ZERO BRINE

D10.3 Policy Brief and Reports – Advancing the ZERO BRINE process and demo projects

October 2020

Draft

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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

Executive Summary

Policy briefs and factsheets are one of the most effective ways to reach policy and decision-makers. For this reason, ZERO BRINE is developing four policy briefs and four media kits – key communication tools to communicate and disseminate ZERO BRINE results and recommendations. The policy briefs are targeted to policy-makers on European and local level (countries of the demo projects). As a key communication tool they are central for presenting the results to all stakeholder groups specifically to industry, associations, environmental agencies, authorities, SPIRE network and media.

This document outlines the strategy and implementation of the ZERO BRINE policy briefs that are developed in a collaborative approach by REVOLVE and WATER EUROPE with inputs from pilot plants WP2, WP3, WP4 as well as the Life Cycle Analysis in WP7, business modelling in WP8 and policy review in WP9. The dissemination and outreach are a key component of the strategy.

This deliverable was submitted in M24 as a draft; due to the interconnectedness of this deliverable with results from other work packages, it was decided with the Project Officer and Executive Project Coordinator to update the draft deliverable in increments of every six months. In order to ensure outreach to respective target groups at an early stage, this deliverable is continuously updated with the latest results and project conclusions, with the final deliverable to be submitted in M48 pending approval of the project extension, which would result in a final submission in M54. The respective policy briefs and media kits (Annex) will be disseminated during the project in alignment with legislation to have most impact.

Contents

List of Figures

1. Overview

The policy briefs will highlight and outline the learnings and recommendations of the project. They will be designed in a P4P (Project for Policy) approach that uses R&I project results to shape policy, ensuring that the ZERO BRINE technology has the best conditions to be implemented in the market.

This way, project results can become an excellent tool for policy-makers to:

- Provide evidence and data for policy development and design
- Highlight gaps or barriers in current policy frameworks or approaches
- Help develop new opportunities and innovative activities for any area of policy-making across Europe and the world.

Four ZERO BRINE policy briefs will highlight the project results and recommendations linked to the European policy context with regards to industry (focusing on the industry of ZERO BRINE's pilot plants), circular economy, energy and climate action.

The **Core policy brief** elaborates on the key project results and conclusions about the technology, impact (economic and environmental) and key legislative directives that influence the implementation of the technology.

Three specialised policy briefs demonstrate key enablers and obstacles as well as recommendations to support policy makers to amend legislation in a way that supports the market implementation of the ZERO BRINE technology and similar green technologies.

- **Policy brief focusing on the Industrial Emission directive**
- **Policy brief focusing on REACH** (Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals)
- **Policy brief focusing on Water**

For a comprehensible illustration of ZERO BRINE technology, results and business opportunities, four media kits including factsheet, videos and photos, one for each demonstration site, will be developed once first results are available.

The policy brief is developed within 35 months between M12 and M48 in line with the availability of the results of the pilot plants (WP2, WP3, WP4), life cycle analysis (WP7), business models (WP8) and policy review (WP9) (see Figure 1). D10.3 will be updated every six months in M30, M36, M41, M47.

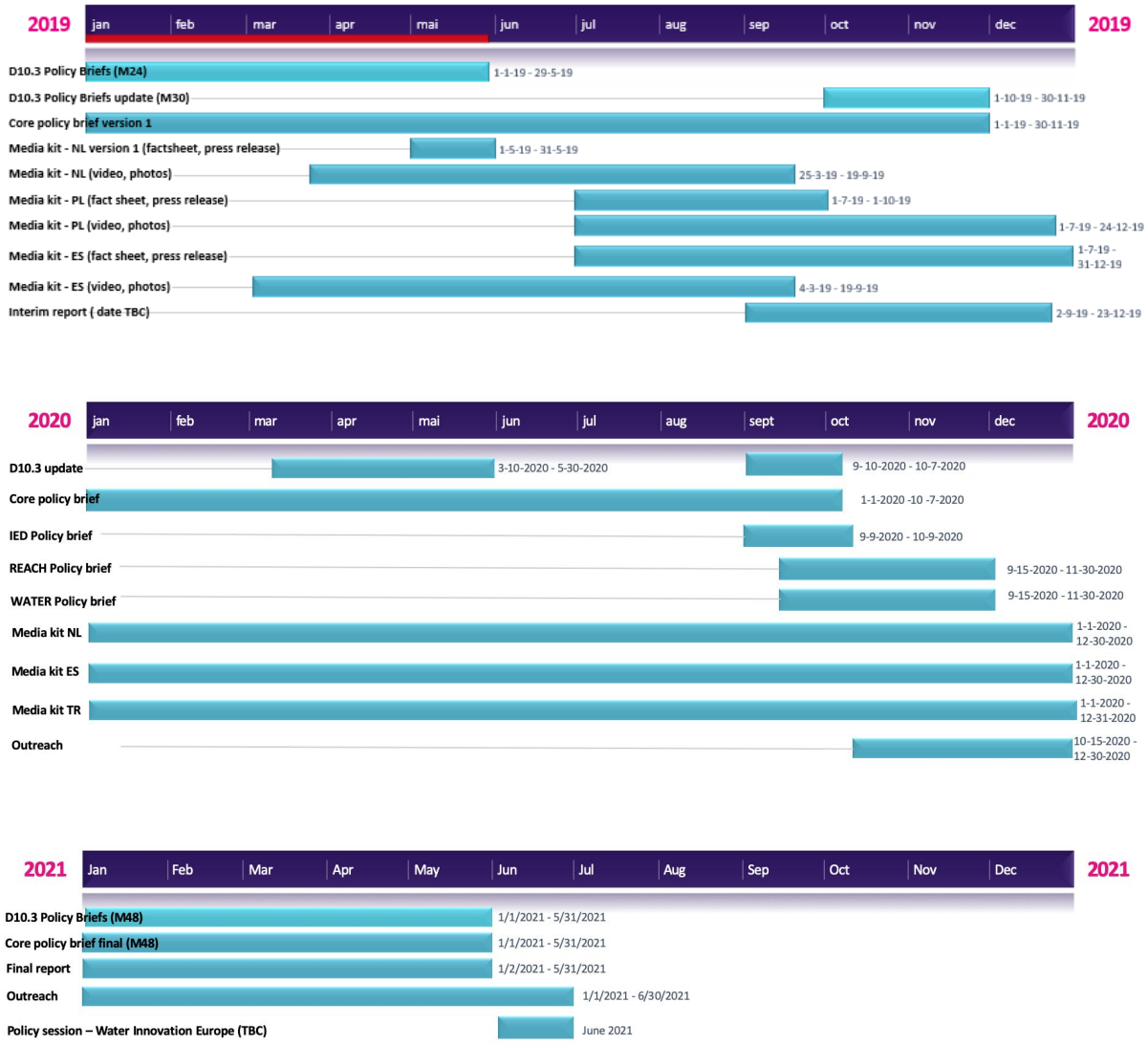

Figure 1 Process Plan Policy Briefs

Task 10.3 is led by REVOLVE, with co-lead Water Europe, in cooperation with all partners. Especially inputs and close collaboration with the following ZERO BRINE tasks and partners is essential to communicate and disseminate ZERO BRINE results effectively via policy briefs:

- WP9: D. 9.1 Environmental impacts of brine and D9.2 Report on policy review and assessment / suggestions for BREF update: NTUA
- WP7: Life Cycle Analysis: TU Delft
- WP2: (Re-designing the supply chain of water and minerals in the Botlek area): TU Delft, Evides
- WP3: (Minimizing energy consumption and increase resource recovery yields through advanced treatment methods in the coal mine and textile industries): SUT, TUBITAK
- WP4: (Promoting circular economy in the chemical sector): Eurecat

- WP8: Business plan/market exploitation and replication / IP: SEALEAU, TU DELFT, Eurecat

2. Development of the policy brief

ZERO BRINE is developing four policy briefs. The core policy brief gives an overview about the key project conclusions in regards to policy. For more in-depth information and recommendations ZERO BRINE developed three policy briefs specialising on directives and topics that are especially relevant to the market roll-out of the technology. The specialised policy brief is cross-linked with the core policy brief.

i. Core policy brief

The ZERO BRINE core policy brief will present the ZERO BRINE results and recommendations linked to the current policy context on European level with a focus on climate action, circular economy, energy, industry, economy and environment. This policy brief consists of the following structure:

1. Introduction
2. ZERO BRINE: Closing the loop for industrial wastewater
3. Impact of the ZERO BRINE approach
4. Pilot Projects and outcomes
5. The path of the green technology
6. Policy recommendations for a green and resilient European industry

The first designed draft of the ZERO BRINE policy brief has been delivered in M36. It was updated with latest results and key conclusions in M41 (see Annex) integrating the feedback from the external review. It will be updated by M48 to integrate key results of the pilot plants, policy review, life cycle analysis and business modelling.

ii. Policy Brief: Focus on the Industrial Emissions directive

ZERO BRINE developed a policy brief focusing on the Industrial Emissions directive (IED) (see Annex) to demonstrate the contribution of a technology like ZERO BRINE to achieve the requirements of the IED and a more resilient European industry. The policy brief highlights the gaps and recommendations of IED to support the exploitation of the ZERO BRINE technology and similar technologies.

The policy brief touches on the following topics:

1. Background

2. ZERO BRINE: A technology supporting the effective implementation of the IED
3. ZERO BRINE: An available technology for a more resilient European industry.
4. Recommendations regarding the revision of the IED

This ZERO BRINE policy brief has been delivered in M41 and will be shared with policy-makers to contribute to the amendment of the IED between M41 and M45. It will be updated by M48 to integrate final results and conclusions of the pilot plants, policy review, life cycle analysis and business modelling.

iii. REACH & Water Policy brief

ZERO BRINE is developing a technology focusing on the REACH regulation (namely the registration, evaluation, authorisation and restriction of chemicals) and Water related regulation. These ZERO BRINE policy briefs will be developed between M40 and M42 and will be shared with policy makers to contribute to the amendment of the IED between M42 and M48. It will be updated by M48 to integrate final results and conclusions of the pilot plants, policy review, life cycle analysis and business modelling.

3. Dissemination and communication strategy for policy makers

The policy briefs will be disseminated to EU institutions to targeted departments such as energy, climate action, environment, economy, regional affairs, local government, environmental agencies, SPIRE network and media with full tracking and outreach reporting of the ZERO BRINE project. The policy briefs will be distributed both in print (5,000 copies) and digitally via the ZERO BRINE website, news alerts and social media. Furthermore, they will be distributed at key EU and international policy events such as: the EU Green Week, the Water Innovation Forum, the International Water Summit, the World Water Week, Global Water Summit, European Sustainable Energy Week as well as the yearly Water Innovation Europe events organized by Water Europe in Brussels.

