Donnan dialysis for tap-water softening

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Hard water is a problem in both domestic and industrial applications and is caused by an excess of calcium and magnesium ions. It significantly decreases the lifetime and efficiency of equipment which has negative technical and economic consequences. Existing water softening technologies have several disadvantages, such as a high chemical use (crystallization, ion exchange), water and energy consumption (nanofiltration). A promising technology for the softening of tap water is based on Donnan dialysis (DD). DD is a separation process with 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 used in DD, ion-exchange is only due to a chemical potential gradient across the CEMs. In this study, a technical and economical assessment is made to create more insight into the potential of DD to become a competitive water softening technology.

The technical assessment consisted of the optimisation of a lab-scale setup for DD, the investigation of operational parameters that influence the hardness removal and ion fluxes and the theoretical modeling to make predictions possible. Accumulation of divalent ions in the CEMs was discovered, therefore a conditioning step was required to have the same starting point in every experiment. In contrary to theory, it was observed that higher salt concentrations in the receiver did not improve the performance, it even deteriorated at high concentrations. The influence of the receiver composition showed that up to 8.4 g L^{-1} Ca^{2+} can be added before replacing of the solution is necessary. The driving force remains high enough to move Ca^{2+} against its concentration gradient. Corresponding to the theory it was observed that a decrease of the recovery and an increase of the flow rate both resulted in an increase of the removal. Different types of Fujifilm CEMs were examined. The electrical resistance (ER) and permselectivity (PS) of the CEMs were found to be crucial as they directly determine the ion flux, a higher ER results in a decrease of the ion flux. Influence of water permeability (WP) was not noticed due to the fact that the experiments performed with a relatively short residence time. The DD process can soften hard water in one pass through the system if sufficient CEM area is available. Theoretical modeling enables to predict equilibrium and ion fluxes, these ion fluxes were validated by experimental results.

The economical assessment in terms of CAPEX and OPEX showed that further improvement of DD is necessary to compete with other water softening technologies. Relatively high amount of salt usage comparing to the ion-exchange resin is the biggest issue that needs to be solved first.

Keywords: Donnan dialysis, Water softening, Cation-exchange membrane

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RevivED Water: Small-scale ED desalination systems for brackish water Experiences from field test in Somaliland

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One of the electrodialsyis based solutions developed by the REvivED water project are small-scale desalination units powered by off-grid solar systems for the use in developing countries.

In 2017 a first prototype for the desalination of brackish water based on capacitive electrodialysis has been developed.

For the first pilot plant the project partners of Ghent University, Deukum GmbH, Fujifilm Manufacturing Europe B.V., Phaesun GmbH and the University of Palermo worked on improving and scaling up all system components. The complete system was constructed and tested in laboratory in April 2018. It includes the following modules:

A) Pre-treatment unit: slow sand filter and active carbon
   ⇒ The slow sand filter technology and activated carbon was chosen out of seven pre-treatment options due to its robustness, simplicity, and economic viability.

B) Capacitive electrodialysis (CED) desalination unit
   ⇒ A desalination unit with capacitive electrodes, new generation of ion exchange membranes and innovative stack design that is able to run three operation modes (single pass, batch, feed & bleed) was developed.

C) Post-treatment: chlorine cartridge
   ⇒ A chlorine treatment of the out-coming water and for the system's cleaning purposes was chosen as the most viable option.

D) Concentrate disposal: evaporation pond for brine
   ⇒ The salt concentrate water as waste product of the system is being collected in an evaporation pond.

E) Solar power supply
   ⇒ The PV system to serve all power needs of the system was sized with the further developed EasySizing RevivED software.