	Project Final Report Energy Efficient Valorization of Components from Process Streams (EuRyDice)	Date:07/2018
Name Cluster Director	Menno Plantenga (ISPT)	
Name project leader	Maarten Oudshoorn (Hexion)	
Name reporter	Frank Oesterholt (KWR)	
Secretary and project partners	AkzoNobel Industrial Chemicals BV, Corbion, Dow Benelux BV, Hexion, ECN part of TNO, VITO, KWR Watercycle Research Institute, ISPT	
Project number	Project starting date	Project End date
WP-20-06	January 1st 2015	June 31st 2018

Project closure approval		
Approved by		Date and signature
Project board	☐	Date:
Program committee or Cluster Committee	☐	Date:
Director ISPT	☐	Date:

Some remarks:

-Please copy and paste from previous documents if still relevant (for instance. management summary from project definition etc.)

-Important to mention: changes that have been made to the original plan (for instance changes in objectives) and the next steps (follow-up).

1. Management summary

(Public and confidential part to be decided by project team)
Public part

Reuse of water and resources from process water streams resulting in zero discharge and water loop closure is getting increasing attention in the process industry. Waste water streams with high salt content that still contain organic compounds that are linked to the production processes (resources, products) pose a particular challenge in closing the water cycle.
The main objective of the study was to find economic and technically feasible solutions for the recovery of salts and organic compounds from process streams in order to raise the chain's energy efficiency by at least 25% and lower its energy consumption by at least 10 PJ per year in the Netherlands. For the different industries involved in this project different objectives applied, e.g. recuperation of organic compounds (as resource or product) from salt process water, selective recuperation of salts and/or brine, selective removal from recalcitrant organic compounds that might hamper the biological treatment or selective removal of organics from salts slurries to make reuse of the slurry feasible.

The project started with the identification of relevant case studies at the industrial partners involved. Furthermore a theoretical screening and preselection of technologies resulted in a the CORETS (Component Recovery Technology) table as a tool that can be used as generic tool to support the selection of potential technologies for the recovery of valuable components from process water streams (WP1). For the most promising technologies or combination of technologies a preliminary technical and economic feasibility study was performed by making conceptual process designs, equipment designs and a techno-economic analysis (work of a PDEng trainee). This work was the starting point for performing laboratory tests with a selection of technologies to get a proof of concept by using model solutions or in some cases practical solutions corresponding to the case studies. With the test results a more in depth evaluation of the economic feasibility was performed (by 2 PDEng trainees) and finally a LCA-study.

The project results show that there are in fact two distinctive groups of case studies. One group with a focus on salt or brine reuse, with a low added value leading to the application of relatively low cost technologies such as adsorption (examples in this research: Dow, Hexion, AkzoNobel case studies). On the other hand there is a group of case studies with a focus on recovery of compounds use of organics with a higher added value so that more advanced technologies and a combination of technologies can be applied (a good example in this research is the Corbion case).

The project resulted in a total of 4 (four) case studies with good economic feasibility for selective removal of organics from salt process water streams that will lead to possible reuse either of the organics themselves (Corbion case compounds in a purge from a fermentation process (lactic acid + amino acids) or the brine (AkzoNobel case 2 EDA/DETA, AkzoNobel case 4 Aniline, Dow case 1 Amines). Two of the case studies (AkzoNobel case 4 Aniline, Dow case 1 Amines) with a good economic feasibility also showed a positive environmental impact in the LCA. (The Corbion case was not included in the LCA.) The LCA study shows that the positive environmental impact for these two cases is mainly caused by the fact that reuse of the brine results in avoided salt mining. When the positive environmental impact of these two cases is translated into CO2-equivalents and subsequently in energy requirements, a total energy reduction of 0.3 PetaJoules/year can be calculated for each case study.

It turned out to be impossible to create an integrated standardised tool to decide what separation technology should be selected for recovery of organics and/or salts from salt process water streams in general. In that sense the water streams in every case study has unique characteristics that make a tailor made solution inevitable. So within this project we have demonstrated that the CORETS-table in combination with expert knowledge and lab-

testing can lead to the employability of technologies on a broad range of process streams containing salt process water and organics streams.

In general the experimental work performed in this project has gained new relevant knowledge about application of technologies on process water with a high salt content. Removal of organics from salt waste water streams (brines) to levels necessary to reuse the brine in the chlor-alkali industry (typically < 1 ppm) is a challenge. Nevertheless the experi-mental results of this project give a good indication that this challenge can be met in practice. Conventional technologies such as affinity adsorption (granular activated carbon) turned out to be a rather good solution for selective removal or organics from different salt water streams. As most of the developments are focussing on activated carbon in process streams without salt, this is an important finding. More innovative technologies based on electrical driven membrane technology (that were meant to remove the salt) were struggling with undesirable breakthrough of organics caused by diffusion through the membranes. Experiments with Eutectic Freeze crystallisation showed that high concentrations of organics can hamper the formation of good distinctive ice crystals. When adsorption is used as a method to remove organics from brine streams, the standard regeneration of the adsorption material (burning off the impurities) is too expensive. In situ regeneration (with hot water and/or pH-adjustment) would be much cheaper, seems possible, but this idea still requires significant technology development.

As a spin off and parallel to the project the Bigger Botlek Brine Recycling (BBBR) initiative was started. This initiative is a direct spin off from the Eurydice project focussing on removal of organics from brine streams at a central location near a chlor-alkali plant so that the brine stream can be a resource for the production of chlorine. The intention of this initiative is to create a closed loop for chlorine and chloride (brine) process streams in the Botlek area. In short the idea is to bring salt process water streams from AkzoNobel, Hexion, Dow Benelux BV and Huntsman to a central brine purification (CBP) unit at the AkzoNobel site. At the CBP-unit organics will be removed from the brine to fulfil the specifications for reuse of the brine. Evides Industry Water is involved as well as intended operator of the CBP. The initiative is still on-going. It might result in a follow-up project of Eurydice as was foreseen in the project plan. The initiative offers a good perspective for a next step as it could meet all four criteria for a follow-up project that were formulated at the start of this project (at least one technology or a combination of technologies that will guarantee a functional process; a positive business case; significant energy savings; acceptable time to realisation) and might bring the application to a TRL 5 – 6 level.