Chapter 5
Membrane Engineering and its Role in Oil Refining and Petrochemical Industry

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ABSTRACT

Nowadays, an important contribution to the sustainable industrial growth might come not only from the development of new materials but also from the re-design of process engineering, which leads to the development and the re-designing of more compact and efficient new processes in many areas of applications. As already done in large part of processes in Nature, membrane operations can serve in molecular separations, chemical transformations, water and energy transfer between different phases. Indeed, these technologies well fit the principles of this design philosophy and this is testified by the various applications of membranes in chemical and petrochemical industry and many are the successful examples of processes that have moved from lab-scale to pilot plant up to a demonstration unit in refinery. The main aim of this chapter is to show the main applications of membrane technology in the petrochemical industry and the related current research trends, focusing on the impact that membrane technology can have on the process sustainability.

INTRODUCTION

The ever more pressing necessity for sustainability is inducing to substitute traditional industrial growth with a sustainable one. In the recent Research Agenda published as part of the Delft Skyline Debates (Gorak & Stankiewicz, 2011), the development of the industrial system in the year 2050 has been well defined. In many sectors such as water, energy, food, health, etc. the necessary transformations will take

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place consistently with process intensification principles. These are based on innovative equipment, design and process development methods that can bring important improvements in petrochemical, chemical and any other manufacturing and processing procedures, such as decreasing production costs, equipment size, energy consumption, waste generation, and improving remote control, information fluxes and process flexibility (Drioli, Brunetti, Di Profio, & Barbieri, 2012). *Green process engineering* can give a great contribution to the attainment of a sustainable industrial development.

Green process engineering is based on the principles of Process Intensification Strategy, which can lead to the development and the re-designing of more compact and efficient new processes allowing better exploitation of the raw material, lower energy consumption and a reduced plant volume. Membrane engineering can play a crucial role in the implementation of this strategy and, in the last few years, membrane technology has grown so much that various large unit operations of process engineering have already been redesigned as membrane units.

Membrane operations are an interesting solution for the rationalization of chemical productions, thanks to their high selectivity and permeability in the transport of specific components, efficiency and operational simplicity, low energetic requirement, good stability under operating conditions, compatibility between different operations in integrated systems, environment compatibility, easy control and scale-up, and large operational flexibility.

There are already interesting cases where the potentialities of membrane technologies, such as membrane reactors, membrane gas separation, pervaporation, membrane emulsifiers, membrane distillation, membrane crystallizers, membrane contactors, membrane strippers and scrubbers, in their various configurations and functionalities, were explored. The most successful case is that of pressure driven membrane operations in water and brackish water desalination and in water reuse, where reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) are the most important technologies. The development of immersed bioreactors in the treatment of municipal wastewater is another significant example.

There are various applications of membranes in the petrochemical industry, the most important of which is membrane gas separation.

This type of application is particularly relevant for hydrogen recovery and it is also considered as a suitable technology for the recovery of olefins, hydrocarbon separations, natural gas processing, etc. Membrane reactors, specifically usable for dehydrogenation or hydrogenations of hydrocarbons and for hydrogen production in pre-combustion capture, are other notable potential applications.

Pervaporation processes are generally used for the separation of liquid organic mixtures, the desulfurization of gasoline as well as for isomers separations.

Another way to separate organic-organic mixtures is by organic solvent nanofiltration (OSN), usually used to separate aromatic and aliphatic hydrocarbons, alcohols, ketones and esters. Dewax process is a notable new application of this kind of technology in the refining of lubricants.

The wastewater produced in the petrochemical industry can be advantageously purified by using pressure driven membrane operations such as MF, UF, RO and by membrane bioreactors also in combined configurations. Recently, membrane contactors have attracted great interest as an alternative technology to the other membrane technologies for their application in CO_2 separation from the flue gas stream as well as for air purification.

The most important applications of membrane technology in the petrochemical industry are described in Table 1 where the status of development and the main limitations for scaling up are also summarized.

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