

Two-dimensional model of cross-flow electro dialysis units for the assessment of membrane deformation effects on the process performance

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In the last years, the Electro dialysis (ED) process has drawn much attention for drinking water production from saline water desalination. Electro dialysis is an electro-driven, membrane based process, where water desalination is achieved by applying an external electrical voltage and employing Ion Exchange Membranes (IEMs), which allow for a selective transport of ions. In ED units, IEMs are separated by means of net spacers or built-in profiles, which create the channels where the solutions flow.

In the literature, several studies have highlighted the detrimental effects of membrane deformation on the performance of many membrane-based processes. However, membrane deformation has been poorly investigated in ED applications. On the other hand, membrane deformation may occur in ED units due to an uneven pressure distribution between the two fluid channels facing an IEM, thus giving rise to a transmembrane pressure (TMP) distribution. Despite TMP is usually small in parallel flow arrangement, non-negligible local TMP values could exist in non-parallel configurations, e.g. cross-flow arrangements.

This work presents a novel multi-scale 2-D process model of ED cross-flow units, including the effects of membrane deformation induced by TMP. The model employs correlations obtained from small-scale numerical simulations (structural mechanics and computational fluid dynamics) to solve the fluid-structure interaction problem (flow redistribution induced by membrane deformation). Then, the model couples these effects with transport and electrochemical phenomena describing the ED process at the scale of an entire cell pair.

Mild membrane deformations were found to alter only slightly the ED process performance. However, larger membrane deformations, which may occur, e.g., with thin membranes, had more significant effects. For example, the specific energy consumption was increased by 6% compared to that predicted by neglecting membrane deformation.

Keywords

Electro dialysis; Membrane deformation; Water treatment; Ion exchange membrane; Modelling