ZERO BRINE

D9.3 Quality Standards

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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

The ZERO BRINE project demonstrates new configurations to recover resources from saline impaired effluents (brines) generated by various process industries, while minimising environmental impact of industries by minimizing saline wastewater discharge. The water treatment system consists of both commercially available technologies, and recently developed technologies. In order to support the Industrial Symbiosis, quality indicators for the exchange material are essential. Another important part of the project will be to create competitive advantage. The project objective mentions for instance that the quality of the recovered end-products will be aimed to meet local market specifications.

In the ZERO BRINE project at several places, the environmental, economic, and social impacts of its technologies are monitored and discussed. The specific and detailed results can be found in several Deliverable documents. The development of Quality Indicators for monitoring and assessing the performance of the ZERO BRINE system is related to four topics: 1) Environmental and economic assessments; 2) Life Cycle Sustainability Assessment; 3) Ecological impacts from brine discharge; 4) Policy review and assessment. Based on these topics Quality Indicators are presented in three areas: 1) Environmental and Ecological impact indicators; 2) Economic and Business-related indicators; 3) Social and Governance related indicators.

During the ZERO BRINE project period data is collected, modelled, and assessed leading to a continuous insight in how the ZERO BRINE system could be improved. Besides the importance to Work Package 7, in which the sustainability performance of ZERO BRINE is assessed and presented, and the importance to Work Package 9, where the policy implications of ZERO BRINE are discussed, the Quality Standards also play an important role in the development of the Circular Economy Business models of Work Package 8 and the policy briefs that are presented to the European Commission from Work Package 10.

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1. Overview of the project

The ZERO BRINE consortium is focused on re-designing the value- and supply chain of water and minerals, and aims to implement practices from circular thinking in various process industries by developing technologies and business models. The ZERO BRINE project will demonstrate new configurations to recover resources from saline impaired effluents (brines) generated by various process industries, while minimising environmental impact of industries by minimizing saline wastewater discharge. The water treatment system consists of both commercially available technologies, and recently developed technologies. The project involves large process industries, small to medium- enterprises and research centres. This collaborative approach leads to more efficient use of resources and reducing environmental impacts, which proves its relevance for sustainable development and industrial ecology. Industrial symbiosis is recognized by the consortium members as one of the key concepts (ZERO BRINE, 2017b). In order to support the Industrial Symbiosis, quality insurances for the exchanges of material are essential.

Another important part of the project will be to create competitive advantage. The project objective mentions for instance that “the quality of the recovered end-products will be aimed to meet local market specifications" (ZERO BRINE, 2017b). The four demonstration locations of ZERO BRINE represent different technologies and configurations. The local markets for the potential products of ZERO BRINE systems also differ, but in all cases the local markets have to comply to REACH-ECHA regulations for material categorisation. For that reason, the potential products of all four locations are presented after which the relevant quality standards for these products are defined.

In the ZERO BRINE project, at several places, the environmental, economic, and social impacts of its technologies are monitored and discussed. The specific and detailed results can be found in several Deliverable documents. This underlying report on Deliverable 9.3 refers to other reports for more detailed information and background, Table 1 presents an overview of the related Deliverables.

Table 1. Overview of ZERO BRINE Deliverables related to Deliverable 9.3

Deliverable Number	Deliverable Title	WP number	Type[15]	Dissemination level
D 7.1	Report on the unified approach of the environmental and economic assessments	WP7	Report	Public
D 7.6	Report on the LCSAresults	WP7	Report	Public
D 9.1	Report on environmental impacts from brine discharge	WP9	Report	Public
D 9.2	Report on policy review and assessment /suggestions for BREF update	WP9	Report	Public

In this Deliverable 9.3 report, first an introduction into the main aspects of Quality Indicators is provided, related to the Deliverables 7.1, 7.2, 7.6 (grounded in Life Cycle Sustainability Assessment, after which the main results of Deliverables 9.1 and 9.2 are given (considering environmental impacts from brine discharge and policy review and assessment). This then leads to the presentation of the Quality Standards for the products at the ZERO BRINE locations.

