EcoSolventCycle

Membrane based process for water treatment of recyclable solvents

EcoSolventCycle aims to develop a membrane-based, solvent-recycling process for the treatment of process wastewater from the membrane manufacturing industry.

THE CONTEXT

Despite the shift towards more eco-friendly technologies in recent years, the membrane manufacturing industry still uses toxic solvents like DMAC, DMF, and NMP to produce synthetic membranes. These solvents are harmful to the environment and difficult to biodegrade, prompting the need for safer alternatives. The European Union's classification of NMP as a high-concern substance has increased urgency even further.

Research has shown the significant potential of green solvents, as f.e. DMSO or Cyrene®, as substitutes for NMP. However, a fully sustainable process would also involve recycling these solvents to reduce pollution and costs, as membrane manufacturing generates large volumes of wastewater containing contaminants, such as solvents and additives. Typically, industries dispose of this wastewater by distillation or burning, leading to high costs. Recycling the solvents would enhance the sustainability of the manufacturing process and conserve resources.

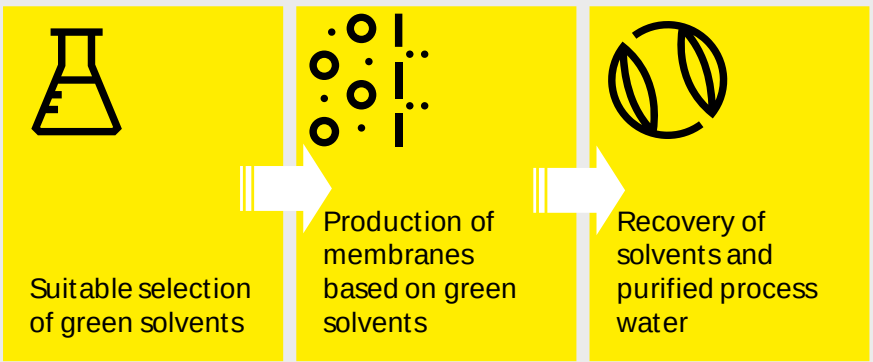

Figure 1. Moving towards sustainable membrane manufacturing!

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THE CHALLENGE

The main goal of the EcoSolventCycle project is to substantially enhance the sustainability of membrane fabrication by investigating the feasibility of process water recycling. Therefore, the challenge is to separate the (green) solvents and polymeric additives (glycerol, PVP) from the wastewater of the manufacturing process. The project partners will study the removal and possible recycling of various organic solvents with membrane technology, as the current industrial solvent recycling relies heavily on thermal separation approaches, which are energy-intensive and account for 80% of the industrial energy use. On the other hand, membrane separations can selectively distinguish molecules based on a nuanced interplay of molecular size, shape, and physicochemical interactions and uses up to 90% less energy than conventional distillation. Within this project, various membrane processes will be explored, including ultrafiltration (UF), nanofiltration (NF), organic solvent nanofiltration (OSN), pervaporation (PV), and membrane distillation (MD).

The project EcoSolventCycle aims to screen a large variety of membranes, identify the optimal membrane processes, and propose an industrial separation cascade. Furthermore, a first techno-economic assessment (TEA) will allow to define the next steps for possible piloting and upscaling of the proposed process.

Figure 2. Small bench-top unit (1 L) for membrane filtration screening (left), membrane distillation unit (middle), and pervaporation unit (right)

THE RESULTS

A simulated waste stream containing PVP, glycerol, and NMP was used. First, eight ultrafiltration membranes were selected for screening to remove the PVP. The results showed that three membranes were able to remove over 99% PVP. The best membrane was chosen based on a combination of high flux and retention, and successfully used in a Proof-of-Concept (POC) concentration test.

Second, a dewatering stage was used to remove the bulk part of the process water by either PV or MD. For both processes, a high NMP and glycerol rejection (> 99%) was reached, while over 90% of the process water could be recycled this way. Third, it was shown that solvent extraction can be used to recover > 75% of NMP at a purity of 98.5% after distillation to remove the extractant. The same processes also work for green NMP alternatives.

Based on the obtained flux results, an economic analysis was performed, which showed that the MD-based process allowed for a significant cost reduction compared to using a full distillation cascade and burning.

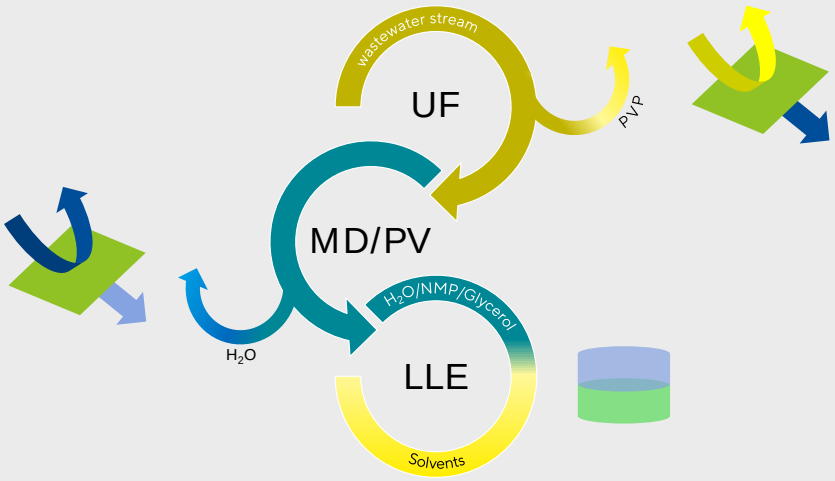

Figure 3. Proposed wagons for the separation train of the solvent recycling process.

CONCLUSION

The EcoSolventCycle project was successful leading to the following conclusions:

- Commercial, open polymeric membranes can successfully remove the PVP with a solvent recovery of over 90% (KPI1).
- Both pervaporation (PV) and membrane distillation (MD) provide excellent dewatering with an NMP and glycerol rejection over 99%. Over 90% of the water can be recovered (KPI2).
- Liquid-liquid extraction (LLE) can be used in combination with distillation to recover over 75% of the solvent mixture (KPI3).
- A first techno-economic assessment (TEA) revealed that the MD-based process costs significantly less than the current burning and a benchmark distillation train.

TECHNIQUES USED

EcoSolventCycle uses the following services and capabilities of the INNOMEM OITB:

- Screening of open polymeric and ceramic membranes with solvent-based streams, requiring UF, PV, and MD setups at the lab-scale, available at partner VITO.
- Techno-economic assessment of membrane-based processes, available within the INNOMEM OITB, but here performed by partner VITO.

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