling fermentation products, further enhances efficiency, making the process both scalable, robust, and universally applicable.

Energetic surplus

The key principle to the great find lies in tuning to the right substrate and/or the bioprocess conditions for energy-saving in microbial metabolism. By picking the substrates that will undergo prolific uptake and integration in the bacteria – you can generate a metabolic energetic surplus. Then the organisms have energy to spare to grow alongside with PHA synthesis. For instance, when the researchers apply the "energy to spare principles", the production of PHA was increased four times more in 48 hours.

Moreover, these conditions preferentially favor PHA-producing bacteria in the mixed microbial community, as others struggle to compete and flourish on the carefully dosed carbon substrate. In that way, the biomass selectively grows to be mostly composed of those prolific producers that are stuffed with PHA. This means more PHA and in less time, that is furthermore easier to recover. Resulting in savings and benefits in the downstream product recovery too.

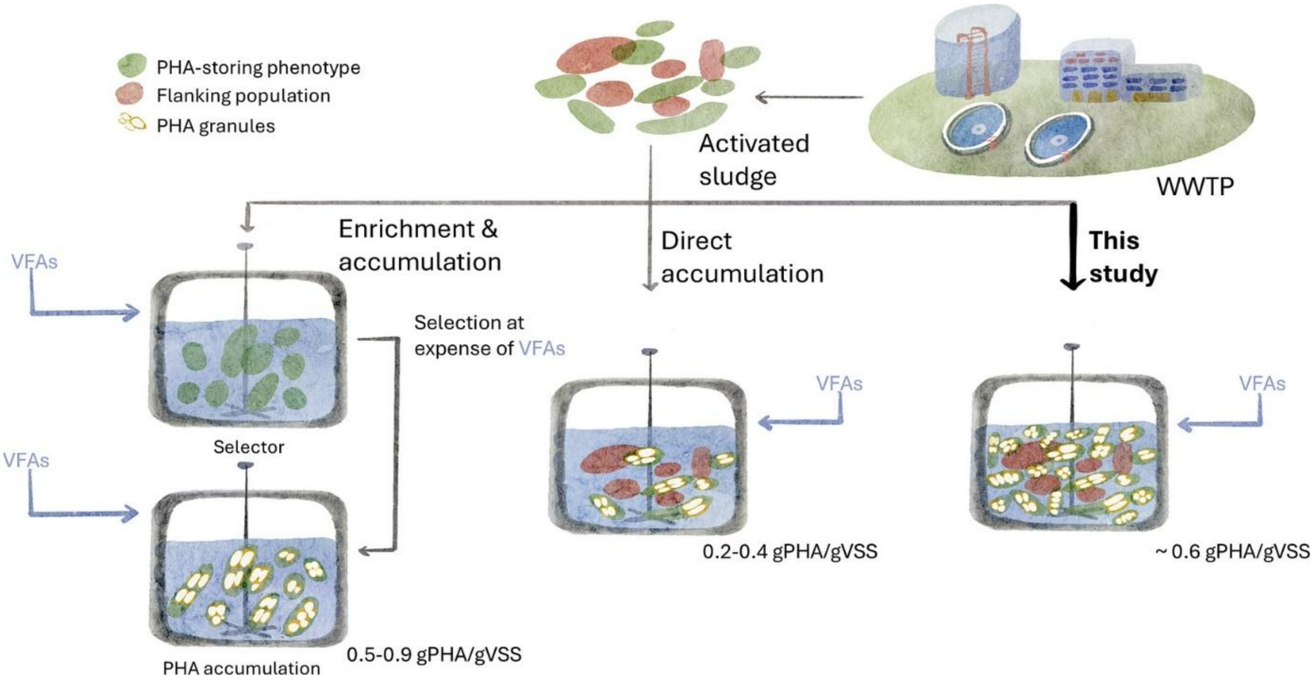


Green-labelled PHA makes up a large part of the overall (red) biomass

Read more:

Xing, Yizhou, Ruizhe Pei, Marta F. S. Cardoso, H. Pieter J. van Veelen, Mark C. M. van Loosdrecht, Robbert Kleerebezem, and Alan Werker. 2025. "Principles for Stimulating Concurrent Selective Microbial Growth and Polyhydroxyalkanoate (PHA) Storage Responses for Enhanced PHA Productivity." Chemical Engineering Journal (Lausanne, Switzerland: 1996) 520 (165907): 165907. https://doi.org/10.1016/j.cej.2025.165907.