The outreach strategy for the dissemination of ZERO BRINE policy briefs is based on three key goals:

1. Outreach to policy-makers to impact European legislation
2. Outreach to platforms to disseminate the information on the new technology and increase the visibility and importance of this technology
3. Outreach to local authorities and potential end users of the new technology

a. Outreach to policy makers to impact European legislation

With regards to the first goal to contact policy-makers and impact the legislation, the first step is to connect with the three key institutions of the European Union, the Council, the European Commission

and the European Parliament. The topic of the ZERO BRINE policy briefs is linked to the Industrial Emissions Directive, the REACH legislation, the Zero Pollution Action Plan as well as the Circular Economy Action Plan. Water Europe has prepared a contact database with around 165 contacts to target this stakeholder group and is going to proceed with three main actions:

- Target MEPs related to the countries of the ZERO BRINE pilots: Dutch MEPs (29), Polish MEPs (52), Spanish MEPs (59)
- Target the Perm Reps related to the countries of the ZERO BRINE partners: Embassy of UK, Embassy of Turkey, Perm reps Belgium, Germany, Greece, Italy, Poland, Spain, Netherlands
- Target key units of the European Commission related to the topics resource recovery and circular economy B.3 DG ENVI, C.1. DG RTD, D.3 DG RTD, B.5 DG RTD, C4 DG ENVI

A policy session dedicated to the topic circular economy and resource recovery for industrial wastewater will be organised at Water innovation Europe June 2021 organised by Water Europe.

b. Outreach to platforms

As the ZERO BRINE technology is a cross-sectoral technology, the EU platforms are the right way to disseminate the information to other sectors at the EU level. This way, we will contribute to breaking the siloed-approach in term of innovative solutions for resource recovery from several sectors. The policy briefs will be disseminated to CEFIC (chemicals industry), CEMBUREAU (silica industry), EURACOAL (coal industry), EURATEX (textile industry), EUROSIL (silica industry), IMA Europe (industrial minerals association), ITKIB (Turkish association of textile exporters). ZERO BRINE is also a SPIRE project and therefore the SPIRE members are one of the target groups to disseminate this information in addition to a broader communication campaign.

c. Outreach to local authorities and potential end users

The potential uptake of the new ZERO BRINE technologies and the whole process of bringing these technologies to the market can be facilitated through the Water Europe's Water Market Europe event in March 2021 dedicated to promoting new technologies and innovations in Europe and beyond. In the occasion of ZERO BRINE, good ambassadors will be also the local users from the pilot project. For this reason, dissemination of the project results in the local languages of the pilot countries is also a key element. REVOLVE will develop policy briefs in English, Spanish, Polish, Dutch and Turkish with translations provided by the project partners running the pilot plants. Water Europe aims to approach local authorities' representatives at the EU level to disseminate the information (Committee of regions & MEPs). ZERO BRINE partners running the pilot plants will support the outreach the national and local actors to (including regional water agencies).

Water Europe will establish relations with all the above-mentioned contacts through direct emailing. In addition to this, Water Europe will consider organising a tailored, specialised policy session at one

of its annual events (e.g. Water Innovation Europe 2021) to bring together the most relevant contacts for the achievement of the three key goals of the policy outreach plan.

ZERO BRINE has good potential to contribute to Water Europe's working groups such as "Water and Desalination", "Resource Recovery", "Industrial Water Efficiency and Reuse practices". Several ZERO BRINE consortium partners are members of existing Water Europe Working Groups that can function as vehicles for the integration and dissemination of ZERO BRINE learnings and technologies to EU stakeholders and contribute to the white papers' development with the outcomes from ZERO BRINE.

4. Development of ZERO BRINE media kits

ZERO BRINE is developing four media kits including factsheets, infographics, interviews, photos and videos for each demonstration site. Infographics that illustrate the results in a comprehensible way will be developed for the factsheets. Furthermore, they will be extracted and used for social media online shareables to target policy-makers, European institutions, environmental agencies and media.

All videos of ZERO BRINE demonstration sites follow the below content structure:

- Challenge: The current situation/problem/barriers
- Need: Why is recovering resources in the respective industry important? > circular economy solution needed
- Technology: Showing the technology, importance and facts about the technology
- Main results created or expected
- Future outlook: usage of technology, benefits, threats, opportunities >> where and what sectors can it be replicated or scaled

a. Case study I: Demineralised Water Plant in the Netherlands

The factsheet for the Demineralised Water Plant (DWP) in the Netherlands, version 1 (see Annex) was developed in M24 and distributed during the field visit to salt and industry experts as well as specialised international and local media outlets. The fact sheet will be updated once the results of site I and site II are available (by M48).

The interview with an expert of this pilot plant will be published by M42.

Photos of the demonstration site are available on the project website (see here).

The video will be developed between M39 and M43.

b. Case study II: Coal mine in Poland

The factsheet for the demonstration site in Poland (see Annex) was developed between M26 and M31 and will be updated based on the results of the demonstration (by M43).

The interview with an expert from SUT was also will be published by M43.

The photos of the demonstration site were taken in M29 during the field visit and are available on the project website (see here) along with the video footage. As the pilot was operational until M35, the video will be produced once the final results are available (M43).

c. Case study III: Textile factory in Turkey

The factsheet for the demonstration site of the textile factory in Turkey was developed in M40.

The interview with an expert from TUBITAK will be conducted M43 - M46.

First photos are available on the project website (see here). More photos of the demonstration site as well as the video will be filmed during the field visit which is yet to be confirmed due to COVID-19 developments, but tentatively planned for by M43-M46.

d. Case study IV: Silica factory in Spain

The factsheet of the demonstration site was developed in M34-M35 based on results of the pilot (see Annex).

An interview with an expert by Eurecat about the demonstration site of the silica factory in Spain will be developed by M42 based on the results of the demonstration.

Photos are available on the project website (see here). The video was filmed by IQE and delivered to REVOLVE by M31; the final results of the pilot will be produced in the video by M42.

Annex

a. Core policy brief

b. Policy brief focusing on IED

c. Factsheet Netherlands

d. Factsheet Poland

e. Factsheet Spain

f. Factsheet Turkey

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THE CIRCULAR ECONOMY APPROACH FOR INDUSTRIAL WASTEWATER

CORE POLICY BRIEF

The Horizon 2020 project ZERO BRINE demonstrates the technical feasibility and economic and environmental benefits of recovering minerals and water from waste industrial brine for reuse, and its compatibility with the principles of a Circular Economy, the EU Green Deal and the Industrial Emissions Directive.

1. INTRODUCTION

The chemical industry alone produces 11.5 million tonnes of brine every year.[1] Brines are highly concentrated solutions of salt water containing many chemicals, minerals, metals, and organics which can be extracted as valuable resources for reuse. The current linear economy approach perpetuates the disposal of brine. This has economic consequences in terms of treatment and disposal costs and environmental impacts such as harmful salinity for land and aquatic ecosystems and the greenhouse gas (GHG) emissions of energy consumption.

ZERO BRINE proposes a circular economy approach to reduce the negative impacts of brine from process industries and to create economic value from the reuse of its constituents such as sodium chloride, magnesium, calcium, sulphates, sodium bicarbonate, heat and fresh water. ZERO BRINE demonstrates the use of a combination of existing and innovative technologies for recovery and reuse. This approach combined with promotion of low carbon energy sources aligns with the EU's Circular Economy Action Plan and Green Deal.

This policy brief first demonstrates the resource recovery, environmental and economic benefits that can be achieved. It then highlights where it aligns with existing policy objectives and includes recommendations on addressing policy gaps and updating BREFS in relation to the Industrial Emissions Directive (IED).

2. ZERO BRINE: CLOSING THE LOOP FOR INDUSTRIAL WASTEWATER

Four industries in diverse geographies implement the ZERO BRINE technology: demineralised water production, coal mining, silica production and textiles. They demonstrate the applicability of this technology for wastewater treatment in a wide range of industrial processes with significant potential for replication. All four pilot studies are monitored intensively by an integrated impact assessment tool based on societal, economic, and environmental aspects. This policy brief presents preliminary results on the potential of ZERO BRINE technology with the final results to be presented - along with the Environmental Technology Verification and an Innovation Deal formulation - at project end (mid 2021).

The outcomes show that ZERO BRINE technology can achieve significant recovery of water, brine and minerals and a reduction in GHG emissions through more efficient process design. They also confirm that reuse of materials can reduce the large-scale value chain demand on fresh and raw materials.

1 Smart Water Grids – A cyber-physical systems approach, 2018, by LLC Francis Group

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3. IMPACT OF THE ZERO BRINE APPROACH

Discover the ZERO BRINE media kits for more information including the pilot factsheets, photos, and videos.

• Resource recovery

Resource recovery is the key outcome, contributing to both environmental and economic benefits. The four pilot projects demonstrated the following results:

- Fresh water recovery between **60% and 91% (average 73%)** of the brine volume.
- Brine recovery as principally NaCl solution of **30% to 40%** of volume.
- **High recovery rates** of a range of minerals (more details in section 4).

• Environmental benefits

Industry accounts for 22% of global water demand.[2] Closing the loop on industrial wastewater helps reduce the demand for fresh water resources and the need to pump water long distances, resulting in fewer GHG emissions. Mineral recovery lessens the demand for mining and processing of raw minerals and the related environmental and transport impacts. The pilot projects achieved the following range of environmental benefits:

- **Reduced abstraction of freshwater resources** due to the volumes recovered.
- **Reduction of GHG emissions through energy efficiency**, waste-heat capture and reduced transport impacts.
- **Reduced volumes of brine** disposal to the environment **of more than 90%.**

• Economic benefits and opportunities

Cost savings.
Circular industry processes are essential to develop a sustainable, low carbon, resource efficient, and competitive economy in the EU. The ZERO BRINE technology addresses the issues of cost and management of brine and the compliance with more stringent, costly environmental regulations for polluting, as is the case in Poland, as well as decreasing costs by reusing water and other resources within the production process.

Resilience & Critical raw materials.
Additional economic benefits include the cost savings from resource efficiency from using less water and resources than required for linear production processes as well as producing critical raw materials such as magnesium. With 99% of magnesium being imported currently, the EU is dependent on imports mainly from China. ZERO BRINE thus contributes to a strong European industrial strategy reducing dependence and transportation impacts of importing resources.

Revenue streams.
Opportunities for companies arise from new possible revenue streams from recovering resources of good market value. What cannot be recirculated into their own production lines can be sold as high quality, second generation minerals at a good market value.

New businesses & jobs.
Additional economic benefits lie in new businesses powered by circular economies, ranging from those companies involved in wastewater treatment and reuse, to the creation of new jobs for technical personnel in process industries and other sectors including environmental fields.

