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Donnan dialysis for tap-water softening

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ABSTRACT

Hard water significantly decreases the lifetime and efficiency of equipment, which has negative technical and economic consequences. A promising technology for the softening of tap water is based on the Donnan dialysis (DD) process. DD is a separation process by which divalent cations can be removed from tap water using cation-exchange membranes (CEMs) and a concentrated salt solution (receiver). No external driving force is required in DD; ion exchange is only due to a chemical potential gradient across the CEMs. The effect of operating parameters that influence the hardness removal and ion fluxes such as receiver concentration (0.5–2 M) and channel flow rate (0.25–0.35 L min^{-1}) was investigated. Contrary to what expected, it was observed that higher salt concentrations in the receiver did not improve the performance. Therefore, it was chosen 1 M as the optimal concentration for the receiver solution. Moreover, a higher flow-rate leads to higher ion-exchanged flux through the membranes thus higher removal efficiency in the batch configuration. A comprehensive mathematical model, consisting of a distributed parameter model with spatial differential equations and a dynamic part including time-differential equations for batch operations, was developed and validated with original experimental data to provide an effective tool for the design and optimization of DD units. With the model, two household systems were designed and simulated based on typical Dutch and German hard feed waters. Three different operating modes were analyzed and compared in terms of outlet target to create more insight into the potential of DD to become a competitive water softening technology.

Keywords: Electromembrane; Ion exchange; Hardness removal; Ion exchange membranes

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