Limiting current phenomena in electro-membrane processes: local occurrence or stack-dependent one?

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Main topic: Electro-membrane processes

Background
Electro-membrane processes are gaining great interest in the field of desalination and brine valorisation. However, limiting current phenomena can be a bottleneck for their techno-economic performances. In the present work, the in-out distribution of current density is measured to elucidate the achievement of limiting conditions in real stacks.

Materials and Methods
A 10-cell pairs Electrodialysis stack (10×40 cm^2 active area), equipped with four-segmented electrodes, was tested. NaCl solutions at an inlet concentration ranging from 0.5 to 60 g/l were fed at velocities of either 2 or 4 cm/s in parallel flow. Current density-voltage curves were built by applying equal increasing steps of voltage to each electrode. Outlet concentrations and current efficiency were investigated [1].

Results
Figure 1 shows the current density-voltage curves for two couples of inlet concentration. Between the final tract of the ohmic region and the plateau region of the overall stack curve, the current density distribution at the four segments changes markedly. In fact, while at the first electrode the current density continues to increase, at the other three it reaches a maximum and decreases. Thus, as the voltage increases, the current concentrates in a shorter tract of the channel, while it reduces in the remaining part, becoming ineffective for desalination, due to its high resistance. This is caused by the high desalination rate in the first few centimetres, making the dilute conductivity much lower. Moreover, the longer tract of channels at high salinity gradient in the final part of the stack promotes larger diffusion, lowering the current efficiency [2].

Figure 1. Current density-voltage curves for tests at a) $C_{dil,IN}$=0.5 g/l and $C_{conc,IN}$=30 g/l and b) $C_{dil,IN}$=$C_{conc,IN}$=1 g/l.

Conclusions
The attainment of limiting conditions in electrodialysis stacks is strongly related to ohmic phenomena and to the distribution of current density, highlighting its importance in the design of efficient electro-membrane systems.

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Reference 1:
Gurreri L., Filingeri A., Ciofalo M., Cipollina A., Tedesco M., Tamburini A., Micale G., Electrodialysis with asymmetrically profiled membranes: Influence of profiles geometry on desalination performance and limiting current phenomena, Desalination. 506 (2021) 115001. https://doi.org/10.1016/j.desal.2021.115001.

Reference 2:
M. La Cerva, L. Gurreri, M. Tedesco, A. Cipollina, M. Ciofalo, A. Tamburini, G. Micale, Determination of limiting current density and current efficiency in electrodialysis units, Desalination. 445 (2018) 138–148. https://doi.org/10.1016/j.desal.2018.07.028.