2 https://www.unwater.org/water-facts/quality-and-wastewater/

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4. PILOT PROJECT RESULTS AND OUTCOMES

• Demineralised water plant, The Netherlands

Recovery of minerals and freshwater with waste heat reuse

Demineralised water is an essential commodity required for many industrial processes. The Port of Rotterdam is one of the largest petro-chemical clusters in Europe whose supply of distilled water is sourced from the Brielse Meer. At the Energy Port and Petrochemical cluster of Rotterdam, residual heat from a nearby factory is used to eliminate brine effluent while recovering high purity magnesium, calcium hydroxide, sodium chloride solution and clean water. Impacts on the aquatic environment are reduced due to reduced surface water discharge. Two sites investigate the ZERO BRINE concept: Site I aims to **recover >90% high purity magnesium and calcium treating 20% of total brine,** Site II demonstrates the concept of using waste heat in a multi company site as one of the energy source to eliminate brine discharge and aims to treat 5% of the brine. Preliminary results achieved:

Resources recovery
- Fresh water: Site I **40-90%** & Site II **80-90%** of brine volume
- Brine: **30%** of original volume as NaCl solution
- Magnesium hydroxide, $Mg(OH)_2$: **80%** recovered at **80-95%** purity
- Calcium hydroxide, $Ca(OH)_2$: **>95%** recovered at **92-98%** purity

Environmental benefits.
Extracting and purifying the water requires a lot of energy. Use of waste heat reduces CO_2 emissions. Reduced brine discharge is a benefit to the Brielse Meer which has experienced increasing salinity over recent decades.

- Brine discharge to the environment **reduced by 100%**
- Freshwater abstractions r**educed by 15%**
- CO_2 emissions reduced by **300 tonnes of CO_2**

Economic benefits.
The recovered NaCl solution and sulphate salts are recycled back into the site and reused, advancing resource efficiency.

• Coal mine, Poland

50% less concentrated brine, reduced energy use and value recovery of salts

At the Bolesław Śmiały coal mine in Łaziska Górne, a technological solution for mine wastewater is demonstrated. An innovative combination of nanofiltration, reverse osmosis (RO), electrodialysis and crystallisation was applied to recover sodium chloride, magnesium hydroxide and clean water. As coal mine wastewaters are similar to sea water, the technology could also be applied in the desalination industry – a sector expected to become increasingly important.

Resources recovery
- Fresh water: **91%** of brine volume
- Sodium chloride, NaCl: **90.5%**
- Gypsum, CaSO4.2H2O: **75.5%**
- Magnesium hydroxide, $Mg(OH)_2$: **94.9%** at **97.9%** purity

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Environmental benefits.
Poland's mining sector currently discharges **4 million tonnes of salt** into its rivers annually including to the country's main river, the Vistula, which contains 55% of Poland's freshwater reserves and covers 60% of its water needs. Mineral reuse reduces the transport impacts of raw materials, reducing transport related GHG emissions. Preliminary results achieved:

- CO_2 emissions reduced by about 340 kg CO_2 per ton of NaCl, the **energy reduction is about 33%** by reduced on site energy consumption and reduced minerals transport
- Recovered demineralised water (0.91 m^3/m^3 of treated brine) can be reused for technological purposes, decreasing the freshwater abstraction by the industry
- Avoiding the discharge of 20.64 kg of NaCl/m^3 of treated brine into the freshwater

Economic benefits.
Recovered salts are a valuable product for resale. The average production in Poland is around 4.3MT/year, with salt-in-brine accounting for around two-thirds of production. Increased salinity of the Vistula river **is estimated to cost industry, agriculture, water, and transport combined losses of $100-250 million per year.** The method includes reduced energy consumption of 50%, thus saving on costs.

• Textile industry, Turkey

Recovery and reuse of sodium chloride for textiles dyeing

The textile industry is **highly water intensive** using 60 to 120 L/kg for cotton products and 110-650 L/kg for wool.[3] Salt (as NaCl) is an important agent for fixing dye to the cloth by creating attracting electrical forces in place of negative forces between water and cloth. Thus, the ability to reuse water and salt is highly beneficial.

At the Zorlu Textile factory in Lüleburgaz, innovative treatment and membrane technology were used to recover high concentrations of NaCl and clean water for direct reuse. The project aims to recover **400 tonnes of salt/year,** thus reducing the demand for raw salt. A further benefit is heat reuse and an associated reduction in GHG emissions.

Resource recovery
- Fresh water: **60%** of brine volume for direct reuse due to internal recycling and reuse of salt product and clean water
- Brine: **40%** of brine volume recovered as NaCl solution
- Sodium chloride, NaCl: **60-70%** recovery for direct reuse

Environmental benefits
- Brine discharge to the environment **reduced by 100%**
- Reduced freshwater abstractions by 50,000 tonnes (15-20%) per year.
- CO_2 emissions reduced by **20% and 200-300 TCO_2** [From reduced onsite energy consumption and reduced minerals transport]

Economic benefits.
The expected outcomes will **decrease the salt consumption of the factory by 40% and water consumption by 15%.** The results will greatly help the textile industry achieve resource efficiency and improve sustainability through reduced consumption of process inputs, as well as the mitigation of GHG emissions with an estimated 20% decrease.

- Cost savings from reduced water consumption of 200-250k EUR/year (Water price of 1 EUR/m^3 for Kırklareli is considered.)
- Cost savings from reduced volumes of purchased salt are 15-20k EUR/year, from reduced water intake and service water treatment about 20-30k EUR

3 The Textile Industry and the Environment, UN Sales No: E93-III-D5, UNEP, Paris 1994.

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- **Silica industry, Spain**

Recovery of minerals and recovery and direct reuse of clean water

The EU silica industry produces **620,000 tonnes of silica per year** for use in the manufacture of a range of products as an additive for food, pharmaceuticals and cosmetics. The industry also **generates over 21 Mm^3 of wastewater**. At the chemical supplier IQE in Zaragoza, an innovative combination of eutectic freeze crystallization and forward fed evaporation are applied to silica precipitate production for the removal and recovery of sodium sulphate (Na_2SO_4).

Resource recovery.
- Fresh water: **more than 90%** of brine volume for direct reuse.
- Sodium sulphate, Na_2SO_4: **more than 90%** recovery
- Zero Liquid Discharge achieved

Environmental benefits
- Wastewater and brine discharge to the environment reduced **more than 90%, 1 Mm^3/year**
- Reduced freshwater abstractions of **30%**

Economic benefits
- Cost savings from reduced demand for freshwater: **460,000 EUR per year** and **turnover of 1.8 M EUR.**
- **20,000 tonnes** of sodium sulphate recovered. At a market price 90 EUR/tonne, sodium sulphate is a valuable product for many industrial sectors including powdered detergent, glass, pulp & paper, textiles, and carpet fresheners.

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5. THE PATH OF THE GREEN TECHNOLOGY

Based on the outputs of this project, the following enablers and barriers were identified.

ENABLERS	BARRIERS
• Brine recovered chemicals already fulfil ECHA and REACH criteria. • The techniques proposed within the project framework are considered as Best Available Techniques (BAT) in Reference Documents (BREFs) for substances and water recovery from waste. • Environmental: EU Circular Economy Package enhances water and substances reuse and recycling partly covering brine. • Economic: New and/or innovative business models support resource efficiency in several industry types which can represent significant economic benefits companies applying the ZERO BRINE approach.	• Existing legislation is oriented more to brine discharging than to brine processing and resources recovery. New sections offering more data should be added to BREFs particularly recovering water and substances from brines. • Few financing programmes for new brine management technologies adoption exist, thus reducing the incentive to apply them. • Technologies that manage a wide range of brine contaminants are not supported financially and a less attractive option for industries. • Difficulties on the market application of secondary raw materials due to lack of information/trust. • Existing legislation focuses on pollution prevention with limited mention of the potential environmental and economic benefits of resource recovery.

6. POLICY RECOMMENDATIONS FOR A GREEN AND RESILIENT EUROPEAN INDUSTRY

Within the framework of a post COVID-19 political context, sustainability is a critical component to rebooting our economy. The new paradigm to build a resilient Europe must be in line with the Green Deal objective, including the 'zero pollution' ambition and support the exploitation of the value in water use and water reuse processes, particularly for industry. The ZERO BRINE technology is relevant to different legislation that needs to be adapted or strongly supported by appropriate guidance for improved implementation.

• EU Circular Economy package - Europe as the world leader of the circular economy

The ZERO BRINE approach will strongly support the Circular Economy Action Plan which includes 54 measures to "close the loop" of product lifecycles: from production and consumption to waste management and the market for secondary raw materials. It also aligns with the 2020 amendments which encourage water reuse and the exploitation of the value in water from industrial processes. ZERO BRINE represents innovative solutions to help achieve these objectives.

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• The Industrial Emissions Directive (IED) 2010/75/EU

The IED is one of the main legislative tools for preventing and reducing polluting emissions (to air, water and land) and for minimising waste generation in the context of health and environmental impacts. IED does not refer to specific standards for water emissions but requires that implementation should be based on Best Available Techniques (BATs) as described in Best Available Techniques Reference Documents (BREFs) and taking into account national emissions legislation on which to base operational permission from the responsible authorities.

IED covers all the industry categories that ZERO BRINE addresses. **The project will make recommendations for updating the relevant BREFs for these sectors** for which present the most effective combinations of technologies. Moreover, results for water and minerals recovery rates, treated water quality, mineral purities, and energy consumption will be presented for each process based on pilot project outcomes.

The existing IED focuses on the need to reduce the negative impacts of pollution and waste. What it does not do is identify and highlight the positive opportunities and benefits of its approach. These can be environmental and economic benefits as demonstrated in the ZERO BRINE pilot demonstrations.

ZERO BRINE proposes to the IED to be more oriented to a circular economy approach to the recovery and reuse of water and minerals, and in particular to highlight the potential economic benefits to the businesses in question.

• Best Available Techniques (BAT) reference documents (BREFs)

There are currently 34 BREFS supporting the IED covering a wide range of industry sectors, including chemicals manufacturing, textiles and wastewater – as relevant to the pilot demonstrations. In the absence of BAT guidance, operators should still ensure their installations meet the highest achievable environmental standards. New science and technological standards must be included in BREF periodic updates of which ZERO BRINE is an example. ZERO BRINE will make recommendations regarding **five technology combinations applicable to the four industry sectors.**

• Water Framework Directive, 2008/98/EC & amendment COM (2015) 595 final

Maintaining the good quality and quantity of water bodies is the main focus of the overarching European Water Framework Directive (WFD) 2000/60/EC. ZERO BRINE pilot plants show how water bodies can be better protected by reducing discharges of brine, and reduced freshwater abstraction. Reclaimed water contributes towards the increase of water availability and improved water quality. More specifically, the WFD refers to the promotion of technologies for water efficiency in industries to establish a good environmental status of water bodies. The ZERO BRINE technology supports a better implementation of the WFD by combining water efficiency with brine management technologies in a range of industry sectors.

• Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH regulation No. 1907/2006)

In the framework of ZERO BRINE, mineral recovery is achieved through the treatment of saline wastewaters. The economic value of recovered minerals is an important consideration and the relevant existing legal and policy framework review was considered as necessary towards this direction. The chemical materials market is subject to legislation to ensure safety in terms of human health and environmental protection related to chemical use and management. All recovered salts within ZERO BRINE are already REACH registered, thus requiring no new registrations. No obstacles are presented for salts commercialisation under the application of this regulation for ZERO BRINE operators.

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• End of waste criteria (Waste Framework Directive, 2008/98/EC)

The End-Of-Waste (EoW) criteria indicate when certain waste ceases to be waste and obtains a status of a product or a secondary raw material providing to EU member states the opportunity to introduce high-quality secondary raw materials and products. The Joint Research Centre (JRC) has outlined a methodology for the development of EoW criteria providing guidelines for analysis principles and parameters against which the criteria should be established and to deliver the necessary impact assessments.