Wolkers, Hans. 2025. Chapter 04: From wastewater to biodegradable plastic alternative. Wetsus Innovations: Examples 2020 – 2025. Leeuwarden: Wetsus. https://www.wetsus.nl/wetsus-innovations-2025



Graphical abstract of this study

Natural flocculants made at semi-pilot scale
a feasible alternative to potentially toxic oil-based polymers

Flocculation, a process to precipitate floating particles, is a widely used method to clean our waters. From dredging to mining, and agriculture to wastewater treatment, flocculants, such as polyacrylamide (PAM), made from petrochemicals, are used and carry a serious environmental risk. Now, Natural Flocculants theme coordinator Dr. Carlos Contreras Dávila and his colleagues at Wageningen University have demonstrated on a semi-pilot scale that a bacterial alternative is a feasible option.

Biodegradable, clean, and nearly identical function

As a multibillion-euro industry, the widespread use of PAM-based polymers is remarkable. This versatile polymer, with its excellent tunability, has dominated many sectors. The effectiveness of PAM has never been doubted, but now there are signals that certain processes can cause it to degrade into harmful products, which the RIVM has labelled as high-risk compounds.

Fortunately, there are biobased alternatives that exhibit similar flocculation properties. Yet none have hit the same effectiveness as the familiar oil-based substance. Certainly, when it comes to its adaptability. Now, a publication in Trends in Biotechnology shows that there is a feasible alternative, nearly ready to go.

Leveraging the natural ability of commonly present bacteria in wastewater treatment plants, researchers have produced reliable Extracellular Polymeric Substances (EPS) – excreted polymers made of proteins and sugars. These naturally occurring biopolymers are biodegradable, clean, and function nearly identically to the negatively charged synthetic flocculants.

The working of the natural flocculants

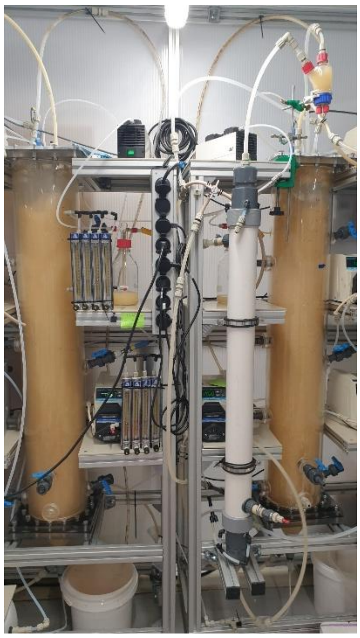
Competitive

And that is quite the feat, as they utilized a wide range of bacteria that are fed analogously disorganized waste streams. Yet they managed to produce a reliable natural flocculant. In this case, the bacteria were grown on readily available waste streams, such as potato starch hydrolysate or glycerol-rich industrial wastewater from biodiesel production.

The team demonstrated that they can precisely tune this quality by adjusting factors such as the water's salinity and carbon-to-nutrient ratios. The research was done at a 10-times bigger scale than before, going from 3 Liter to 35 Liter continuous bioreactors located in the Wetsus lab. It enables a technological readiness level (TRL) between 4 or 5. A great leap forward, but it’s not enough, says team lead Contreras Dávila, as they plan to further demonstrate the technology at TRL 6 or even 7.

Notably, the tests have demonstrated that the raw mixture of microbes and newly formed biopolymers could be used directly as a flocculant, thereby avoiding costly purification steps and saving a significant amount of energy. Scaling up would only make the biopolymer even more competitive at the commercial level.

Further steps would also involve working with regulators to grant these waste-derived biopolymers an "end-of-waste status" and establishing rules that encourage industries to choose these environmentally sound, bio-based options over cheap synthetic polymers. This promises to create a cleaner, safer future for our water and sludge resources.



Bioreactors at work to produce EPS

Read more:

Contreras-Dávila, Carlos A., Yixin Liu, Dainis Sudmalis, Hardy Temmink, and Cees J. N. Buisman. 2025. "Upscaled open-culture production of microbial flocculants from industrial wastewaters." Trends in Biotechnology. https://doi.org/10.1016/j.tibtech.2025.10.006.

