iets
Industrial Energy-Related Technologies and Systems
An Implementing Agreement established under the auspices of the International Energy Agency

IETS TOPIC SHEET
No 5
January 2019

MEMBRANE PROCESSES IN BIOREFINERIES

Reference

IETS Annex XI, Membrane Processes in Biorefineries.
Annex Manager: Frank Lipnizki, Department of Chemical Engineering, Lund University, Sweden

Topic sheet prepared by Per-Åke Franck, IETS TCP Secretariat.

Introduction

The global society has started a journey from using fossil-based raw material to the utilisation of climate-smart sustainable raw materials. In particular, biomaterials such as e.g. algae and cellulose-based feedstock have been identified as an abundant and renewable resource which can be used for production of fuel, platform chemicals and value-added materials within the concept of biorefineries. One of the critical success factors for biorefineries is the energy and cost efficient purification and concentration of the biomass components on an industrial scale. In most mature chemical processes separation accounts for 60 to 80% of the total process cost and is related to a significant part of the overall industrial energy demand. Thus the development of energy and cost efficient separation processes is of utmost importance for the sustainable success of biorefineries.

The membrane separation technique

In current petro-chemical refineries distillation is the unit operation that dominates the separation concept 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 makes membrane processes a natural key separation technique in biorefineries.

System integration of the membrane separation technique

Much effort has been put into the development of processes using biomass feedstock such as sugar, starch, algae and cellulose-based biomass, instead of fossil-based raw materials. However, research in this area is mostly focused on development of selective reaction pathways, while downstream processes, so far, have gained less attention. This is quite natural since the reactions decide whether a chemical process is possible or not, whereas the separation “only” decides whether a chemical process is profitable or not. Once the process is to be scaled up, all too often it turns out that the process is not economically feasible because the separation stages are too expensive for the biomass-based products to be competitive with alternative fossil-based products. Thus it is important to overcome some of these gaps.

Membrane processes have been identified as high selective energy-saving processes and as such they have been anticipated to become key components in future biorefineries. In recent years, membrane technology has established itself on large industrial scale, e.g. sea desalination units can produce 500.000 m3 of fresh water per day. The fact that the performance of membrane processes decreases with increasing concentrations matches with the need in biorefineries dealing with commonly relative diluted process streams, which means that large volumes of water need to be removed. Guiding principles for the energy requirement for evaporation is 30-40 kWh per m3 water removed, for ultrafiltration < 5 kWh/m3 and for reverse osmosis < 10 kWh/m3. In order to minimise energy demand, the aim is therefore to maximise the dry content by membrane filtration before using energy-intensive drying techniques, such as evaporation and spray drying, used for final drying.

Since the energy requirement of membrane processes increases with increasing concentrations, it is not only important to optimise the operating conditions of the membrane processes but also to define the optimal final concentration achievable by membrane processes from a techno-economical point of view. This optimal final concentration defines then the change-over concentration between membrane processes and classic concentration technologies and is as such a critical parameter in the development of the overall biorefinery concept.

Design and optimization of membrane processes in biorefineries

Optimization of membrane processes in biorefineries in order to reduce investment and operating costs is a prerequisite for the implementation of new biobased chemicals. Furthermore, for biorefineries it can be foreseen that separation processes with several separation stages combined for recovery of chemicals and energy give maximal economic benefits while maintaining the high quality of products and minimising fresh water consumption. Operating parameters that need to be optimized include feed concentration, permeate flux and module hydrodynamics.

Energy requirement in membrane plants is mostly associated with electricity used for pumping. Membrane plants are equipped with a feed pump to deliver the inlet pressure of the plant, and recirculation pumps to compensate for the frictional pressure losses and to maintain a certain circulation flow in the membrane modules. The energy required by the feed pump to deliver the inlet pressure usually dominates in reverse osmosis and nanofiltration plants, whereas the energy required in the recirculation pumps to maintain a certain cross-flow velocity dominates in microfiltration and ultrafiltration plants. Radical decrease achieved by reducing the cross-flow velocity in an ultrafiltration plant treating wastewater in a pulp mill is only one example of the importance of optimization of operating parameters in membrane plants.

CONTACT ANNEX XVII

Frank Lipnizki, Lund University, Sweden
Email: frank.lipnizki@chemeng.lth.se

CONTACT IETS TCP

Thore Berntsson, Chair of IETS TCP
Email: thore.berntsson@chalmers.se

About IETS

The IEA TCP on Industrial Energy-Related Technologies and Systems (IETS), founded in 2005, is dealing with new industrial energy technologies and systems.

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.

Through its activities, IETS will increase awareness of technology and energy efficiency opportunities in industry, contribute to synergy between different systems and technologies, and enhance international cooperation related to sustainable development.

Disclaimer

The IETS TCP is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes or TCPs. The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the IET TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.