Reverse Electrodialysis process with seawater and concentrated brines: a COMSOL model for equipment design

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Reverse Electrodialysis Technology

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RED process with seawater and concentrated brines – COMSOL Conference Rotterdam 2013
### Modelling goals

#### Investigated physics

- Mass transport through membranes
- Transport of electrolytes
- Electrochemical reaction
- Fluid dynamics

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[Diagram showing various modules and their interconnections, with red circles highlighting CFD Module and Batteries & Fuel Cells Module.]

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System definition and model assumptions

Model assumptions:

- Empty channels
- NaCl aqueous solutions
- Negligible solvent flux through membranes
- Adopting Nernst-Planck equation
- Activity coefficients equal to unity
- Adopting Einstein relation for ion diffusion coefficient
Governing equations

• Laminar flow for Newtonian fluid:

\[ \nabla u = 0 \]

\[ \rho \frac{\partial u}{\partial t} + \rho u \nabla u = -\nabla P + \mu \nabla^2 u + F \]

• Transport equation through solutions (Nernst-Planck model):

\[ N_i = -D_i \nabla c_i - z_i u_{m,i} F c_i \nabla \Phi_l + u c_i \]

\[ i_l = F \sum_i z_i (-D_i \nabla c_i - z_i u_{m,i} F c_i \nabla \Phi_l) \quad \sum_i z_i c_i = 0 \]

• Electrode kinetics (Butler-Volmer theory):

\[ i = i_0 \left[ \exp \left( \frac{\alpha_a F \eta}{RT} \right) - \exp \left( \frac{-\alpha_c F \eta}{RT} \right) \right] \]

\[ \nabla \cdot i_l = F \sum_i z_i R_{i,sr} Q_l \]
Model tuning/validation

Experimental data collected with a 50 cell pairs stack, Fujifilm membranes, Deukum 270 µm spacers. Brine: 5 M NaCl. T=20° C. Fluid velocity: 1 cm/s.
Concentration profiles along channels
Electric potential through the stack
Salt fluxes through membranes

Total flux (mol/(m^2*s))

Distance from anode (m)

Flux, x component (mol/(m^2*s))

-20 -15 -10 -5 0 5 10 15 20

0 0.0001 0.0002 0.0003 0.0004 0.0005 0.0006 0.0007 0.0008 0.0009 0.001 0.0011 0.0012 0.0013 0.0014 0.0015

Na Cl Fe2(CN)6 Fe3(CN)6 Sum electrode Na-Cl
Conclusions

✓ **Model validated** on experimental data under different conditions

✓ Simplified approach to simulate both **fluid dynamics/electrochemical phenomena**

Next steps

• **Activity coefficients** evaluation

• **Mechanical analysis** on membranes

• Description of **Donnan Potentials** across membranes
Acknowledgments

www.reapower.eu

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Thank you for your attention

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