ZERO BRINE: Circular economy approach to industrial wastewater

The ZERO BRINE project, coordinated by Delft University of Technology (TU Delft), aims to reduce industrial saline wastewater streams by recovering and reusing minerals and water from brine. Project Innovation Manager Dimitri Xevgenos and Danielle Kutka and Vanessa Vivian Wabitsch of REVOLVE provide an overview of the European Union Innovation Action initiative that will demonstrate circular economy solutions at four pilot plants.

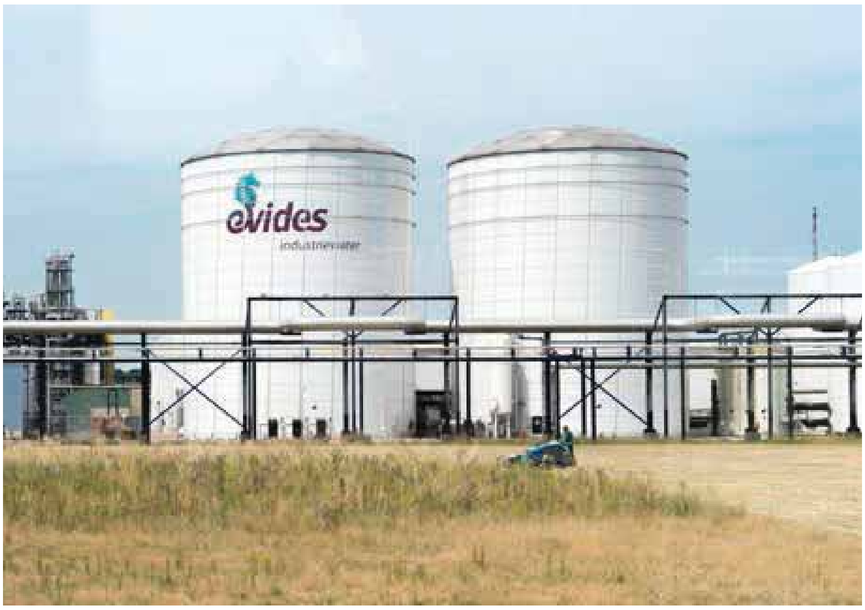
In January 2018, the United Nations-backed report, "The state of desalination and brine production: A global outlook," raised alarm on the environmental impacts of global brine production as desalination plants are increasingly used to meet growing water needs. The report cites the need for further innovations in brine management and disposal, highlighting that the recovery of resources is possible, yet it remains largely economically uncompetitive.

In addition to desalination, process industries are a major generator of brine. In Europe alone, the chemical industry accounts for nearly 11.5 million tons of chloride per year, representing a complex challenge for companies in terms of management and costs. But what if brine was regarded not as waste – but rather as a resource? To help unlock the potential of waste streams such as brine, the European Union (EU) has pledged US$1.14 billion (€1 billion) to finance circular economy projects in the final Horizon 2020 work program from 2018-2020.

As one of the largest EU Innovation Action projects launched within the Horizon 2020 framework, ZERO BRINE offers circular economy business solutions and technological innovations in the field of industrial wastewater. The $12.5-million project, which has been in operation since June 2017 and will continue until May 2021, offers a circular economy approach for the recovery of resources from saline-impaired effluent generated by process industries, integrating existing and novel technologies to recover end-products of high quality and sufficient purity.

The concept of ZERO BRINE is ambitious: to close the loop of these problematic effluents and eliminate wastewater discharge, minimizing the impacts of industrial processing while recovering minerals and resources that can be recycled in the same process industries (internal valorization) and other process industries that do not produce brine streams (external valorization). The project will demonstrate new ways of raw material production through the recovery of resources including water, energy (through waste heat recovery), minerals, magnesium, potassium salts, sodium chloride, carbonates, and other salts, addressing environmental concerns while strengthening Europe's competitiveness.

To achieve these aims, ZERO BRINE integrates technologies focused on organics treatment, brine purification/ion separation, brine concentration, and brine crystallization. Nearly half of the fourteen technologies that the project will employ have been developed within other EU-funded projects. One of its main objectives is to effectively demonstrate these technologies at pilot sites to help bring the innovations to market. Having identified specific industrial sectors for its pilot studies in water, mining, silica, and textile industries, ZERO BRINE will showcase real examples of circular economy solutions that involve stakeholders throughout the value and supply chains to help advance the project toward commercialization.



