초청강연 II

Progresses and new perspectives of integrated operations for a sustainable industrial growth

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1. Introduction

Research progresses in Chemistry and Chemical Engineering have been made during the last decades with important contributions to the industrial development and to the quality of our life.

An interesting case is related to the membrane science and technology continuous impact to innovative processes and products, particularly appropriate for a sustainable industrial growth.

Membrane operations have been familiar for many years to biologists and chemists working in their laboratorier or studying biological phenomena.

Only recently engineers started to operate in this area. The preparation of asymmetric CA membranes at University of California, Los Angeles in the early 60_s is generally recognized as a crucial moment for membranology (1).

Loeb and Sourirajan with their discovery of how to increase significantly the permeability of polymeric membranes without significant changes in their selectivity, made realistic the possibility of their use in large scale operations for desalting brackish and sea water by reverse osmosis and for various other molecular separations in different industrial areas.

Reverse osmosis is today a well recognized basic unit operations, togheter with ultrafiltration, crossflow microfiltration, nanofiltration, all pressure driven membrane processes. Already in 1992 more than 4 millions m^3/day were the total capacity of RO desalination plants and in 1995 more than 180.000 m^2 of ultrafiltration membranes were installed for the treatment of wheys and milk (2) (3).

The concept of asymmetric structures realized with composite polymeric membranes made possible in the early 80s the separation of components

from gas streams. Billions of cubic meters of pure gases are now produced via selective permeation in polymeric membranes (4).

New membrane operations as pervaporation, membrane contactors, membrane distillation, etc., are growing rapidly.

The possibility of combining in a single step a molecular separation with a chemical conversion, realizing a membrane reactor, is offering new important opportunities for improving the efficiency of important productive cycles particularly in biotechnology and in the chemical industry. In September '97 five large petrochemical Companies made public their alliance for a research project devoted to the development of inorganic membranes to be used in the syngas production. This action came in parallel to the announcement of a 84 million dollars similar project, partly supported by the DOE in the USA, having AIR Products and Chemical Inc. working togheter on the same objective.

The basic properties of membranes operations make them ideal for a rationalization of the industrial productions; the fact they are athermal, (except membrane distillation) and don't involve phase changes or chemical additives, simple in their conception and in their operations, modular and easy in their scaling up, suggests significant reduction in energy consumption with a potential more rational utilization of raw materials and recovery and reuse of by products.

Various membranes operations are available today for industrial applications. It can be said that the existing membrane technology cover the widest spectrum of applications than any others single separation technology. Most of them can be considered as basic unit operations and particularly the pressure driven processes such as MF, UF, NF, and RO; electrodialysis, pervaporation, membrane contactors are other examples of mature technologies.

It is interesting to mention that recent statistical analysis carried out by EDF on 174 different membrane installation in France using MF, UF, RO and ED mainly in small and medium size industries found a normall percentage of satisfaction between 70 and 95%, one of the highest positive response received in these kind of analysis. This results is in part surprising due to the high innovative content of the technology and to the lack of education still existing on their basic properties.

It is however consistent with the important contributions the membrane operations can give in terms of cost reduction, quality improvement, pollution control, etc.

The use of ion exchange membrane cells in chloro-soda production represent an interesting case study for analyzing the potentialities of membrane operations and one of the first success of their electrochemical application in minimizing environmental impact and energy consumption. The technology is based on the discovery and utilization of fluorinated polymeric membranes stable in the specific environment, as the Nafion ones.

The traditional Mercury cell with the problems related to the recovery of the Hg and the diaphram cells where the separation and concentration of final products still create difficulties, is today overcome by the membrane systems where the anodic and cathodic species are directly produced in separate compartments without any mixing and therefore any final separation problems. All new chloro-soda installations are now practically based on this design which represent a typical razionalization of the process, cancelling all the pollution problems which in the past characterized the chloro-soda productions.

The success of this process suggested recently another interesting applications still based on cation transporting membranes as Nafion: the Anhydrous Electrolysis for Chlorine Recovery. Hydrogen chloride is a reaction by product of many manufacturing processes; its recovery and feed back of the Cl_2 to the manufacturing process is the most desirable route for handling the HCl by product in excess to its demand in the process. A comparison of the anydrous electrolysis with the other traditional electrochemical processes or catalytic oxidation confirms the lower cost of this new technique. Other molecular halogens could be produced in principle from their respective gases. The direct production of essentially dry chlorine gas, reduce also the oxygen formation, which permits to run the reaction at much higher current densities, with much less purification and drying required compared to the chlorine produced by other systems.

As already mentioned desalination of sea water and brackish water has been at the origin of the interest for membrane operations and the research efforts on reverse osmosis membranes had an impact on all the progresses in membrane science and technology.

Evaporation plants have been substituted with RO systems in different part of the worlds. Size of the desalination plants varies from large to small. The relative low energy consumption is one of the reason for this success. In the Sea Water desalting, in fact, the global energy consumption of RO, with a recovery factor of 30% and energy recovery, has been 5.32

Kwh/m^3 corresponding to a primary energy consumption of 59.94 KJ/Kg (8). RO desalination is not only devoted to the production of drinkable water but is today strategic in various industrial sectors and particularly in the ultrapure water production for the electronic industry. It is interesting to realize that in Japan the largest part of the water produced with RO is e.g. for the electronic industry where the country has a worldwide leadership. Reverse osmosis has not been generally used until recently in the purification, separation or concentration of chemicals, due particularly to the osmotic limitation, and to low chemical and thermal resistance of the existing membranes. The recent development of nanofiltration membranes with interesting selectivity and fluxes, higher chemical and thermal resistance has been rapidly utilized for realizing innovative processes in various industrial sectors.

The potentialities of redesigning innovative integrated membrane processes in various industrial sectors characterized by low environmental impacts, low energy consumption and high quality of final products have been studied and in some cases realized industrially.

Interesting examples are in the dairy industry or in the pharmaceutical industry.

Research projects are in progress in the leather industry or in the agrofood industry based on the same concept.

The availability of new high temperature resistent membranes and or of new membrane operating as the membrane contactors is offering new important tools for the design of alternative production systems appropriate for a sustainable growth.