Economic evaluation of salt recovery from wastewater via membrane distillation-crystallization [1]

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Membrane contactors are devices basically allowing a non-dispersive contact between two phases. When used for crystallization purposes, they are considered to be able to outperform conventional processes [2]. Their advantages are indeed numerous: reduced size of the module, high and known interfacial area, linear scale-up, good crystallization control on supersaturation and good crystal size distribution [3]. Figure 1 illustrates the working principle of vacuum membrane distillation. The solvent is transferred across the membrane from one phase to the other by the difference in partial pressure. The phase that is gradually depleted of solvent due to vacuum is concentrated until it reaches the saturation level required for crystallization, which happens on the surface of the membrane [4]. The crystal nuclei are then taken away by the flow to further grow in a crystallizer.

This work addresses the economic analysis of crystallization of three inorganic salts i.e., sodium sulphate, sodium carbonate and potassium nitrate, using osmotic membrane contactors. The costs, salt sale profits and benefits of the process of salt recovery from wastewater using membrane distillation-crystallization are evaluated. Furthermore, a sensitivity analysis is performed.

The results show that crystallization using membrane contactors can be economically profitable (Fig. 2). Figure 3, representing the sensitivity analysis, shows that the market value of the salts to be crystallized is the parameter influencing the most the benefits. Then come the plant availability, the membrane price and the overall mass transfer coefficient. It can thus be concluded that recovery of high-value salts from wastewater using membrane contactors can be economically profitable and that it is important to focus on research about low-cost and high-performance membranes to increase membrane performance and process viability.

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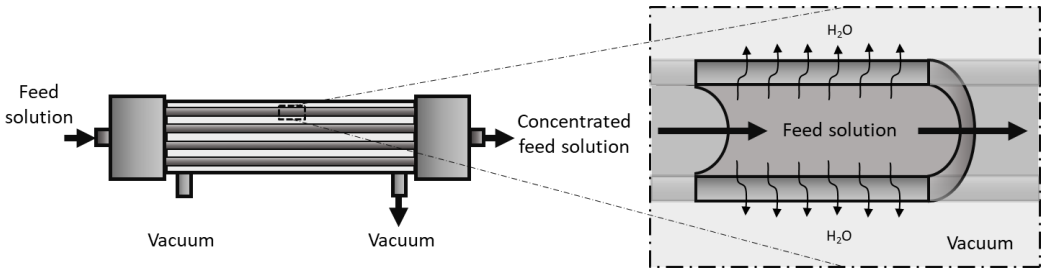

Fig. 1: Working principle of a vacuum membrane contactor used for concentration of a solution with water as volatile component.

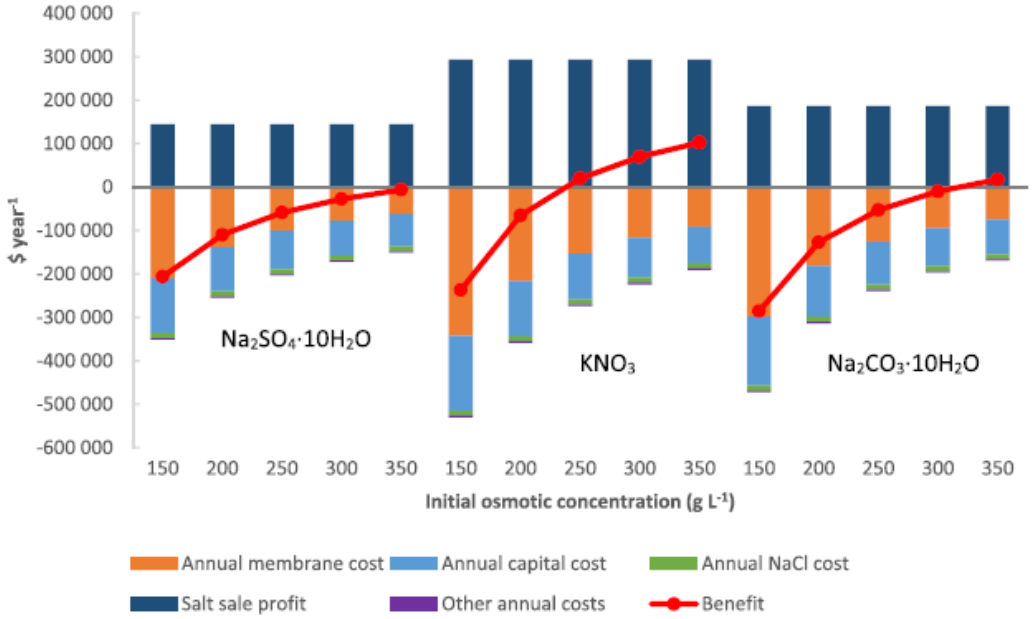

Fig. 2: Costs, salt sale profit and benefit for the crystallization of the 3 salts. Different initial osmotic concentrations are illustrated. Initial feed concentration and flow rate are 100 g L^{-1} and 500 L h^{-1} respectively and osmotic flow rate is 27 L h^{-1}.

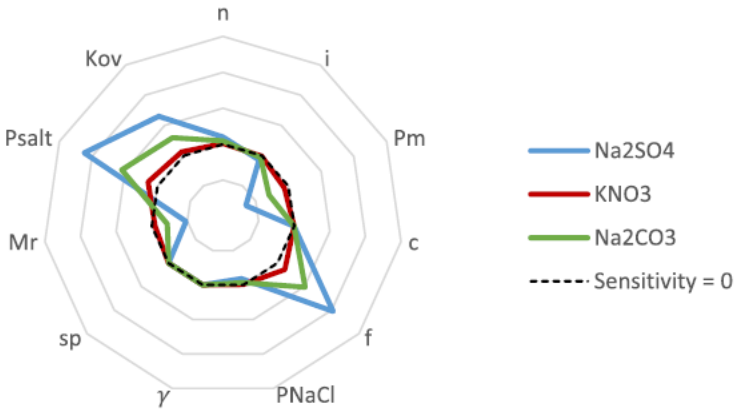

Fig. 3: Sensitivity coefficients at room temperature for initial feed concentration and flow rate of 100 g L^{-1} and 500 L h^{-1} and initial osmotic concentration and flow rate of 350 g L^{-1} and 27 L h^{-1}. n: plant life, i: interest rate, Pm: membrane price, c: electric cost, f: plant availability, PNaCl: NaCl price, γ: specific cost, sp: spare parts, Mr: membrane replacement rate, Psalt: salt price, Kov: overall mass transfer coefficient.