Above: View of the Evides Industriewater demineralized water plant, located at the Botlek industrial area at the Port of Rotterdam.

Left: The demonstration plant at the Evides Industriewater site in the Netherlands.

The demonstrations will take place at four large pilot plants in Europe. At the industrial cluster of Rotterdam Port in the Netherlands, the demineralized water supplier Evides Industriewater uses a combination of ion exchange and membrane technology: dissolved air flotation, reverse osmosis (RO), and mixed bed ion exchange. To produce demineralized water, the softening of raw water is required, which is often performed by ion exchange units.

During this process, the calcium and magnesium ions are exchanged with sodium ions. The ion exchange unit requires regeneration before it is again used, which is done with a solution of sodium chloride. To create this sodium chloride, the plant consumes close to 2,000 tons of solid salt per year, which is mined and transported from a site that is 300 kilometers (km) away. The salt is then diluted to a solution of 9 percent weight for weight to regenerate the ion exchange resins. In its current operation, large amounts of energy are consumed to evaporate brine at the production stage. This brine is again diluted at the consumption/end-user stage, releasing greenhouse gas emissions that could be avoided through employing a ZERO BRINE approach.

In the demonstration plant, the chemicals needed to regenerate the softening units will be recovered from the brine effluent (internal valorization). The aim at the Evides site is to demonstrate the nanofiltration–evaporation concept for the treatment of ion exchange regenerate and RO concentrate at large industry scale as well as demonstrate the anionic ion exchange–nanofiltration–evaporation–eutectic freeze crystallization concept at demonstration scale.

Part of the energy for the brine treatment will be supplied from waste heat. Waste heat and wastewater streams will be combined in a multi-company site environment eliminating brine effluent (target: zero liquid discharge) of the industrial water supplier, recovering high purity magnesium products (NaCl solution and sulphate salts) and recycling streams within the site (target: greater than 70-percent internal recycling of recovered materials).

The large-scale demonstration at Evides is expected to provide a new paradigm of circular economy industrial water production that provides a solution for both brine streams that are generated while waste heat from neighboring factories exhibit industrial symbiosis. Bringing the industry water producer closer to the design and production phase for salt production will result in sustainable sourcing of raw materials and avoid overproduction, waste, and other environmental impacts while enabling the optimization of production processes through the internal valorization of minerals recovered.

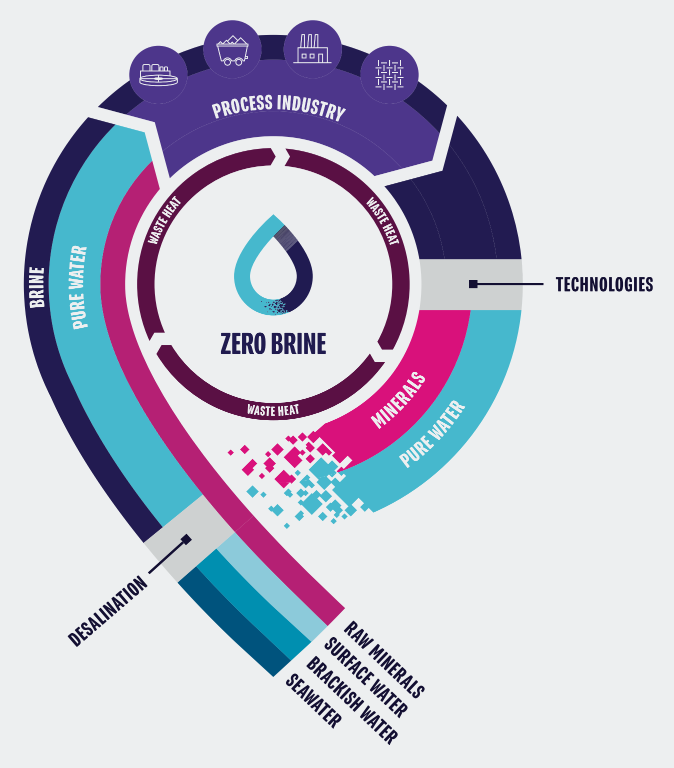
At the Bolesław Śmiały coal mine in Łaziska Górne, Poland, a pilot plant demonstrating the application of circular economy principles will aim to decrease the energy consumption by 50 percent when compared to the energy consumption of a reverse osmosis (RO)-vapor compression system, which represents the current best practice. The coal mine water, which has a salinity of approximately 23 grams per liter (g/L) and is rich in calcium sulphate, will be treated using an integrated system consisting of nanofiltration, RO, and electrodialysis. A new crystallizer solution, developed by the University of Palermo, will also be tested. The aim of the plant is to demonstrate that coal mine water, considered to be a waste by the industry, can be the source of valuable raw materials such as concentrated brine, magnesium hydroxide, calcium chloride, clean water, and gypsum. The plant is scheduled to be operation in February of 2019.

