PERSPECTIVE FOR MEMBRANE RESEARCH AND APPLICATION IN WATER PURIFICATION

E. Drioli [1,2], E. Curcio[1]

[1] *Institute on Membrane Technology, ITM-CNR, Via P. Bucci Cubo 17/C, Rende (CS) 87030 Italy*

[2] *Department of Chemical Engineering and Materials, University of Calabria, Via P. Bucci Cubo 17/C, Rende (CS) 87030 Italy*

Process intensification and process integration represent the most promising strategies believed to bring drastic improvements in manufacturing and processing, substantially decreasing equipment-size/production-capacity ratio, reducing raw materials, saving energy input, replacing and reducing hazardous, recycling waste materials.

In this contest, membrane science and technology is expected to give a substantial contribution to satisfy process intensification goal and develop sustainability pathways, thus providing reliable options for both industrial growth and environmental protection.

Membrane operations, with their intrinsic characteristics of efficiency and operational simplicity, high selectivity and permeability for the transport of specific components, compatibility between different membrane operations in integrated systems, low energetic requirement, good stability under operating conditions, environment-compatibility, easy control and scale-up, and large operational flexibility, represent an interesting answer for the rationalisation of chemical productions. Many membrane operations are practically based on the same hardware (materials), only differing in their software (methods). The traditional membrane separation operations (Reverse Osmosis, Micro-, Ultra- and Nanofiltration, Electrodialysis, Pervaporation etc.), already largely utilised in many different areas, are today completed with new membrane systems such as catalytic membrane reactors and membrane contactors. At present, the possibility to redesign important industrial production cycles by combining various membrane operations available in the separation and conversion units, so realising highly integrated membrane processes, is an attractive opportunity because of the synergic effects that can be reached.

Membrane Contactors represent an emerging technology in which the membrane is used as a tool for inter-phase mass transfer operations: the membrane does not act as a selective barrier, but the separation is based on the principles of phase equilibrium. All traditional stripping, scrubbing, absorption, and liquid-liquid extraction process can be carried out according to this configuration.

Today, applications of the gas/liquid membrane contactors technology can be found in many relevant industrial segments. In the beverage industry, a number of different treatments are needed in order to obtain mineral water with desired chemical properties and quality targets: natural water sometimes contains species such as oxygen or hydrogen sulphide which have to be removed or, in the case of sparkling water production, carbon dioxide has to be added (water carbonation). While in conventional processes the absorption and stripping are carried out separately in different devices, membrane contactors can be used for simultaneous extraction and injection of gases with advantages in terms of costs and energy requirements.

Membrane Distillation (MD) and Osmotic Distillation (OD) are well-known methodologies having agreat potential as concentration process carried out at low temperatures. MD and OD operations are not affected by the concentration polarisation phenomenon, whereas it represents the critical limit for pressure driving processes such as NF or RO. Production of a high purity distillate, absence of limitation caused by fouling, lower energy consumption with respect to conventional evaporation or distillation operations are additional advantages of these techniques.

Crystallization from solution is a widely utilized unit operation due to its ability to provide large amount of high-purity product, generally in one processing step and with lower energy requirement than other conventional separation processes. The recent development of a membrane-crystallization unit, aiming to induce supersaturation in solution, has been successfully tested in the crystallization of ionic salts, low molecular organic acids and proteins; potential applications in the desalination industry are also increasing in interest.

Membrane operations are today largely applied in water desalination and in waste water treatments. Large scale desalination plants are under construction or will be realized in the next years making the pressure driven membrane systems the leader technology in this strategic area. Problems still exist related to the low recovery factors of RO units, to the brine disposal, overall costs, membrane fouling. Integrated membrane operations might be a solution for improving the desalination and water treatment systems in the logic of processes intensification. Membrane crystallizzers, membrane strippers, membrane distillation combined with the more traditional UF, NF, RO have been studied for contributing to the solution of the brine disposal problem and for increasing the recovery factors.

The development of integrated membrane systems is expected to allow the recovery of valuable salts present at low concentration in the feed stream of desalination plant. In a project in progress at ITM-CNR the experimental work aims to produce salts as solid products from nanofiltration retentate. The preliminary objective is to limit calcium sulphate precipitation that causes the reduction of SO_4^{2-} content in the solution and drastically limits the recovery of magnesium sulphate.

Ca^{2+} ions are precipitated as carbonates by reaction with $NaHCO_3/Na_2CO_3$ aqueous solutions obtained by reactive carbon dioxide mass transfer into sodium hydroxide solutions in a membrane contactor system; in principle, this approach leads to a reduction of the emission of CO_2 on the environment. The crystallization unit allows to recover NaCl and $MgSO_4 7H_2O$ salts, also giving a mother liquor eventually susceptible of other treatments.

Preliminary experimental results in this project are consistent with the objectives indicated.