2. Introduction

In this chapter, first some of the concepts given above are introduced, in order to provide sufficient background for the interpretation of the presented Quality Standards. The following concepts are described below:

1) Environmental and economic assessments
2) Life Cycle Sustainability Assessment
3) Ecological impacts from brine discharge
4) Policy review and assessment

a. Key concepts for Quality Indicators

i. Environmental and economic assessments

For all involved technologies in the ZERO BRINE consortium a sustainability evaluation is carried out applying Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCCA) methodologies. The environmental impact and the cost of the applied technology are assessed over its entire lifetime. To demonstrate the environmental and economic potential, comparisons to standard linear economy practice and current brine disposal are made. Cost values as well as environmental relevant inputs (material and energy resources) and outputs (emissions, and wastes) of the different analysed life cycle stages are collected by surveys, interviews and in situ measurements in plants. The results of this task are presented in Deliverable 7.1.

ii. Life Cycle Sustainability Assessment

Besides the LCA and LCC approach mentioned above, the three pillars of sustainability (people, planet, profit), are assessed through Life Cycle Sustainability Assessment (LCSA) in which LCSA is considered to be a combination of Life Cycle Assessment with economic and social impact factors. Within the LCSA a set of impact indicators is developed, that assesses the technological systems by:

- Environmental impacts: GHG emissions (CO2, CH4, N2O, H2O), Land transformation, Eutrophication, Acidification
- Economic impact: Resource scarcity, Return on Investment, External costs

- Social impact: Health risks, Acceptability, Stakeholder involvement, Legislation and Permitting procedures.

Existing databases are used for the system boundaries and conventional parts of the value chains. External and contextual information will be obtained from existing European databases, like EcoInvent or Eurostat. Specific attention are given to the social impacts of the value chains for which the consortium innovations are developed.

iii. Ecological impacts from brine discharge

In order to assess the ecological quality status of the Port of Rotterdam and in particular in the vicinity of two demineralized water plants with brine discharge activities at Botlek (Brittaniëhaven) and Maasvlakte (Hartelkanaal), field surveys were conducted. Benthic macroinvertebrates are the key biological indicator examined, supported by physicochemical and hydromorphological data and algae communities. Community level metrics (abundance, species richness, and Shannon-Weiner diversity) were analysed, including multivariate analysis using PRIMER software. The biotic indices AMBI and BEQI were applied to establish the ecological status of the study areas. The BOPA index, which uses an opportunistic polychaete / sensitive amphipod ratio, was also applied, yielding results in order to distinguish impacts from various anthropogenic sources.

iv. Policy review and assessment

The Zero Brine project presents a combination of various technologies to treat effluent brines from four different industrial sectors, aiming to shift from the linear model to a circular economy model. Therefore, brine treatment systems focus on the recovery of resources from brines and not on the removal of salts as pollutants before the disposal of treated water to WWTPs or receiving water bodies. Initially, the relevant legislative frameworks are reviewed, namely:

1. Registration, Evaluation, Authorization and restriction of Chemicals (REACH),
2. Waste Framework Directive and End-of-Waste Criteria,
3. Water Framework Directive,
4. Industrial Emissions Directive, and
5. Best Available Techniques Reference Documents

In order to see the relevance for waste management from extractive industries, large volume inorganic chemicals-solids and other industries, textiles industry, wastewater, and waste gas treatment/management systems in chemical sector.

b. Choice for type of Quality Standards

The task description for Deliverable 9.3 asks about "minimum quality standards (requirements) for salt reuse in different applications (end-markets)" and "the main aspects that will be considered are: land use and land transformation, added value for local farming and food processing industry, development of specialized industry, job creation." During the execution of ZERO BRINE more attention has been given to the second part, because in that way the quality can be justified of the technological innovation.

