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Hydrodynamic Model of Desalination by "Overlimiting" Electrodialysis with Electroconvective Vortices RHOKYUN KWAK, Korea Institute of Science and Technology, VAN SANG PHAM, Hanoi University of Science and Technology, JONGYOON HAN, Massachusetts Institute of Technology — In 1968, Sonin and Probstein developed a hydrodynamic theory of desalination by electrodialysis (Desalination, 5, 293-329, 1968). Under a laminar flow between ion exchange membranes, linear ion concentration gradients are developed near the membranes by ion concentration polarization (ICP) in Ohmic-limiting current regimes. This linear ICP determines the relations between current, voltage, and desalting performance. Here, we revisit the hydrodynamic model with nonlinear ICP phenomenon at overlimiting currents. In this regime, electroconvective vortices on the membrane induce flat and extremely low concentration zones. Based on the previous prediction of the vortex height under shear flow (Kwak et al., PRL, 110, 114501, 2013), we verify that the height directly represents the amount of the removed salt because there is almost no ion in the vortices. Next, from the mass continuity of ions, the amount of the removed salts is equal to the ion flux through the membrane (i.e. current); as a result, we can develop the relations between current, voltage, and salt removal. Lastly, from these relations, power consumption and desalination cost can be calculated to find the optimal operating condition of overlimiting electrodialysis.

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