Within these policy contexts that ZERO BRINE proposes the following recommendations:

RECOMMENDATIONS

- Support the development and updating of strong and credible BREF documentation with detailed information on different brine concentrates, mineral concentrations, efficiency of processing techniques and environmental and societal impacts.
- Establish financial instruments for advancing associated business models of new brine management technologies to contribute to the Green Deal's objectives. However, no specific criteria are currently available for brine materials. This situation constitutes a barrier that the EU can shed to open up new sustainable business, improve the competitiveness of the European industry and create green jobs.
- Further implement industrial symbiosis and multi-stakeholder platforms to advance sustainable production and EU industry competitiveness, information exchange and the Resource Efficient Europe flagship initiative.
- Initiatives under the Circular Economy Action plan should strongly support new business models enhancing the collaboration of renewable energy resources and brine management associated economic actors.
- Facilitate communication with National Legislative Helpdesks for brine recovered materials to develop EoW criteria that considers the ZERO BRINE technology, as well as between recovery operators with downstream users of the supply chain for pricing information.
- Promote technologies for water efficiency in industries with supportive national and EU legislation with a particular focus on digital water solutions.
- Expand schemes such as Extended Producer Responsibility and eco-design.

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ZERO BRINE

THE CIRCULAR ECONOMY APPROACH FOR INDUSTRIAL WASTEWATER
POLICY BRIEF: INDUSTRIAL EMISSIONS DIRECTIVE

The Horizon 2020 project ZERO BRINE demonstrates the technical feasibility, economic and environmental benefits of recovering minerals and water from waste industrial brine for reuse, and its compatibility with the principles of a Circular Economy, the EU Green Deal and the Industrial Emissions Directive.

1. BACKGROUND

The Industrial Emissions Directive (IED) is key legislation preventing and reducing polluting emissions to air, water, and land, and for minimising waste generation in the context of health and environmental impacts by identifying Best Available Technologies within the BREF process. While important progress has been achieved, **the IED needs to be reviewed not only to be fully fit with the new climate objectives of the European Union in terms of energy efficiency and circular economy, but also to update the BREF process.**

ZERO BRINE proposes a circular economy approach to reduce the negative impacts of brine from process industries and to create economic value from the reuse of its mineral salts, containing sodium, magnesium, calcium, sulphates, bicarbonates, and fresh water. ZERO BRINE demonstrates the use of a combination of existing and new or innovative technologies for recovery and reuse of both the material constituents as well as energy such as waste heat. **This approach can support a better implementation of the IED, to offer new standards within an updated IED while going beyond the siloed approach, particular for chemicals.**

2. ZERO BRINE: A TECHNOLOGY SUPPORTING THE EFFECTIVE IMPLEMENTATION OF THE IED

As stressed in the Evaluation of the IED, there is a necessity to reduce resource use and support the circular economy. ZERO BRINE technology offers a new technology to fulfil these objectives which is already aligned with the requirements of the existing IED.

Table 1 – How Zero Brine contributes to key objectives of the existing IED

	IED Requirement (existing)	ZERO BRINE's contribution
1	An integrated approach to prevent and control pollution	Recovery and reuse of salts takes them out of the waste cycle.
2	Prevent or reduce emissions to water, land, and air	Significant reduction (>90%) in the volumes of brine disposal and constituent pollutants to the environment, impacting land and water. The newly proposed technologies of ZERO BRINE also reduce the emissions to air by using less polluting solvents and other consumables in the treatment process.
3	Prevent or reduce the generation of waste	Brine as a 'waste product' is almost entirely removed from the waste cycle.
4	Reduce impacts on the environment	Reduce discharge of saline water, constituent minerals and of greenhouse gas emissions (GHGs) through efficiency energy use and reduced transport impacts.

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	IED Requirement (existing)	ZERO BRINE's contribution
5	Apply the best available techniques (BATs)	The ZERO BRINE pilots demonstrate a range of best techniques, in some cases developing new ones.
6	To prioritise generated waste in line with the order of priority of the Waste Framework Directive: re-use, recycle and recover, with responsible disposal as a last resort	While the potential for direct reuse of brine is limited, there is significant recycling following recovery of salts/minerals and fresh water. Waste generation is minimised.
7	With energy efficiency	Energy efficiency and heat recovery is demonstrated. Reduced transport needs (for importing new minerals) reduces total energy use and GHG emissions.

The proposed technologies for the treatment of brine effluents will reduce adverse impacts to the environment, firstly through the elimination of the need for brine disposal that today causes significant environmental degradation to land and aquatic environments. The United Nations Environment Program (UNEP-MAP) has stated that "one of the two major, urgent threats to the Mediterranean Sea environment is the pollution caused by the increased number of desalination plants and the releases and the effects of brine to the Mediterranean Sea".

In order to **produce one tonne of salt**, by applying the most energy-saving technologies established today (Mechanical Vapour Recompression – MVR) approximately 150 kWh (electricity) is required, which **results in approximately 75-150 kg of CO_2-eq emissions.** For the case of the large-scale demonstration in EVIDES – The Netherlands, 34,000 tonnes of industry water is produced per day, which requires approx. 2,000 tonnes of NaCl per year, which is an equivalent of 300,000 kWh or **300 tonnes of CO_2 emissions per year.** Even though in terms of mass, the quantity of salt used compared to the quantity of industry water produced is less than 0.01%, in terms of energy consumed it represents approximately 6% of the energy required to produce this quality of industry water. On top of this, energy consumed for transportation and relevant costs and CO_2 emissions should also be considered.

Producing 34,000 tonnes of industry water per day causes 300 tonnes of CO_2 emissions per year.

ZERO BRINE proposes a shift from the model of raw minerals extraction to recovery of resources through closing the loop of industry brines.

In the table below, key numbers for reduction are presented, related to the ZERO BRINE project, representing the chemical-, water-,coal mine- and textile industry.

Table 2 – Expected impact of the ZERO BRINE technology on water, CO_2, energy use and raw materials in industry

Expected impact	Reduction in:			
	Water use	CO_2 emissions (yearly)	Energy use	Raw materials
Water plant	-15%	-300 tonnes CO_2	Waste heat recovery	-75% (salt), Water recovery
Coal mine	>75% water recovery	-414 kg CO_2/t of NaCl	-50%	Salt recovery
Textile factory	-50 kt/year	-200 tonnes CO_2	Waste heat recovery	400 tonnes NaCl/year
Silica factory	-70%	-1300 tonnes CO_2 (emissions avoided due to Na_2SO_4 recovery)	Waste heat recovery	-70% (water) 2,300 tonnes Na_2SO_4/year -25% H_2SO_4 and NaOH

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3. ZERO BRINE: AN AVAILABLE TECHNOLOGY FOR A MORE RESILIENT EUROPEAN INDUSTRY

Several points of attention in the IED have been stressed by the European Commission that make the revision a priority. ZERO BRINE partners welcome the revision of the IED to update the directive in line with the EU Green Deal and the Zero-pollution strategy.

Particularly, the ZERO BRINE technology demonstrates the opportunity for industries to contribute to GHG reduction and energy efficiency meeting requirements in terms of brine management:

- **GHG reductions and energy efficiency** by the promotion of heat-reuse in the recovery processes.
- **GHG indirect reductions and energy efficiency** by **reduced transportation impacts** from the import of raw minerals, often from outside the EU. The reuse of water will also reduce the energy needs for pumping water.

The **ZERO BRINE** technology proposes the following standards for a more resilient IED:

- **To include sectors outside of the existing IED scope that generate brine**
- **To increase the emphasis on reducing emissions to water**
- **To strengthen contributions to the circular economy**

The IED BREFs focus principally on individual industry sectors. However, the ZERO BRINE approach applies to a wide range of sectors that produce brine. It also provides **strong opportunities to break the siloed approach and develop industrial symbiosis** by the interconnection of sectors by, for example, recovering minerals or water volumes that are of value to others.

The ZERO BRINE technology position can then support the revision of the BREF process and the update of the BATs by either creating a horizontal and mandatory BREF on water-efficiency or including the need for circular brine management in several key industrial processes.

ZERO BRINE focuses on the manufacturing sector. According to Eurostat, this sector includes a vast array of economic activities performed by 2.1 million enterprises in Europe. It therefore contributes to:

- Highlighting the environmental benefits of reduced demand for raw materials and resources that re-use and recycling can achieve. The impacts that will be reduced include less mining (both inside and outside Europe) and all its associated impacts, and reduced transportation with its associated energy and GHG emissions.
- Identifying and highlighting the positive opportunities and benefits of compliance. For the operator, they can include: a reduced need to purchase raw materials, and reduced spending on energy and water supplies. Some operators will also gain an economic benefit from the selling of recovered minerals to others.

See the ZERO BRINE core policy brief for the environmental and economic benefits.

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4. ZERO BRINE RECOMMENDATIONS REGARDING THE REVISION OF THE IED

Considering the results of the ZERO BRINE technology, the project suggests the following amendments of the IED for a modern and resilient legislation on industrial emissions.

- Have the IED more oriented to a circular economy approach to look at **both emission reduction and recovery and reuse of water and minerals.** Better consider the opportunities in brine management to improve energy savings and also to effectively implement reduction of resource use through recycle and reused processes.
- Consider the indirect **environmental benefits of reuse**, principally the reduced demand for raw materials and their transportation.
- Emphasise the **BATs that contribute to cross-sectoral benefits such as brine management** to maximise the impact of the IED as a key legislation in the EU's arsenal for climate neutrality.

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ZERO BRINE

ZERO BRINE PILOT DEMONSTRATION

DEMINERALIZED WATER PLANT (DWP) OF EVIDES IN BOTLEK, ROTTERDAM, THE NETHERLANDS

Context

ZERO BRINE advances circular economy business model solutions to reduce industrial saline wastewater streams by recovering and reusing the minerals and water from the brine. Demineralized water is an essential commodity in the Botlek area, the industrial district of the port of Rotterdam, because it is required for many production processes. Reverse osmosis (RO) has become one of the main processes for producing demineralized water, but reverse osmosis alone is not enough to produce water of the required purity from the available water (fresh surface water), and several pre- and post-treatment processes are used. At the Evides DWP, one of the largest demineralized water production facilities in Europe, wastewater is treated by reverse osmosis combined with ion-exchange softening, among other technologies (see Graph 1).

Objective

At the Demi Water Plant (DWP) of Evides in the Botlek industrial area, ZERO BRINE demonstrates the circular economy approach to treat industrial wastewater through redesigning the current brine treatment process from linear to a circular model recovering all the resources (see graph 1). A large-scale demonstration plant is tested at PlantOne, a test facility focused on sustainable technology and innovation in the Energy Port and Petrochemical cluster of Rotterdam Port, by using the waste heat from one of the factories in the port. The objective is to recover Ca- and Mg-salts as well as demineralized water from the discharges of the water-softening unit. The quality of the recovered products will be aimed to meet local market specifications.

