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Book Review

MEMBRANES IN CLEAN TECHNOLOGIES
Theory and Practice

Andrzej B. Koltuniewicz, and Enrico Drioli (Editors), vol. 2
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The second volume of the book *Membranes in Clean Technologies. Theory and Practice* continues with part II *Membranes in Clean Industry* and part III *Materials in Management with Membranes – Separation of Metals, Acids, and Hydrocarbons.*

Chapter 12 presents membrane processes and applications in food industry. Membranes were introduced in different food industry sectors more than 30 years ago, and therefore the list of their application is very wide ranging. The typical applications of membranes used in food industry are removal of undesired substances, clarification, fractionation and concentration of fluid products, and recovery of valuable components from diluted solution. In the food processing industry water is used for initial and intermediate cleaning, as an efficient transportation conveyor of raw materials, as the principal sanitizing agent for plants, areas and machineirs. The content of chapter 12 has been divided into several parts, with the following topics: fruit juices and pulps (Section 12.2), aroma processing (Section 12.3), wine processing (Section 12.4), beverages processing (Section 12.5), edible oils production (Section 12.6), potato and starch industry (Section 12.7), sugar processing (Section 12.8), meat technologies (Section 12.9), dairy industry (Section 12.10), and the last section 12.11 about food additives – polyphenols. The third part of the volume, *Materials in Management with Membranes – Separation of Metals, Acids and Hydrocarbons* presents current application of membrane processes in separation of metals, acids, and hydrocarbons.

Chapter 13 is dedicated to the practical application of membranes used in metal separation. In this chapter there are presented characteristics some of metals, and cases studies on membrane separation of these metals. This chapter refers to membrane separation applied for metals like arsenic and antimony, cadmium, cesium, gold, lead, mercury, silver, uranium and others. Reverse osmosis and nanofiltration are the methods that can be used to complain with the lowered arsenic concentrations in drinking water. The performance of nanofiltration id related to the nature of target solute and needs to be optimized for each one. Ultrafiltration was proved a successful and suitable process to produce drinking water of the required quality from raw water with high arsenic content in a pilot plant. The experiments showed that boron removal depends on several factors, such as type of membrane, pH of the solution, the degree of desalination, boron concentration in the field. Also, the implementation of advanced seawater reverse osmosis membrane in a configuration comprising Hybridization of the second reverse osmosis pass with an ion-exchange system using boron selective resins is very promising.

Membrane separation is a promising technology from the energy-saving point of view for the selective separation of heavy metal ions. Supported liquid membranes have been attracting attention as a potential method for heavy metal removal, which are three-phase extraction processes. These solutions simultaneously enable attaining high separation with flux, which improves efficiency and reduces the costs of separation. The application of pressure-driven membrane processes integrated with conventional precipitation dissolution operations to enable recycling of the material streams and reduce chromium loads in wastewaters proved to be feasible. A cascade comprising prefiltration, ultrafiltration and nanofiltration can split wastewater into two valuable streams that can be recycled. The results of experiments with ceramic membranes in nanofiltration and ultrafiltration range were performed with nonactive and radioactive model solutions and original radioactive waste samples. A cobalt rejection of 94% has been achieved. The membrane processes may be considered good alternatives for cooper separation offering better performance than the conventional separation processes. Separation of lead by means of nanofiltration, hybrid ultrafiltration and electrodialysis are promising processes for lead removal and recovery in industrial clean technologies. Applications of emulsion liquid membranes in the treatment of dilute actinides liquid nuclear waste.

Membrane processes which can be used for inorganic and organic acids separation are presented in fourteenth chapter. A few case studies are mentioned with applications for the separation of HCl, H_3PO_4, HF, H_2SO_4, HNO_3, HI and others inorganic acids. In what organic acids separations are concerned, the case studies presented in this chapter refer to lactic acid, acetic acid, citric acid, amino acid and others. Inorganic acids are commonly used in numerous industrial processes such as steel treatment, surface treatment, metal refining, electronic and glass industry, pigment and chemical production. Clean technologies recover and reuse acids as valuable materials and contribute to reduction of the environmental load and water conservation, improvement in water management, reduction in energy, chemicals and additives in wastewater treatment. Membrane processes such as electrodialysis, diffusion dialysis, nanofiltration, reverse osmosis can be successfully used for recycling acids. Innovative production schemes based on membrane operations may be applied during production in fermenters as well as by conversion of organic salts. Membrane extraction represents a suitable choice for intermediate concentrations, as membrane contactors which represent a new way to carry out separation processes like gas absorption and solvent extraction. Identification of an efficient separation method for lactic acid recovery was focused on membrane extraction which is considered a promising alternative to regenerate carboxylic acids of low volatility into appropriate aqueous solutions from organic phase. Composite membranes could be either water selective or acetic acid selective, depending on the pore size of the support membrane and the condition of the silicone rubber coating. Separation of acetic acid/water mixture by pervaporation indicated that the process is feasible and depends on membrane structure and layers. A hybrid membrane process could perform the recovery of citric acid from a fermentation broth. The dilute sodium citrate solution arising from fermentation broth is first clarified by microfiltration and then concentrated and purified by electrodialysis. Also, citric and lactic acids in aqueous solutions were separated using solvent extraction and supported liquid membrane. The separation of amino acid mixtures may be carried out by means of reverse osmosis, electrodialysis, nanofiltration.

In Chapter 15, the main topic is the use of membrane processes for organics separation from water, removal of organics from the air, dehydration of organic components, and separation of organic-organic mixtures. Separation of organic mixtures onto groups or even pure components is important from technological viewpoint and they are divided in five major groups of organic mixtures, separation of aromatic-alicyclic mixtures, separation of aromatic-aliphatic hydrocarbons, separation of alkenes-alkenes and alkenes-alkynes, and separation of alkanes-alkenes. The membrane processes such as pervaporation, vapor permeation, membrane distillation, reverse osmosis, nanofiltration, hybrid systems can be applied for volatile organic compounds removal. Pervaporation membranes are able to remove endocrine disruptors from water and food. Novel membrane modules (tubular and spital type) with numerous hollow fibers of silicone rubber were incorporated into bioreactors for effective degradation of VOCs in wastewaters. Phenol separation and degradation can be carried out in membrane bioreactors, pervaporation membranes, membrane contactors, emulsion liquid membranes, anion exchange membranes. Dehydration of organic solvents is the best developed area in pervaporation, which has been shown to be an effective and energy-efficient technique for the separation of azeotropic mixtures. Zeolite membranes are palying an important role in the separation of a variety of materials used in chemical and petrochemical industries.

Chapter 16 of the second volume presents a membrane selection chart that contains the application (the substances that have to be removed) for which the membrane process is applied, the name of the company that produces a specific membrane, the type of the membrane, the membrane material and the membrane process that can be applied (microfiltration, ultrafiltration, nanofiltration, reverse osmosis) with references to the pages where these topics are presented. In conclusion, the table offers a number of selection criteria that can be followed efficiently in working with membrane processes and its applications.

Chapter 17 is in fact a list containing symbols of variable, Freek letters, subscripts, symbols of polymers, symbols of membrane processes. The book also includes an Appendix with lists of institutions dealing with clean technologies, companies dealing with membranes, dangerous substances (the "black list"), prescribed substances for discharge to water under integrated pollution control induced in 1991 (the "red list") and some regulations. The book ends wit a subject index.

This work is a practical "how to do" guide for reengineering existing technologies or implementing innovative processes.

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