The first task, as described above, relates to the definition of minimum requirements for salt reuse. In the ZERO BRINE project it has been decided that, since the quality of salt and minerals to the end market, is required by the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) legislation, this REACH legislation is studied in detail and recommendations to REACH are given in Work Package 8.

In Deliverable 9.2, it is stated that the REACH legislation is reviewed, aiming to define potential limitations and requirements on the commercialisation of salts produced by the pilot systems of ZERO BRINE. All inorganic salts produced in ZERO BRINE are already registered to ECHA. To commercialise them, operators need to prepare material Safety Data Sheets (SDS) and Technical Data Sheets (TDS). Information for TDS and SDS are produced from the chemical analyses (exact composition) of the salts, and from data uploaded in the ECHA platform. To get access to this data, operators need to send an inquiry (access letter) to ECHA and pay a fee to the first registrant of data. This is a very well described procedure in ECHA site. National REACH Helpdesks, which are very easily accessible, can also provide information on how this letter shall be prepared, as well as on the cost of access to these data. However, if the recovered materials will be used in the same industry, no such data are needed.

3. Quality Standards per ZERO BRINE location

In the ZERO BRINE project, in four countries experiments have taken place. Below, first an overview is given of the main products per location.

We have to comment that in all cases, it has been proven that the mentioned materials can be recovered from the waste water by ZERO BRINE systems with average quality (90%-99%). This means that they all fit in the bulk material descriptions of REACH and that new applications for the materials are not needed.

All experiments also have shown that further treatment is needed to come to higher purity or that investment is needed in automation and control systems to decrease the operational expenses and production failures. Also in the economic calculations of WP7, it is assumed that the salts and minerals are produced with average quality. Further investigation can show whether the next strep to ultrapure (>99%) would be affordable in terms of the investment for an additional treatment or processing step and the additional market value of the upgraded product.

Below, we will first present the potential products and then the possible end markets. This then leads to a final conclusion on which quality standards play a role in the implementation of ZERO BRINE technologies.

a. Potential end markets for The Netherlands

In Work Package 2, the experiments have been carried out and data is collected for The Netherlands (Chemical industry). In this location, the following materials can be produced:

- $Ca(OH)_2$
- $Mg(OH)_2$
- Na_2SO_4
- NaCl solution

In The Netherlands, the experiments also produce Demineralized Water, for which the following Quality Standards can be given:

- Water free of ions (< 50 mgTDS/L) can be supplied to costumer as ultra-pure water.
- Ideally, the salinity of recovered clean water must be below 75 µS/cm, but for short term (few days per month) the salinity in the range of 75-700 µS/cm is also acceptable and mixed-bed polishing step can get this stream as feed.

b. Potential end markets for Poland and Turkey

In Work Package 3, the experiments have been carried out and data is collected for the two demonstration projects of Poland (Coal mine industry) and Turkey (Textile industry). In both locations, the following materials can be produced:

- $CaSO_4$
- $Mg(OH)_2$
- NaCl salt

c. Potential end markets for Spain

In Work Package 4, the experiments have been carried out and data is collected for Spain (Silica industry). In this location, the following materials can be produced:

- $Ca(OH)_2$
- $Mg(OH)_2$
- Na_2SO_4

d. Potential end-market applications

In summary, the materials presented above are potential products for ZERO BRINE, they are given in Table 2 together with their CAS no. from the REACH database (https://echa.europa.eu/information-on-chemicals/registered-substances).