Technology

The demonstration plant comprises two sites combining residual heat and wastewater streams with the aim to eliminate brine effluent (zero brine discharge). At Evides (Site 1) the aim is to treat the regeneration solution of the ion exchange (IEX) unit (spent regenerant) and to recover valuable minerals and salts as well as water from this flow. This is done by nanofiltration, crystallization and evaporation of IEX (see Graph 2). Site 2 is an innovative design that aims to treat the reverse osmosis concentrate of DWP. Additionally, nyex is used to remove the anions and charged organic matter (see Graph 3).

Business opportunities

Industrial saline impaired effluents (brines) are an environmental challenge and an economic opportunity. The following materials with potential commercial value are recovered on the two sites that will be used in the same factory by Evides or in the industrial area Botlek.

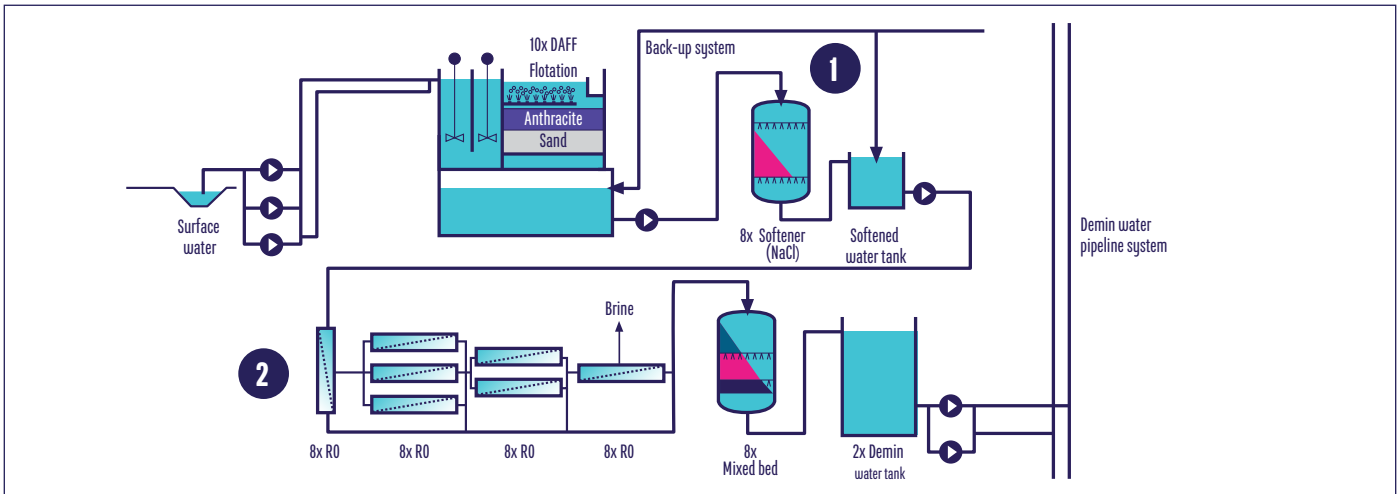
Site 1

- High purity magnesium & calcium
- Clean Water
- NaCl regeneration solution

Site 2

- Sulphate salts
- NaHC03
- Clean Water
- NaCl regeneration solution

Graph 1: Schematic view of the current processes at the DWP plant at Botlek



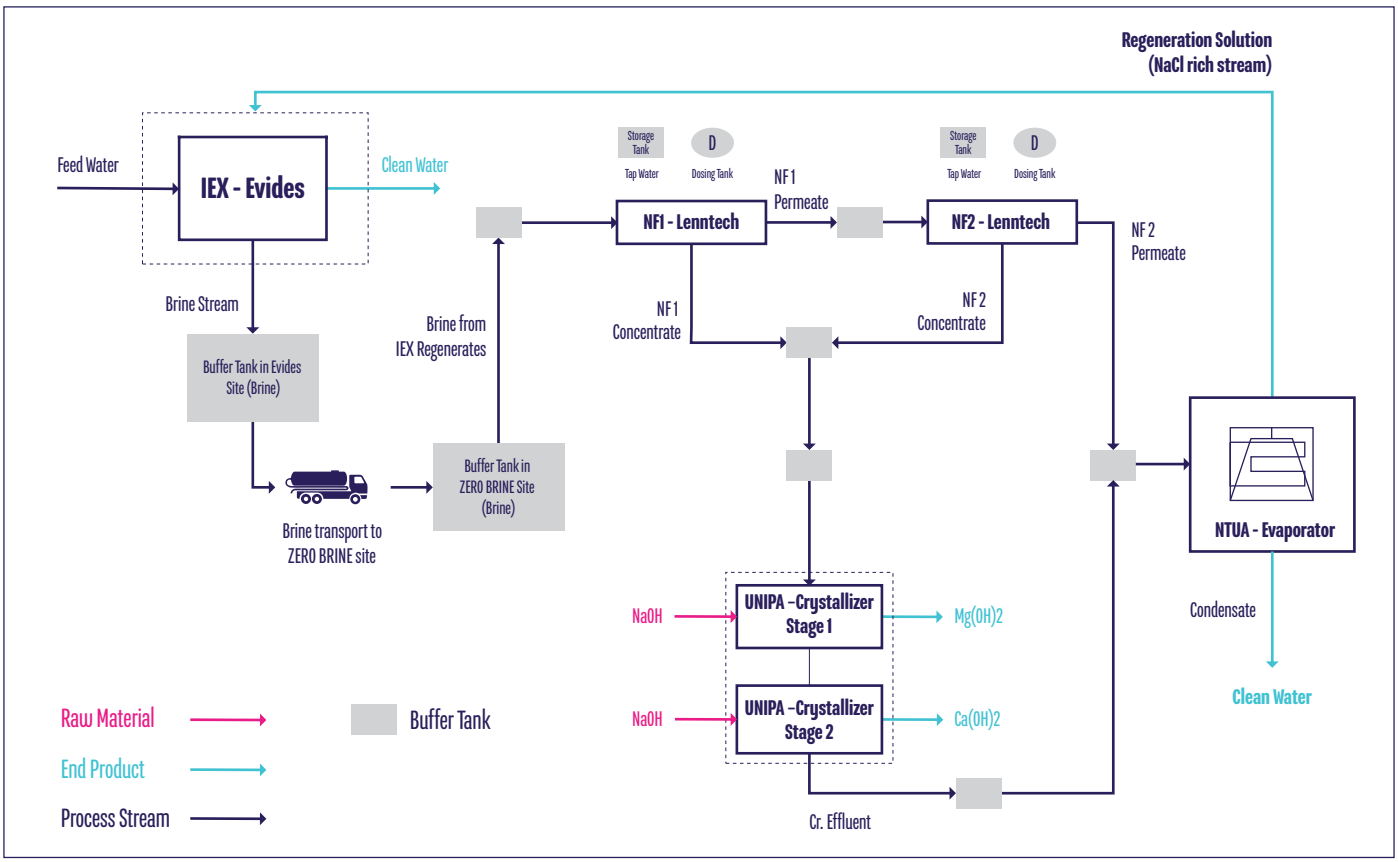
1 Site 1: Technologies

Demonstration of Nanofiltration (NF) – Crystallizer (MF-PFR) Evaporation for treatment of Ion Exchange (IEX) Regenerates

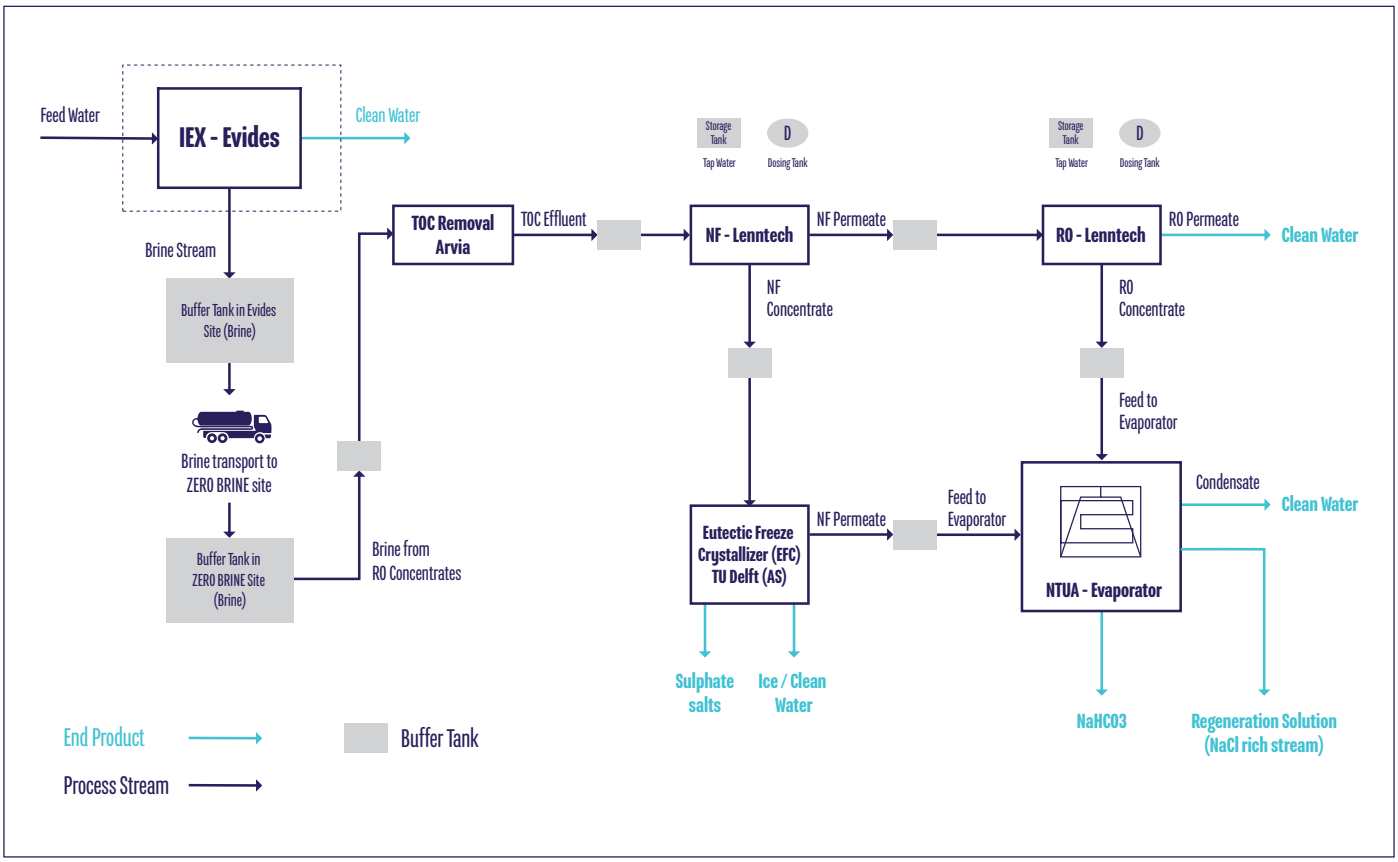
2 Site 2: Technologies

Nyex (TOC Removel) – Nanofiltration – Reverse Osmosis (RO) – Evaporation Eutectic Freeze Crystallization (EFC) for treatment of RO Concentrates

Graph 2: Site 1



Graph 3: Site 2



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ZERO BRINE PILOT DEMONSTRATION
BOLESŁAW ŚMIAŁY COAL MINE IN ŁAZISKA GÓRNE, SILESIA, POLAND

Context

Saline wastewaters are a concern of many industries. The coal mining industry is particularly affected: every year Poland discharges around 4 million tonnes of sodium chloride (salt) into rivers, coming mainly from coal mines. This causes environmental damage and economic strains due to pollution fees. ZERO BRINE is turning this problematic issue into a source of income by recovering valuable resources such as water, salts, and minerals for reuse in other industries, creating potential jobs and societal improvements. The pilot plant is operated and overseen by the Silesian University of Technology (SUT) that is located nearby in the small city of Gliwice.