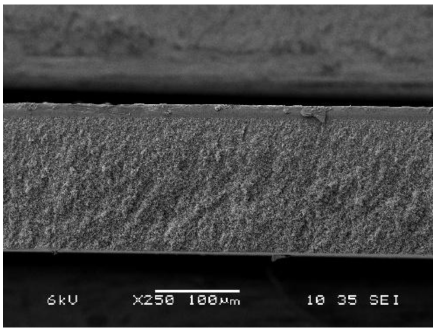
Wolkers, Hans. 2025. Chapter 14: Sustainable sedimentation using natural flocculants. Wetsus Innovations: Examples 2020 – 2025. Leeuwarden: Wetsus. https://www.wetsus.nl/wetsus-innovations-2025

Highly stable layered membrane developed for filter tunability in salty environments

In the past two decades, polyelectrolyte multilayer (PEM) membranes have made a significant impact as a new generation of nanofiltration membranes for advanced water treatment (low fouling, persistent pollutant removal etc.). However, they share a critical flaw: they fall apart or lose efficiency when exposed to highly saline water, such as industrial brine. Zhang, and colleagues in the Desalination & Concentrates, theme demonstrate that a simple crosslinking tweak renders high-performing membranes stable enough to handle highly saline waters, paving the way for tunable and sustainable next-generation nanofiltration.

The team demonstrated their new membrane in a recent publication in the Journal of Membrane Science. By adding a single, common crosslinking agent, they created PEM membranes that retain their high separation efficiency even in extremely high salinity — far exceeding the previous performance of filters with layers that rely purely on electrostatic interactions to stay together.

Strong adherence with a flaw

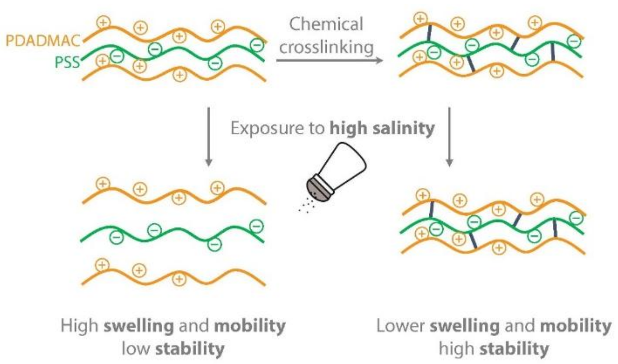


PEM nanofiltration membranes are strong contenders for chemical-free cleaning procedures. Their outstanding resistance to extreme pH and hypochlorite, especially when coated with polyDADMAC and PSS, is a feature that makes them a favorite. They exhibit extraordinary chemical stability while offering the tunability of separation that makes the membranes so attractive. Though their tolerance only goes so far.

Wastewater and industrial brines often exceed the salt tolerance of conventional PEM membranes, causing them to swell and lose the tight structure needed for separation. As electrostatic forces hold together these alternating charged layers, they can only remain tightly adhered if there are few ionic particles to drive them apart.

Previously impossible for nanofiltration membranes

To fix this flaw, crosslinking the different-charged polymers has been tried. Though, as of yet, that is only doable with different layers, as PDADMAC and PSS are so chemically resistant that a binding agent cannot interfere either. Now, Zhang et al. have found an alternative agent that does manage to creep between the molecules to hold them both tightly. DAS, as it's called, chemically binds the layers when exposed to UV light.



This internal structure resists the aggressive osmotic pressure and charge screening effects of high salt concentrations. Non-crosslinked membranes experienced a 300% surge in permeability when exposed to 4 M NaCl – ten times the salt concentration of seawater. In contrast, with DAS included, the membrane demonstrated a swelling that was more than three times smaller. Furthermore, the new setup showed no permanent increase in permeability or loss of selectivity up to a more typical concentration of 1.5 M NaCl. This means these sieves remain effective separators in conditions previously impossible for this nanofiltration technology. The linking thus opens new niches and introduces tunability that was previously impossible in such salty settings.

Read more:

Zhang, Xiao, Antoine J. B. Kemperman, Henk Miedema, Esra te Brinke, and Wiebe M. de Vos. 2025. "Crosslinking PDADMAC/PSS Polyelectrolyte Multilayer Membranes for Stability at High Salinity." Journal of Membrane Science 725 (124007): 124007. https://doi.org/10.1016/j.memsci.2025.124007.

New PhD Researchers at Wetsus in 2025

Wetsus is pleased to introduce ten new PhD researchers who started in 2025. Their projects demonstrate a strong commitment to scientific excellence and long-term innovation in collaboration with our academic and industrial partners. Nine of these new PhD projects are co-funded through UPPWater Dutch Water Tech, and one project is supported by UrbanM2O (Horizon Europe), reflecting our contribution to European research initiatives. The new PhD candidates will address a wide range of challenges in the water sector, from improving monitoring systems and nutrient recovery to advanced treatment processes and material-based solutions. Together, they represent a comprehensive and coherent research agenda.

