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Two-pass closed circuit desalination for high-recovery (96%) low-energy production of quality permeates with saving of water and energy

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Municipal water sources are commonly used as feed in two-pass convention RO plug flow desalination (PFD) techniques of 85% overall recovery for high quality permeates production of increasing demand for turbine power generation as well as by the solid-state, cosmetic and pharmaceutical industries. Since the cost of municipal water increased substantially over the past several decades, the cost-effectiveness of such two-pass processes could be enhanced if performed with higher overall recovery and lower energy, and the present study explores the prospects of reaching the stated objectives using the a two-pass closed circuit desalination (CCD) process instead of conventional PFD techniques. In light of a recently reported CCD of municipal water with 96% and low energy, model simulations are explored of two-pass CCD processes of first-pass of 96% recovery with 25 lmh and second-pass of 85% recovery with 31 lmh, where second-pass brine is mixed with first-pass feed. The simulation results reveal an overall recovery of 95.33% with permeates quality and energy consumption (in parentheses) for the cited membranes elements being as followed: 1.20 MΩ (0.768 kWh/m^3) for ESPA2-MAX; 2.17MΩ (0.997 kWh/m^3) for CPA3; and 3.38 MΩ (0.878 kWh/m^3) for SWC6-MAX. The upgrade of the cited quality permeates (1.20–3.38 MΩ) to the level >16 MΩ can be easily and inexpensively accomplished by means of ion exchange techniques. The simulation results suggested the prospects of considerable saving of expensive municipal water and energy by CCD instead of conventional PFD, for more cost-effective high quality permeates production for diverse applications.

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Thermal regeneration of ammonium bi-carbonate solutions for closed-loop reverse electrodialysis

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Reverse electrodialysis is a novel technology that exploits a salinity gradient to generate electrical energy. The salinity gradient can be available from natural waters such as seawater and river water or they can be artificially generated and used within closed-loop applications. This last option has been recently investigated leading to the development of the RED heat engine concept. In this case, the deployed salinity gradient exiting the RED unit is regenerated in a thermally-driven unit using low-temperature heat, thus being able to convert heat to power within an integrated system.

Among the different regeneration alternatives, the use of thermolytic salts has been presented as a promising option, due to the possible use of very-low grade heat (40–60°C) to regenerate the solutions by means of degradation/stripping/re-absorption processes.

In the present work, different regeneration strategies for ammonium bi-carbonate aqueous solutions have been investigated by means of process simulation (Aspen Plus) and experimental tests. Simulations have been performed looking at two different regeneration methods: i) stripping with air and ii) distillation (in practice, also a stripping process, but with vapour). A sensitivity analysis has been performed to study the effect of different operating variables (streams' temperature, pressure, flow rate, inlet concentration) on the regeneration performance. The experimental campaign has been carried out mainly on the air stripping concept, which did turn to be the most promising within the expected range of operating conditions.

Experiments were also aimed at identifying the main dependences (e.g. the effect of different packing materials and operating conditions on the performance indicators), technological limitations and relevant solutions.

Eventually, a comparison between experimental information and model predictions has been performed in order to highlight the main discrepancies and validate model prediction capabilities.

Keywords: Reverse electrodialysis, Salinity gradient power, SGP heat engine, Waste heat, Ammonium hydrogen carbonate.

Acknowledgements

This work has been performed within the RED-Heat-to-Power project (Conversion of Low Grade Heat to Power through closed loop Reverse Electro-Dialysis) - Horizon 2020 programme, Grant Agreement n. 640667.

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Water-organic systems in closed-loop reverse electrodialysis for lower regeneration requirements

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Salinity gradient power (SGP) is an emerging opportunity to produce sustainable energy. Among the different SGP technologies, reverse electrodialysis (RED) looks very promising. In a RED system the salinity gradient between two different solutions is used to directly produce electricity. Closed-loop RED is an innovative process, combining a RED unit with a regeneration system. If low grade waste-heat is used for the regeneration stage, in which the initial concentrations of the solutions exiting the RED unit are restored, the closed-loop can be seen as a RED-heat-engine able to convert thermal energy into electricity.

The aim of this work is to perform a preliminary analysis of a regeneration unit based on an evaporative process, in which water-organic systems are used as solvent solution. The use of organic solvents with water, in fact, results in a reduction of the specific energy consumptions and/or the evaporation temperature compared to the "standard case" in which only water is adopted. This reduction can allow the use of very low temperature heat sources.

In this work results are reported for the case of different organic-water systems with a different liquid vapour equilibrium behaviour: (i) water-organic heterogeneous azeotropic systems, (ii) water-organic homogeneous azeotropic systems and (iii) water-organic miscible systems. Advan-