Coal mines are an important sector in the EU. Overall, coal is produced in 11 EU countries, having a major contribution to the energy security in nearly half of the Member States. In addition, coking coal is identified by the European Commission (EC) as one of the 27 critical raw materials since its supply risk is high. Coking coal also has a high economic importance due to its use in the metallurgy sector. As such, coal production will remain a very important sector in the future.

The coal mining industry is deeply affected by the environmental and economic problems with saline wastewater disposal. Every year, the mining sector discharges around 4 million tonnes of salt into the rivers in Poland. Poland's two longest rivers (Vistula and Odra) are under significant pressures from mining activities. For many years, excessive salt concentration has been found in the Vistula River, with 94% of the chlorides originating from hard coal mining activity. The Vistula River contains about 55% of the total fresh water resources in Poland and covers about 60% of the water needs in the country (including the river basin). The rising salination of the Vistula River is the cause of losses in industry, agriculture and water transport, which are estimated to be $100-250 million per year.

One possible solution is to use coal mining wastewater as the source of raw materials, thus turning the problem into a business opportunity. Poland only has one industrial-scale desalination plant in Czerwionka-Leszczyny, owned by PGWiR, which produces around 70,000 t/year of salt from coal mine water. The plant operates on coal mine water originating from operational "Budryk" mine and from an inactive mine, "Dębieńsko". The plant does not use chemical treatment. The low salinity coal mine water is pre-concentrated by reverse osmosis (RO). Then, after mixing with more saline coal mine water, it is subjected to further concentration by vapour compression (VC), and salt is obtained in a VC crystallizer. Unfortunately, this technology exhibits high energy consumption as well as limited salt recovery due to the presence of bivalent contaminants such as magnesium and calcium, which are not removed from the feed stream. The existing technology also does not allow the recovery of valuable raw materials, such as magnesium hydroxide.

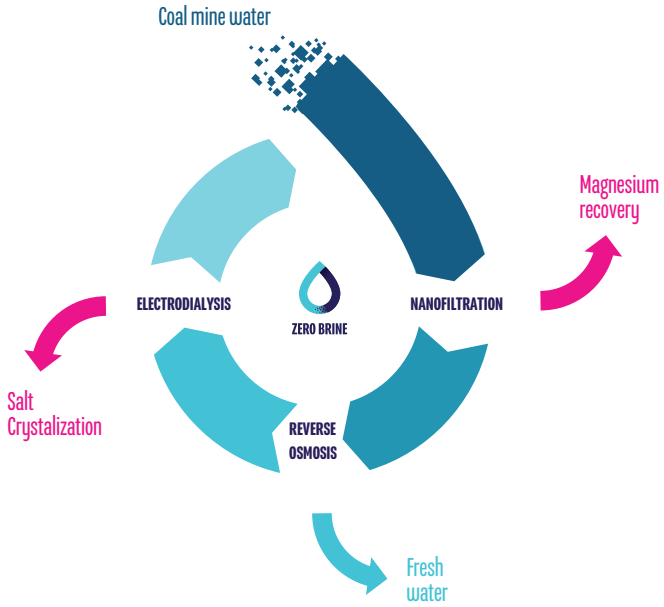
Decrease energy consumption by **50%**

Faster processing time than existing technologies

Recover materials such as **salt or concentrated brine, magnesium hydroxide**

Impact

ZERO BRINE aims at providing a technological solution of the saline wastewater problem for the coal mining industry. The ZERO BRINE technology is expected to decrease the energy consumption in the production of concentrated brine by 50% (target: 22 kWh/m3 of brine treated), compared to the vapour compression technology already used in Czerwionka-Leszczyny. The technology will also allow the recovery of raw materials: evaporated salt or concentrated brine, which both have multiple applications in the chemical industry, as well as magnesium hydroxide, which is a valuable commodity in the refractory materials industry. The ZERO BRINE team has already confirmed the interest of Poland's refractory materials manufacturer in new sources of high-purity magnesium hydroxide. Moreover, the same technology can be applied to other branches of industry which generate saline discharges.



Business opportunities

The problem of saline wastewaters is not unique to only one mine or one company – it has been a systemic issue throughout the whole industry for years. At the moment, 18 hard coal mines are still operational in Poland, provided below by coal mine industry: Jastrzębska Spółka Węglowa JSW Group (4 coal mines), Polska Grupa Górnicza (8 coal mines), Tauron Wydobycie (3 coal mines), Przedsiębiorstwo Górnicze Silesia (1 coal mine), Węglokoks (1 coal mine), Lubelski Węgiel Bogdanka S.A. (1 coal mine). All of those companies might be interested in turning their big environmental problem into a potential source of income.

An important business opportunity is the production of salt. The average production in Poland is around 4.3Mt/y, with salt-in-brine accounting for around two-thirds of production. Some 63% of salt-in-brine produced domestically is consumed in two synthetic soda ash plants (operated by Soda Polska Ciech). Around 21% of salt-in-brine is used in the production of evaporated salt and 16% in chlor-alkali production (by Anwil Nitrogen Plant, PCC Rokita and Organika-Zachem Chemical Works).

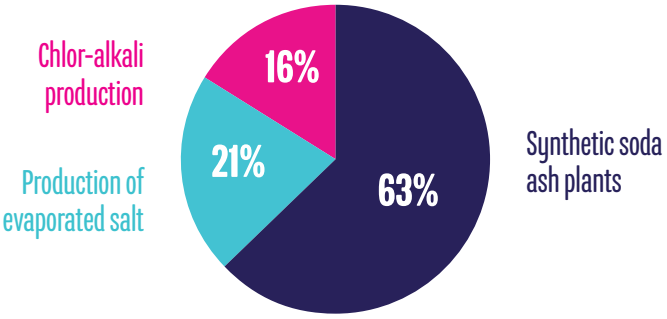
The magnesium hydroxide is of interest for the refractory materials industry. In 2006, the production of refractories in Poland reached nearly 300,000 tonnes, around 28% of which were unshaped materials. The main manufacturers in Poland include ZM Ropczyce S.A., PMO Komex (part of Alcerol-Mittal), PCO Z˙arów S.A., Vesuvius Skawina.

The business opportunities of ZERO BRINE are not limited to Poland. Because of how similar in composition the coal mine waters are to the sea water, the proposed technology could also be applied in the desalination industry – a sector which will become increasingly important due to the increasing water stress.

Turning waste into a potential source of income for operational coal mines

Salt production: **4.3 MT/y**

Usage of salt-in-brine:



Magnesium hydroxide is used in refractory materials industry - which reached **300,000 tonnes** in 2006

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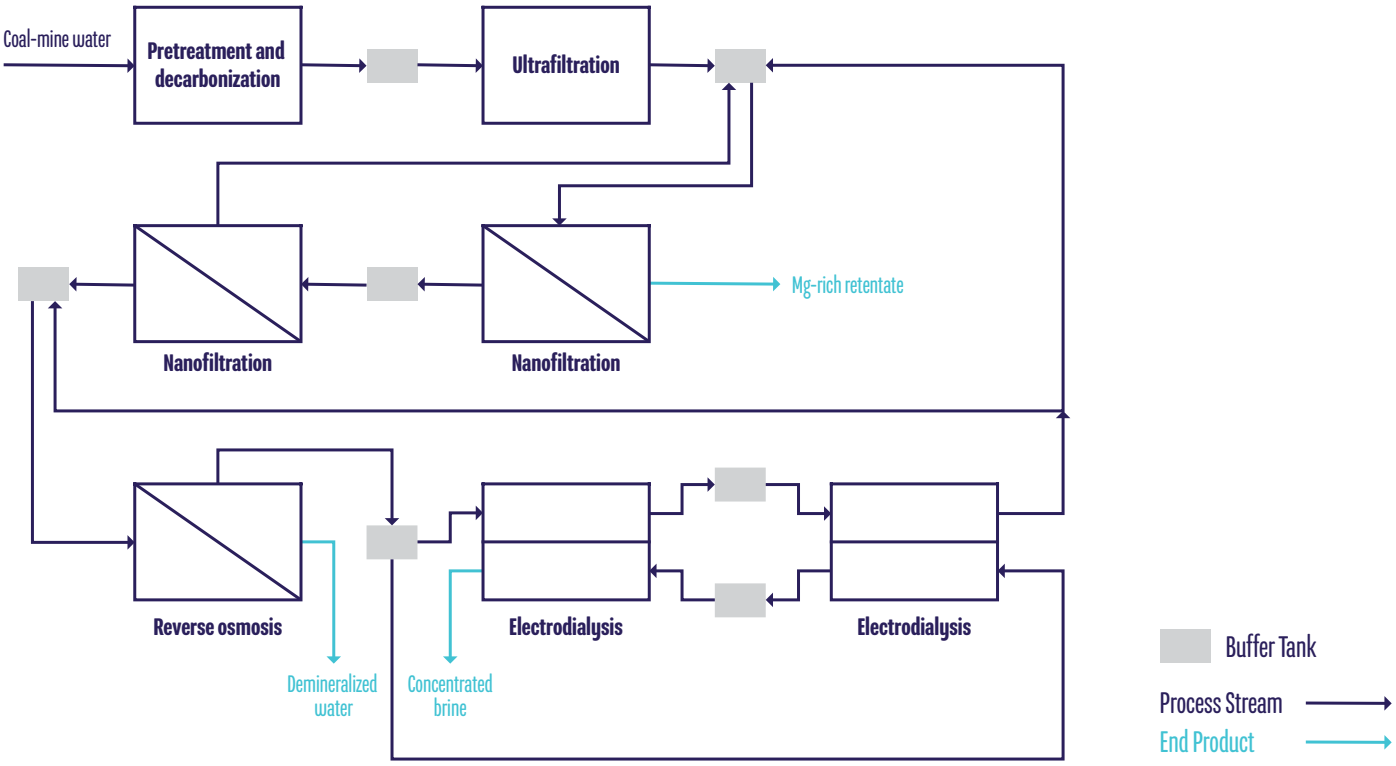
Technology

The feed – coal mine water – after being pre-treated with decarbonization and ultrafiltration, is subjected to a two-pass nanofiltration. Nanofiltration is a membrane method, which allows separation of univalent ions – such as sodium and chlorides – from bivalent ions – calcium, magnesium, sulphates. The nanofiltration unit thus splits the coal mine water into two streams: salt-rich permeate and calcium and magnesium-rich retentate. The retentate can be used n the recovery of magnesium hydroxide. Magnesium is a critical raw material officially listed by the European Commission as having high commercial value. (Currently, Europe imports over 95% of its magnesium from China.) The remaining calcium-rich solution could be used as a de-icing liquid. The nanofiltration permeate is concentrated in a hybrid reverse osmosis-electrodialysis system, which produces demineralized water of quality close to distilled water, highly saline concentrate, and the diluate, an essential commodity that can be used at the site. The highly saline concentrate could then be sold directly or used as a source for salt crystallization.