The pilot project in Zaragoza, Spain, will be implemented at Industrias Quimicas del Ebro SA (IQE), a producer of soluble silicas, with the objective of demonstrating the technical and economic feasibility of implementing a circular economy scheme in the silica industry to recover water, sodium sulphate, waste heat, acids, and alkalis. The technologies that will be evaluated here include nanofiltration for concentrating effluents with high sulphate concentration, eutectic freeze crystallization and forward-feed evaporation to crystallize sodium sulfate from concentrated streams, and electrodialysis with bipolar membranes (EDBP) to recover sodium hydroxide and sulfuric acid. Nanofiltration and crystallization pilot plants will be implemented at IQE to demonstrate these technologies while EDBP will be evaluated at bench-scale.

The final pilot study focuses on the development of an innovative brine treatment system for the textile industry, with the aim to recover concentrated salt solutions for reuse in the textile dyeing process baths. TUBITAK MRC will complete the pilot study in cooperation with ZORLU Textile and Energy Groups in Kırklareli, Turkey. The methodology involves initial comprehensive physical and chemical characterization studies, which are followed by bench-scale treatability studies. Removal of impurities such as color and hardness from the salt stream is achieved. These parameters are crucial for the recovery of the brine solution for textile process requirements; therefore, pre-treatment options will be carried out and optimized. Technologies such as nanofiltration, oxidation, and ion exchange will be tested at this stage.

Secondly, the increase of the salt concentration up to the concentration of the targeted reuse criteria will be tested. In this case, the proposed technology options are membrane distillation – by making use of waste heat from the enterprise – and RO. Furthermore, tests on the fabric to check suitability of the developed system for the point-of-production process will be carried out. The treated effluent generated after these processes will be assessed for reuse. In the case of failure for fulfilling the textile process requirements, salt recovery will also be investigated and tested by using the evaporation/crystallization processes to obtain recoverable salt as an external valorization option for other sectors.

ZERO BRINE process diagram



But what if brine was regarded not as waste – but rather as a resource?

The expected results from the textile industry brine recovery system have been pre-assessed at 50 kilotons per year of water consumption reduction due to achievement of additional water reuse, the recovery of 400 tons of sodium chloride per year for production processes, and a reduction of 200 tons per year of carbon dioxide emissions due to the sodium chloride recovery and attainment of waste heat recovery.

In addition to the pilot plants, the ZERO BRINE project has developed the Online Brine Platform – an active web service to connect stakeholders at all stages along the value and supply chains of brines, industrial water, and salts. The platform facilitates the exchange of information and data, automatically matching partners according to their economic and environmental objectives. The first of its kind, this digital platform will advance the industrial symbiosis in Europe and worldwide. In addition, five Brine Excellence Centres will be developed within partner organizations in the Netherlands, Italy, Greece, Poland, and Spain to provide the opportunity for end-users to test and develop customized and validated brine treatment solutions.

As the pilot plants progress, a series of site visits will be coordinated to display the innovative technologies at each of the demonstrations. For more information on the project, visit www.zerobrine.eu.

Authors' Note

Dimitris Xevgenos is the Innovation Manager of the ZERO BRINE project. Danielle Kutka and Vanessa Vivian Wabitsch are project managers at REVOLVE, based in Brussels, Belgium.

About ZERO BRINE:

The ZERO BRINE project – "Re-designing the value and supply chain of water and minerals: A circular economy approach for the recovery of resources from brine generated by process industries" – is coordinated by TU Delft and includes 22 partners from research institutes, small and medium-sized enterprises, construction companies, and end-users from 10 countries.