Advancing monitoring and data-driven water management

Two PhD researchers will focus on improved water quality monitoring and wastewater process control through data integration and machine learning. **Abdelrahman Habash** (Monitoring & Quality I Wageningen University & Research) develops artificial intelligence tools that combine affordable sensor data with laboratory measurements to improve urban water quality monitoring. His research is supported by the UrbanM2O project and contributes to better understanding and management of pollutants in urban water systems. **Soheil Hadisi** (Monitoring & Quality I Wageningen University & Research) investigates optical sensing and predictive modelling to support wastewater treatment automation. His work seeks to help treatment plants manage fluctuations in influent conditions and energy demand, contributing to more resilient and efficient operations.

Optimizing nutrient recovery and sludge management

Three new PhD projects aim to improve the management of phosphorus, nitrogen and sludge in wastewater treatment systems. **Yilin Yang** (Phosphate Recovery I Wageningen University & Research) studies purification and valorization routes for vivianite, a phosphate-rich mineral recovered from sludge. Her research examines new applications, including the potential use of vivianite as a precursor for energy storage materials. **Elizaveta Romanenko** (Phosphate Recovery I Wageningen University & Research) explores regenerative adsorption strategies to recover both phosphorus and ammonium from wastewater. Her work supports efforts to reduce chemical consumption while enabling the integrated recovery of nutrients from secondary wastewater streams. **Ragashree Srinivas** (Resourceful Sludge Dewatering I TU Delft) aims to improve sludge dewatering by identifying the relationships between sludge characteristics and dewatering performance. Her research combines data-driven methods and laboratory investigation to reduce operational costs and environmental impact.

Addressing PFAS contamination in water treatment

Two PhD researchers will contribute to improved removal and destruction of per- and polyfluoroalkyl substances. **Esther de Kroon** (Integrated PFAS Treatment I University of Twente) studies thermo-chemical treatment of sewage sludge to remove PFAS. Her work evaluates pyrolysis, gasification, and incineration processes, with attention to emissions, mass balance, and process optimization. **Monir Taherkhani** (Advanced Water Treatment I Wrocław University of Science and Technology) investigates foam fractionation for PFAS removal in water treatment. She studies PFAS interactions at the gas-water interface and examines how process parameters affect removal efficiency, including the concentration of both long- and short-chain PFAS.

Material and process innovations for separation, scaling control and carbon capture

Three PhD projects focus on advanced separation processes and material-based solutions for improved water treatment and resource recovery. **Tomáš Červenka** (Sustainable Carbon Cycle I TU Eindhoven). Tomáš develops electrospun bipolar membranes for scalable production of acid and base using water dissociation. His research contributes to improved separation processes for carbon capture and resource recovery applications. **Zahra Taghavi Zinjenab** (Applied Water Physics I University of Twente) investigates the formation, stabilization, and application of charged nanobubbles for industrial and environmental water treatment processes, including scaling inhibition and pollutant degradation. **Saghar Ahmadia**n (Advanced Coagulation for Nanoparticles I TU Delft) applies kinetic modelling and data analysis to improve coagulation and flocculation processes. Her research aims to provide predictive tools that support more efficient removal of micro- and nanoparticles from water.

Outlook: additional PhD positions in 2026

In the first quarter of 2026, Wetsus will welcome another ten additional PhD positions across multiple research themes, who are currently recruited. These forthcoming projects will address topics including advanced sensing techniques, energy-efficient separations, soil amendment development, PFAS treatment, biofilm management, and selective electrodialysis. In addition, new PhD vacancies will be opened again in March and September 2026, ensuring continuous innovation and maintaining a program of approximately 65 active PhD researchers.

Together, the newly started and upcoming PhD projects ensure continuity and renewal within the Wetsus research program, while strengthening long-term collaboration with participating companies and universities.

For more information on the started and ongoing PhD projects check our Research themes - Wetsus pages, and for upcoming vacancies check our open PhD positions.

Save the Date for European Water Technology Week 2026

October 26–28, 2026 — De Harmonie, Leeuwarden, The Netherlands

Save the Date for European Water Technology Week 2024: Connecting Global Water Tech Networks

The European Water Technology Week 2026, a gathering at the intersection of science, innovation, talent and business in water technology, will be held on October 26 - 28, 2026. The EWTW brings together leading experts, researchers, entrepreneurs, and policymakers to explore the latest advancements and opportunities in the field. Whether you're interested in the latest scientific breakthroughs, seeking business opportunities, or looking to network with industry leaders, EWTW offers something for everyone.

Integrated in the EWTW are the annual Wetsus Congress and activities of the Water Alliance.