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Intensification of Separation Processes in a Model Electrodialysis Unit

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Electrodialysis (ED) is a promising electromembrane technique used for selective ion separation, particularly in water desalination and resource recovery. However, its performance is often limited by concentration polarization and the associated electric resistance near ion-exchange membranes. Our recent studies suggest that natural convection, driven by solute-induced density gradients, can effectively mitigate polarization effects even under underlimiting conditions. We confirmed the dominant role of natural convection in model ED channels by measuring concentration profiles in the diluate stream, which showed significant vertical variations: desalted and highly concentrated solutions were withdrawn from the top of the diluate and the bottom of the concentrate channels, respectively.

This accumulation of desalted solution at the top naturally suggests implementing side withdrawal streams for its recovery, whereas similar bottom-side streams can recover highly concentrated solution. Our research therefore focusses on the development and experimental evaluation of a model electrodialysis unit designed to promote natural convection and enable the recovery of additional streams through side ports. We constructed a novel flow-through ED cell that comprises a central diluate channel and two concentrate channels, each equipped with additional strategically positioned side outlets. Cell geometry was optimised through preliminary 2D numerical simulations and practical experiments to promote natural convection.

Experimental characterisation was performed using NaCl solutions at various flow rates through the additional side ports and at various applied currents. The system was evaluated by measuring the concentration and voltage with continuous sampling of diluate or concentrate through the side ports. The results confirmed the possibility of the withdrawal of the desalted and concentrated solutions accumulated at the top and bottom of the flow-through channels. These side streams exhibited enhanced separation efficiency without the need for overlimiting voltages or turbulizing spacers.