The pilot plant operating in the "Bolesław Śmiały" coal mine tests the nanofiltration-reverse osmosis-electrodialysis part of the proposed technology.

General scheme of the proposed technology



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Key results and conclusions

The pilot plant aimed at testing the proposed technology has been constructed in the "Bolesław S´miały" coal mine in Łaziska Górne, Poland. The pilot plant consists of pretreatment system, ultrafiltration, decarbonization, two-pass nanofiltration, reverse osmosis and electrodialysis, and is capable of treating 400 L/h of coal mine wastewater. The desalination experiments have been run in the pilot plant since July 2019 and the initial results are promising. Though some modifications were required to the pretreatment and decarbonization unit, it was confirmed that nanofiltration can split the coal mine wastewater into sodium-chloride rich stream suitable for further concentration and the magnesium-rich stream suitable for magnesium hydroxide recovery. The projected energy consumption in the production of concentrated brine is equal to 12 kWh/m3 of brine treated at 82.8% salt recovery (vs. ca. 70% in existing technology); however, these results are only preliminary and still need to be confirmed and the process needs further optimization.

The ZERO BRINE plant is capable of treating
400 L/hr
of coal mine wastewater

Energy consumption of
12 kWh/m^3
of brine treated

82.8%
salt recovery from treated brine

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ZERO BRINE PILOT DEMONSTRATION

INDUSTRIAS QUIMICAS DEL EBRO (IQE) IN ZARAGOZA, SPAIN

1. Industry context

Synthetic amorphous silica are used in a wide range of industrial applications. Due to their physico-chemical properties, they are used in synthetic resins, plastics, rubbers, cosmetics, nutritional products and drugs, for example, as fillers or anti-caking agents. Synthetic amorphous silica are produced either by a wet process – precipitation of a water glass solution with acids (precipitated silicas, silica gels, silicates) – or by high temperature hydrolysis of chlorosilanes (pyrogenic silicas).

In the production of silica by a wet process, high amounts of water (≈40m^3 per each tonne of silica) are consumed, as well as sulfuric acid (H_2SO_4) and sand. As a result, around 35m^3 of wastewater containing a high concentration (20 g/L) of sodium sulphate (Na_2SO_4) are produced. This wastewater is normally discharged to natural water sources such as rivers and seawater after passing through wastewater treatment plants.

It is estimated that 620,000 tonnes of precipitated silica is produced per year in the EU and 21,700,000 m^3 of wastewater is discharged.

Industrias Quimicas del Ebro (IQE) is seeking novel methods to recover resources (water and sodium sulphate) and minimize the wastewater generated, while reducing the cost of water supply and wastewater treatment. Even so, as it is stated in the BREF for the inorganic chemical industry sector, the concentration of sodium sulphate in wastewaters from the production of precipitated silica is too low for its recovery to be economically viable through available methods (spray drying, precipitation of gypsum or membrane dialysis, etc.).

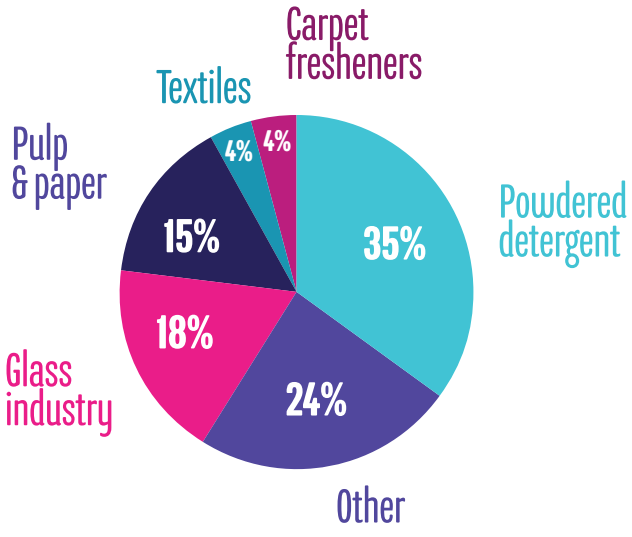
2. Impact of the ZERO BRINE technology

ZERO BRINE aims at providing a technological solution for the saline wastewater problem for the silica industry. The technology applied in the ZERO BRINE project would enable IQE to recover up to 80% of wastewater generated, producing water suitable for its reuse in the same company, thus reducing freshwater consumption. In addition, the technology allows the recovery of raw materials: sodium sulphate, which is a valuable product for various industrial sectors, like the powered detergent or the glass industry.

3. Business opportunities

The ZERO BRINE solution can be applied not only to the silica industry, but also to other industries which generate saline discharges containing high concentrations of sodium sulphate. This is the case for the pulp and paper industry, where sodium sulphate is one of the main reagents and also by-products of the pulping processes, especially the kraft process.

Na_2SO_4 – Uses & Market Shares



Price: €90/tonne

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An important business opportunity is the production of sodium sulphate that is a valued product for various industrial sectors, like the powdered detergent or the glass industry.Business opportunities of ZERO BRINE are not limited to saline wastewater containing sodium sulphate. The technology developed and tested in ZERO BRINE can also be applied to recover valuable inorganic compounds other than sodium sulphate. The potential users are all industries with a high concentration of inorganic compounds in their effluents that could be recovered instead of discharged into the environment, such as desalination plants, salt mining, and chemical industries.

4. Technology + proposed scheme

The ZERO BRINE process is based on: a) a first membrane-based process using tailor-made membranes produced by regenerating end-of-life reverse osmosis (RO) elements from desalination plants otherwise destined for a landfill; b) treatment of the concentrate stream produced in the first stage by crystallization to achieve Zero Liquid Discharge. In order to avoid scaling problems during treatment with membranes, a pre-treatment to remove aluminium and iron is applied.

Regenerated membranes are able to achieve a suitable quality of water, equivalent to the current quality in the industry that could also be reused in the production process. In addition, a high saline concentrate is obtained to be treated by crystallization, either Eutectic Freeze Crystallization (EFC) or Evaporation. The concentration of wastewater using membranes reduces the energy consumption of the crystallization stage.

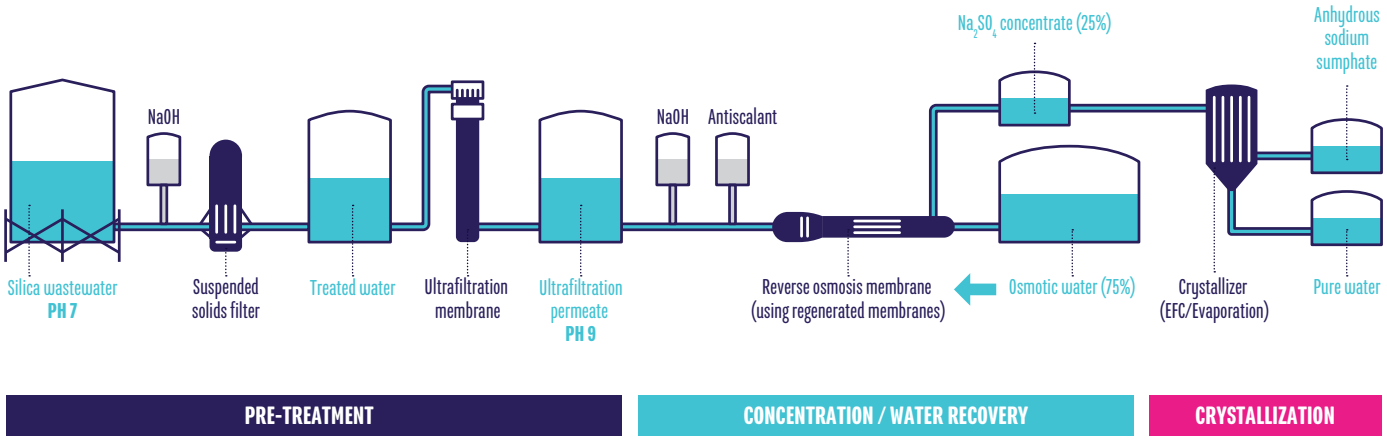
The ZERO BRINE process has been demonstrated at IQE at pilot plant scale.

5. Key results and conclusions

The technology applied in the ZERO BRINE project would enable IQE to recover 20,000 tonnes per year of sodium sulfate and 80% of the wastewater generated (1,000,000 m^3 per year).

The concentration of saline wastewater using regenerated membranes before the crystallization process allows the reduction of treatment costs up to 70% when compared with the direct evaporation of wastewater.

The preliminary business plan elaborated for the development of the ZERO BRINE proposal foresees savings in the cost of water supply and wastewater treatment of around €460,000 per year and turnover of €1,800,000 per year from the sodium sulphate recovered.



The ZERO BRINE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730390.

ZERO BRINE

ZERO BRINE PILOT DEMONSTRATION
ZORLU TEXTILE FACTORY IN LÜLEBURGAZ, TURKEY

1. Context

The management of industrial wastewater to comply with Zero Liquid Discharge (ZLD) has been receiving significant attention. The textile industry is one of the largest sectors in Turkey and makes up 10% of the country's GDP and employs around 750,000 people. However, the industry is also responsible for numerous environmental effects due to untreated wastewater discharges which contain various chemicals from unit processes. The industry covers 1-3% GNP of the countries worldwide. Turkey ranks 5th and 6th in production of woolen and cotton products worldwide which makes up close to 40% of total export income and 10% of the industrial work force. Therefore, the implementation of a well-designed solution to prevent pollution along with the ZLD concept is highly favorable for both environmental concerns and economically.

The textile industry is a highly water intensive sector. Water consumption ranges between 60 to 120 L/kg for cotton products and 110-650 L/kg for wool. Water is utilized at various steps of the unit processes such as pre-treatment, dyeing or finishing. Processes require extensive water use for dyeing, rinsing, conditioning and finishing operations. The crucial parameters of discharges from textile enterprises include mainly organic constituents, dissolved solids, inorganic salts, color, sulfate and pH.

Salt usage is also significant in the textile industry. Salt is consumed for dyeing cotton or linen fabrics and acts as a raw and auxiliary material.

Physicochemical and biological treatment techniques are widely employed to treat textile industry wastewater to comply with local discharge criteria. Moreover, membrane processes such as Nanofiltration (NF) and Reverse Osmosis (RO) are also utilized following conventional treatment methods as a tertiary treatment step to obtain a reusable stream. Membrane treatment for reuse is a very effective method for removal of ions and other pollutants. Reusable, high quality water is obtained using RO membrane processes.