Table 2. Recovered materials by the four locations of ZERO BRINE

Recovered material	CAS no.	Source of waste water	Location	Potential end-markets (professional use)
$Ca(OH)_2$	1305-62-0	Chemical industry, Silica industry	The Netherlands and Spain	This substance is used in the following areas: building & construction work, municipal supply (e.g. electricity, steam, gas, water) and sewage treatment, agriculture, forestry and fishing, formulation of mixtures and/or re-packaging, health services, printing and recorded media reproduction and scientific research and development. This substance is used for the manufacture of: mineral products (e.g. plasters, cement), wood and wood products, textile, leather or fur, rubber products, plastic products, machinery and vehicles, electrical, electronic and optical equipment, pulp, paper and paper products and furniture.
$Mg(OH)_2$	1309-42-8	Chemical industry, Coal mine industry, Textile industry, Silica industry	The Netherlands, Poland, Turkey, Spain	This substance is used in the following products: lubricants and greases, anti-freeze products, coating products, polishes and waxes, adhesives and sealants, polymers and fillers, putties, plasters, modelling clay. This substance is used in the following areas: building & construction work, agriculture, forestry and fishing, mining and formulation of mixtures and/or re-packaging. This substance is used for the manufacture of: chemicals, plastic products, textile, leather or fur, pulp, paper and paper products and machinery and vehicles.
Na_2SO_4	7757-82-6	Chemical industry, Silica industry	The Netherlands and Spain	This substance is used in the following products: plant protection products, textile treatment products and dyes, washing & cleaning products, cosmetics and personal care products and fertilisers. This substance is used in the following areas: agriculture, forestry and fishing, printing and recorded media reproduction and mining. This substance is used for the manufacture of: chemicals, textile, leather or fur, pulp, paper and paper products and food products.

Recovered material	CAS no.	Source of waste water	Location	Potential end-markets (professional use)
$CaSO_4$	7778-18-9	Coal mine industry and Textile industry	Poland and Turkey	This substance is used in the following products: fertilisers. This substance is used in the following areas: agriculture, forestry and fishing, mining, building & construction work and formulation of mixtures and/or re-packaging. This substance is used for the manufacture of: chemicals, mineral products (e.g. plasters, cement), pulp, paper and paper products and wood and wood products.
NaCl (both solution and salt)	7647-14-5	Chemical industry, Coal mine industry, Textile industry	The Netherlands, Poland, Turkey	This substance is used in the following products: pH regulators and water treatment products, fertilisers, water treatment chemicals, anti-freeze products, textile treatment products and dyes, laboratory chemicals, cosmetics and personal care products, inks and toners and paper chemicals and dyes. This substance is used in the following areas: agriculture, forestry and fishing, building & construction work, scientific research and development, printing and recorded media reproduction and health services. This substance is used for the manufacture of: textile, leather or fur, wood and wood products and food products.
Demineralised water		Chemical industry	The Netherlands	Can be used in the neighbouring chemical production as ultra-pure water.

e. Economic consequences

In order to illustrate the effect of the various levels of purity on the economics of the ZERO BRINE implementation, the following study has been performed for $Mg(OH)_2$ and $Ca(OH)_2$ in the production location in The Netherlands (Rastegarianjahromi 2021). When the production of high purity crystals fails, it has several financial consequences. By assuming the capability to recover crystals with a lower limit, average quality, and upper limit quality of recovered magnesium and calcium hydroxide (90%, 95%, and 99% purity), the loss in revenues due to production failure was estimated (Figure 1).

