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MEMBRANE PROCESSES IN BIOREFINERIES

Reference

Based on the final report from IETS TCP Task XVII, *Membrane Processes in Biorefineries*.
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Introduction

The transition from a society largely dependent on fossil-based materials to a climate-smart society based on biomass does not only mean a change in the raw material base but will also require other separation processes and concepts than used during the "oil era". In current petro-chemical refineries distillation is the unit operation that dominates the separation concepts as most compounds are volatile. In contrast to petro-chemical compounds, most compounds derived from biomass are non-volatile. Therefore, molecular size, charge and solubility are the main separation characteristics of extracted biomass compounds, which make membrane processes a natural key separation technique in biorefineries.

The goal of the extended IETS TCP Task XVII on "*Membrane processes in biorefineries*" was to support biorefineries to optimize their energy efficiency by integrating membrane processes for energy demanding fractionation and separation processes. The goals were aimed for in Subtasks with the following key results.

Subtasks

Separation in biorefineries

The subtask addressed the following challenges:

- Mapping of separation challenges in biorefineries.
- Benchmarking of separation technologies for separation duties.
- Selection tool for separation processes in biorefineries.

The Græs4Food project developed a new process including membrane technology for refining high-quality food protein from clover grass and alfalfa. On the background that the demand for sustainable plant-based proteins for food is increasing, there is a huge potential in extracting such proteins from green biomasses. It is planned that the experiences from this project will be used for transferring this process to a large plant production plant and other grass plant proteins.

In the Farm2Furan project focus is on developing a value chain for chemicals production as part of a future biorefinery based on surplus agricultural biomass streams in Sweden, i.e., wheat bran and –straw, oat hulls, beet sugar and -molasses. Target products are 5-hydroxymethylfurfural as a versatile platform chemical for chemical- and fuel industries, and some of its derivatives for use as building blocks for plastics and –surface coating applications.

Overall, these projects highlighted the potential of membrane technology as key separation processes in the concept of biorefineries using different types of feedstocks.

Integration and optimization of membrane processes in biorefineries

The subtask had the following aims:

- Optimization of membrane processes to reduce investment and operating costs.
- Adjusting operating parameters to minimise energy consumption.
- Techno-economical evaluation of hybrid processes in biorefineries.

To achieve this a mapping of the state-of-the art is currently ongoing. The work focused on the integration and optimization of membrane processes in the concept of lignocellulosic biorefineries. The work was be divided into three key areas based on the pulping process used: sulfite, kraft or thermomechanical pulping.

Sulfite pulping process

The separation and purification of galactoglucomannan from sodium-based spent sulfite liquor was a research focus in one project. On-site pilot studies of this application with a plate-and-frame module using polymeric UF membranes showed that high and stable average fluxes can be achieved over several concentration cycles. However, in all cases, the lignin and galactolgucomannan had a molecular weight of the same size meaning additional methods were required for the actual separation of these components. Therefore, antisolvent precipitation and adsorption were used for the separation of these components.

Kraft pulping process

A study related to the Kraft process focused on the separation of low-molecular-weight lignin from the ultrafiltration permeate of high-molecular-weight lignin concentration. In this work, nanofiltration was evaluated for the separation and concentration of low-molecular-weight lignin from the ultrafiltration permeate. It was shown that the nanofiltration process can produce a concentrated lignin fraction, which can be either used to produce valuable chemicals or used to make lignin oil.

Thermomechanical pulping process

The recovery of hemicelluloses from the process water of a thermomechanical pulp mill processing spruce was investigated on pilot scale study using a MF-UF membrane cascade process. The results showed that the limiting part of the process was the MF stage. This was due to the high risk of fouling of the ceramic MF membranes used for the colloidal extractives removal. Further improvements in the process of removing the colloidal extractives can have a great impact on the overall process economy.

Finally, a general overview of the application potential of membrane processes in the concept of lignocellulose biorefineries was prepared. The potential of the membrane processes in this conversion of pulp mills into lignocellulosic biorefineries.

The projects demonstrated how membrane processes can be successfully integrated in different pulping processes on lab and partly pilot scale.

Fouling and cleaning of membranes in biorefineries

The Subtask had the following focus areas:

- In-situ analysis of fouling and cleaning.
- Modelling and fouling prediction.
- Techno-economical optimisation of fouling and cleaning.

A comprehensive overview of in situ real-time monitoring techniques for membrane fouling in the biotechnology, biorefinery and food sectors was compiled. Additionally, different approaches to produce low fouling membranes were investigated.

The work shows that for the successful integration of membrane processes in biorefineries both further understanding of membrane fouling and cleaning by advanced in-situ methods is required as well as the development of new low fouling membranes.

Emerging membrane processes

In recent years several emerging membrane processes became commercially available. To gain further understanding on these processes and their potentials a key output of this subtask was the "Guideline for the integration of emerging membrane separation processes in biorefineries for research, industry and decision-makers". The objective of the guideline was to give an overview of the emerging membrane technologies, map the actions done so far and include know-how transfer within the international consortium, including integration concepts of membrane applications in biorefineries, such pre-treatment and cleaning approaches. The aim of the guideline is to support and enable the integration of potential membrane technologies in biorefining industry.

The guideline developed underlined the potential of emerging membrane processes in different concepts of biorefineries.

Water and wastewater treatment in biorefineries

In this subtask, the focus was on the water loop of biorefineries since membrane processes are key processes in water preparation and wastewater treatment. The subtask was based on the following aspects:

The water loop is a key loop in biorefineries

- The ideal scenario is the biorefinery with a closed water loop.
- Membrane processes can be part of the in-take water preparation and wastewater treatment.
- Water recovery in processes and recycling of water from the wastewater treatment plant can be achieved with the support of membrane processes.

The KLIVER project focused on the production and purification of volatile fatty acids from wastewater as a resource for biomass substrate/energy source. The goal of this project was to develop a climate friendly wastewater treatment concept by investigating to what extent primary sludge can be hydrolyzed to create an internal carbon source that can be used for both biogas production, nitrogen and phosphorus removal.

The project shows the potential membrane technology for water and wastewater treatment but also highlights that the real development potential in this area is in water and resource recovery.

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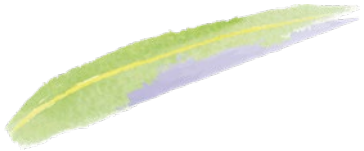

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The mission of IETS is to foster international cooperation among OECD and non-OECD countries for accelerated research and technology development of industrial energy-related technologies and systems. In doing so, IETS seeks to enhance knowledge and facilitate deployment of cost-effective new industrial technologies and system layouts that enable increased productivity and better product quality while improving energy efficiency and sustainability.

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