RO on the other hand, results in the formation of highly polluted concentrate (brine) along with the high-quality, treated water stream. The impurities and pollutants in brine have serious adverse impacts on the environment. Principally, the brine discharges may cause environmental and ecological impacts on especially inland receiving water bodies such as lakes and rivers and may cause salinization of the soil which is one of the most severe environmental problems in agriculture.

The concept of circular economy and ZLD options are investigated for Zorlu Textile's integrated polyester yarn and cotton home textile manufacturing industry within the context of ZERO BRINE project. In this manner, treatment and recovery of the concentrated salt solution (brine) which can be reused in the dyeing baths of the textile plant and/or utilized as feed for salt production is targeted.

The demo project is primarily focused on the management of brine generated from the RO unit and developing an innovative brine treatment and recovery system. Brine from the RO treatment unit presents an important environmental concern due to the high concentration of impurities including various chemicals, salts, colors, hardness, alkalinity and nutrients. The primary difficulty to be overcome by this approach is the separation of hardness and color from brine while concentrating the salt solution which can, in turn, be used in textile dyeing processes. The recovered salt solution should also comply the criteria for textile dyeing process requirements.

Fig. 1 – Expected outcomes

Decrease salt consumption by 40%	**Reduction in water consumption by 15%**
Decrease CO_2 emissions by 20%	**Significant improvement of aquatic environments and protection of soil from salinization.**

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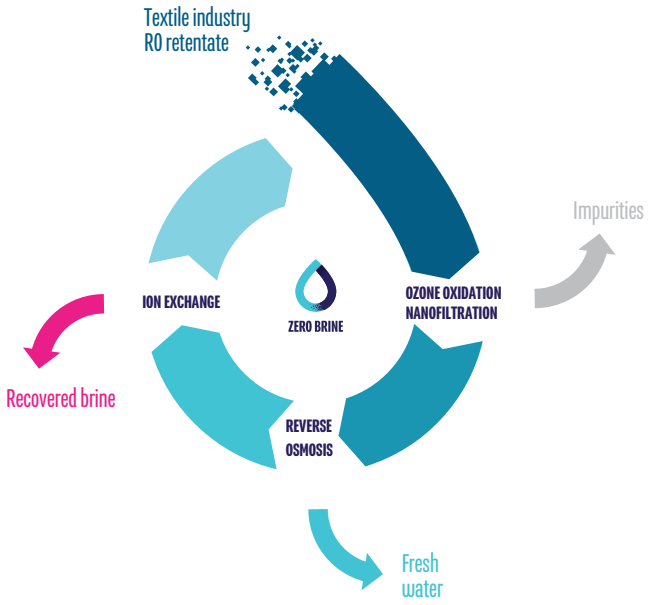
2. Impacts

The ZERO BRINE project intends to reduce saline wastewater streams generated by industry by recovering and reusing minerals, water and metals from wastewater. ZERO BRINE aims at the development of innovative technological solutions of the highly saline wastewater problem for several industrial sectors including the textile sector. In this context, concentrate (brine) recovery of approximately 400 tons/year as NaCl is targeted for Zorlu Textile. Depending on the brine impurity, recovered concentrate is utilized for in-plant processes. The conditions for recovery is appraised, and off-site use may also be made possible. Moreover, production 50 Kt/year high quality water is also among the goals.

The results would have great impacts on the textile industry in achieving resource efficiency and improving sustainability due to the reduced consumption of process inputs, as well as the mitigation of greenhouse gasses accordingly. In this way, it is estimated that the reduction of 200 tons of CO_2 on an annual basis could be achieved.

Moreover, the similar technology and approach can be applied to other sectors of industry which generate saline discharges.

Fig. 2 – Conceptual scheme for textile pilot



3. Business opportunities

Brine is a valuable resource for the recovery of salt and water. In this way, the purpose is to close the loop between the saline wastewater generated by process industries and to contribute the circular economy. The goal is achieved by means of innovative existing and new technologies to recover and reuse high quality end-products. By taking into account the demo system results, other various enterprises actively operating in the textile sectors will likely be encouraged. The solutions developed may sustain;

I. compliance with the relevant regulations likely to be in force in the near future,

II. economic benefits for the enterprise implemented ZLD approach due to the reduction in consumption of salt and water,

III. improvements in visibility of the enterprise due to the increased concerns for environmental issues, and also relevant growth in export potential with good market value,

IV. business opportunities foreseen for the companies involved wastewater treatment and reuse/recovery options,

V. creation of new job alternatives for technical personnel in both textile or other relevant enterprises for various sectors including environmental fields (wastewater treatment and reuse companies).

6. Technology

Zorlu Textile industry wastewater is treated with physicochemical, biological methods and advanced treatment processes (activated carbon adsorption, ultrafiltration and RO) to obtain a reusable stream which is utilized for an energy company's cooling systems located near the Zorlu Textile. RO treatment consequently results in the generation of a highly polluted concentrate retantate (brine).

The proposed configuration of the brine treatment and recovery pilot system was developed based on the comprehensive characterization in bench scale tests, as well as the relevant assessments.

In this perspective, ozone oxidation and (NF) membrane processes are applied as the pre-treatment phase essentially to remove or mitigate impurities such as color, hardness, organic constituents and sulfate. NF provides 50-60% rejection of impurities whilst allowing 10-20% salt passage. Whereas, after NF membrane systems, RO is utilized as the concentration step for the NF permeate stream. At this stage, the concentrate stream of the RO unit is the recovered salt solution while the permeate of the RO unit is the reusable water – close to demineralized water quality – that can be reused for textile processing purposes.

The ion exchange softening process is also applied as the final step to acquire extra hardness removal of the recovered salt solution prior to the dyeing applications. This step would provide additional assurance as hardness is considered to be the critical parameter for textile dyeing processes. An activated carbon adsorption column and an UV oxidation unit are also provided within the pilot system to remove excess ozone remaining in the concentrate stream to provide protection for the membranes.

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Fig. 3 – General outline of the proposed system at Zorlu Textile

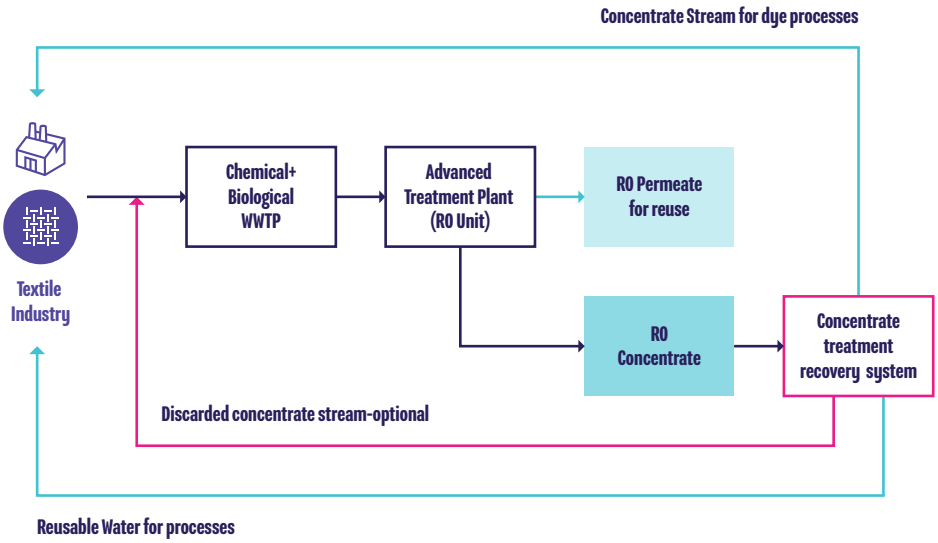
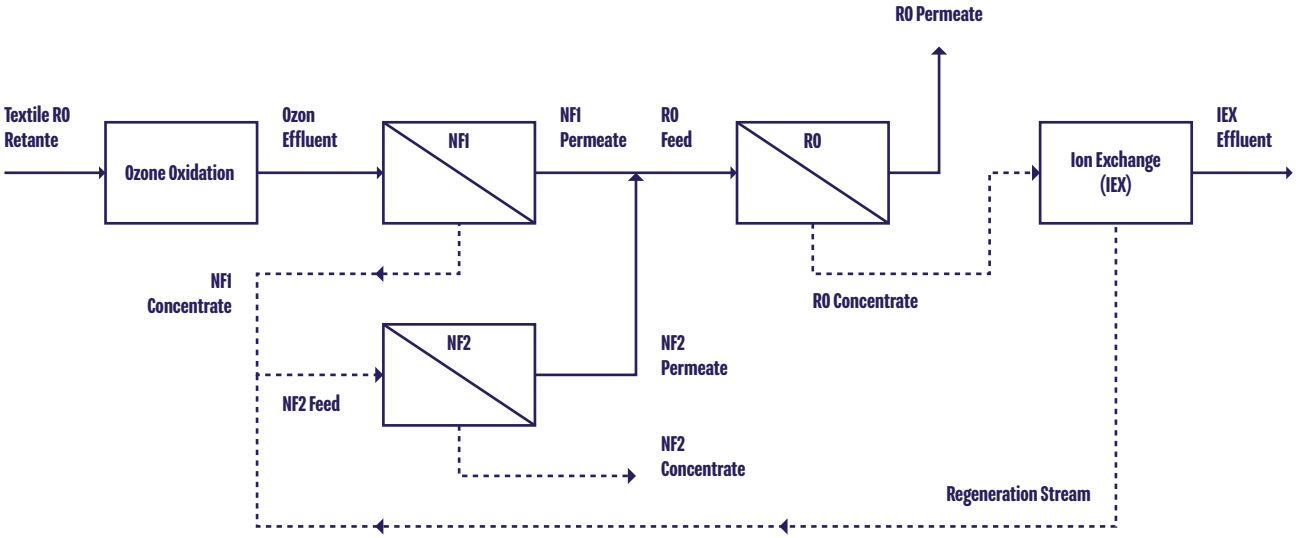


Fig. 4 – Process scheme of the applied technology for the pilot system



7. Key results and conclusions

The textile brine recovery pilot plant is intended for testing and verifying the proposed technology. It has been constructed and is being operated at the Zorlu Textile premises at Lüleburgaz, Kırklareli.

The pilot system involves a pretreatment stage with ozone oxidation, nanofiltration, concentration stage with reverse osmosis and, as a precaution, a softening unit by an ion exchange column. The pilot plant is capable of treating 300 L/hr of RO retentate discharged from advanced wastewater treatment facilities of Zorlu Textile. The developed process scheme results in 70-80% of recovery of NaCl for the dyeing processes. Whereas, the clean water recovery as permeate of the RO treatment unit would be 55-60%. Alternatively, this stream will be reused within the enterprise for various purposes. The process design system allows the flexibility to be operated at relevant variable flow intervals. Moreover, the arrangement of the proposed treatment units and the piping connections could be varied to a certain extent depending on the operational conditions and the requirements throughout the operation period. Hence, by this approach it is anticipated to accomplish efficient recovery of salt solution for dyeing processes.

The ZERO BRINE textile pilot is capable of treating 300 L/hr discharged RO concentrate

70-80% of recovery of NaCl for textile dyeing	**55-60% reusable pure water stream for process**

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