Laboratory and Pilot Scale Experiments with a Monovalent Selective Membrane Capacitive Deionisation

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Abstract

The application of size selective membranes in capacitive deionisation can increase the retention of monovalent ions as sodium and chloride in partial brackish water desalination. Within the joint project innovatION (BMBF 02WV1572A), novel selective ion exchange membranes are used in laboratory and pilot scale plants to examine the desalination performance.

Monovalent Selective Membrane Capacitive Desalination

Need of monovalent selective desalination

The interest in efficient desalination processes is increasing due to the globally increasing water demand and decreasing available freshwater resources (Jones et al., 2019). Fresh groundwater resources, affected by seawater intrusion or geogenic salt deposits, show high sodium and chloride concentrations. Increasing nitrate concentrations usually result from agricultural influence (UN, 2022; Yang et al., 2022,). A complete desalination of water is usually not required since only a reduction of the monovalent ions is necessary (Guyes et al., 2021; Rosentreter at al., 2021).

Membrane Capacitive Deionisation

Membrane capacitive deionisation is an electrochemical technique for brackish water desalination, whereby anions and cations are retained in electrical double layers. Selective desalination can be obtained by specific materials of electrodes, coatings and membranes, as well as by specific operation conditions. However, membranes with high selectivity for monovalent ions still need to be developed and tested within capacitive deionisation (Zhang et al., 2020). Within the joint project innovation, which is supported by the BMBF (02WV1572A), selective membranes for specific retention of monovalent salts are developed and integrated into newly designed electrochemical driven desalination modules (Figure 1). These modules are used in laboratory and pilot scale desalination plants to identify optimised process and plant parameters depending on different raw water qualities and treatment targets.

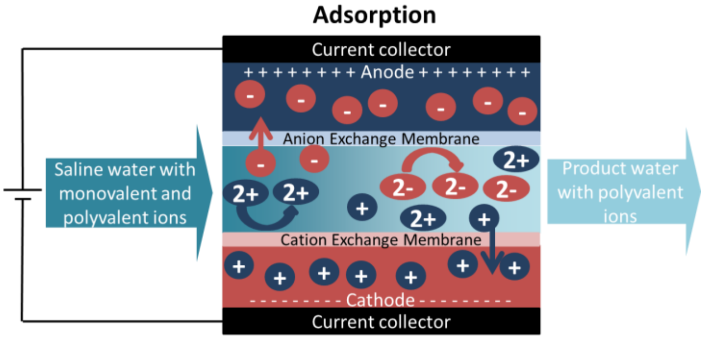

Figure 1. Principle of the selective membrane capacitive deionisation with high retention of monovalent ions.

Laboratory and pilot scale desalination experiments

Laboratory Plant

The laboratory plant was built by DEUKUM GmbH, consists of 1-7 cells and can be used to partly desalinate up to 20 L/h brackish water with a total dissolved solids (TDS) concentration ≤ 2 g/L. During the experiments electric current and voltage, as well as the electric conductivity and pH of feed, product and concentrate are measured online to evaluate the selective desalination performance using novel membranes by FUMATECH BWT GmbH, Germany and Leibniz Institute of Polymer Research Dresden, Germany. The selective desalination is examined using 0.3 and 1.0 g/L TDS artificial and real brackish groundwater during short-term (3 h) and long-term (1 week) experiments. Long-term experiments are used hereby to analyse the scaling and fouling potential at different temperatures. The electrodes, membranes and operation conditions, which showed the best selective desalination performance in the laboratory plant, are implemented in pilot plant.

Pilot Plant

The pilot plants will be set-up on Langeoog (East Frisian Islands) and in Nienburg in Lower Saxony, Germany to reduce the concentration of sodium and chloride, and the concentration of nitrate, respectively, to comply with the drinking water regulations or to be used for managed aquifer recharge. According to non-ideal conditions at the pilot plant, the influence of long-term effects, organic components and varying conditions will be examined using a flexible control and regulating system within the monovalent ion selective membrane capacitive deionisation.

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