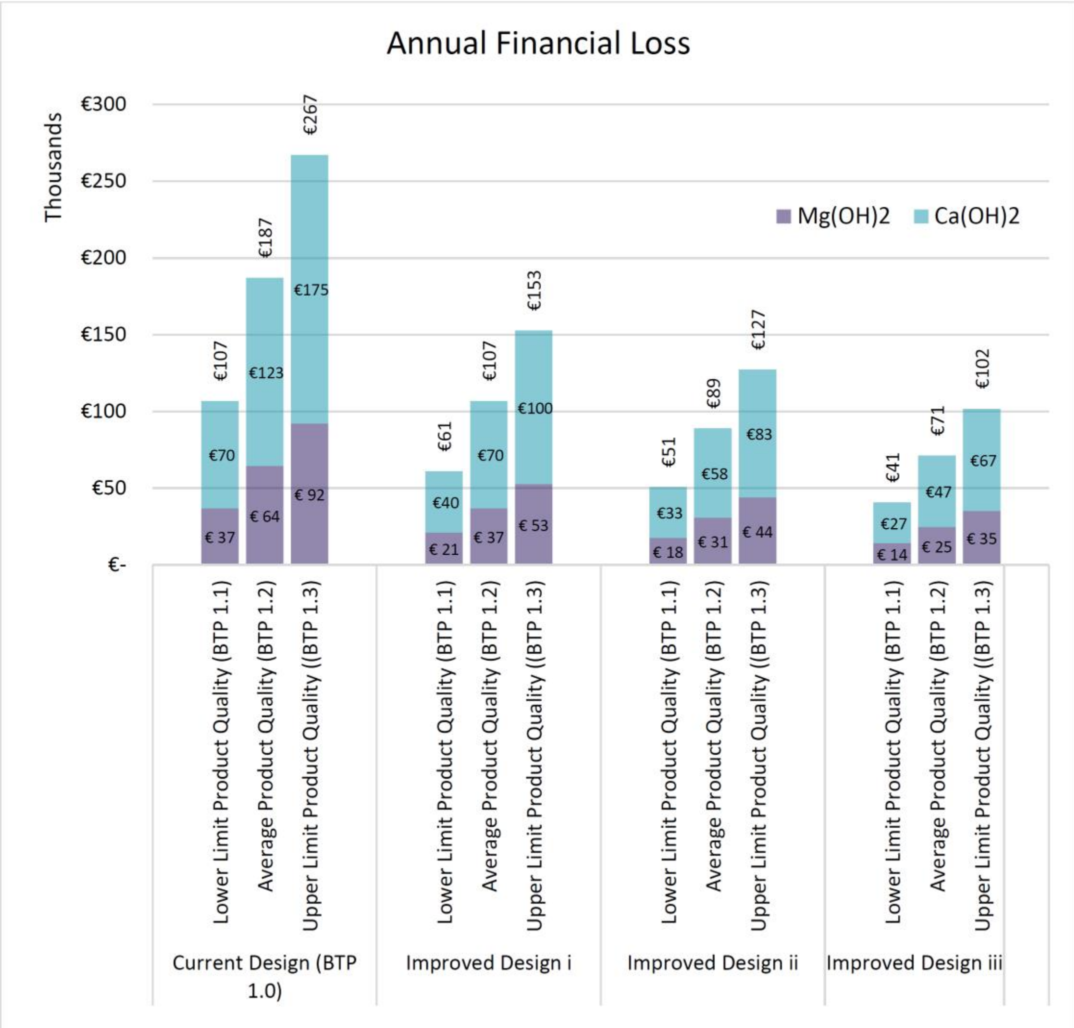

Figure 1. Financial consequences of failure in production of high purity $Mg(OH)_2$ and $Ca(OH)_2$

4. Reflection and Conclusions

During the ZERO BRINE project period data is collected, modelled, and assessed leading to a continuous insight in how the ZERO BRINE system could be improved. Besides the importance to Work Package 7, in which the sustainability performance of ZERO BRINE is assessed and presented, and the importance to Work Package 9, where the policy implications of ZERO BRINE are discussed, the Quality Standards also play an important role in the development of the Circular Economy Business models of Work Package 8 and the policy briefs that are presented to the European Commission from Work Package 10.

The Quality Standards are also used to determine the quality and purity of the recovered minerals. In the previous chapter, it is illustrated what the financial consequences are of the failure in production high purity minerals. All minerals are of sufficient quality, also illustrated in Table 2, to be sold to external partners. However, higher purity will result in the possibility to sell the minerals also in niche markets and create a higher value with it. In the work packages 2, 3, 4, it is specifically reported whether the outflow can be see as high purity minerals or not. In work package 8 this is taken as an important issue for determination of the possible business cases.

5. References

ZERO BRINE (2017), Grant Agreement document

H. Rastegarianjahromi (2021), Design Report - Demineralized Water Production with ZERO BRINE Discharge, TU Delft