Optimisation of membrane separation processes via Computational Fluid Dynamics modelling and simulations

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Ion Exchange Membranes processes

Concept

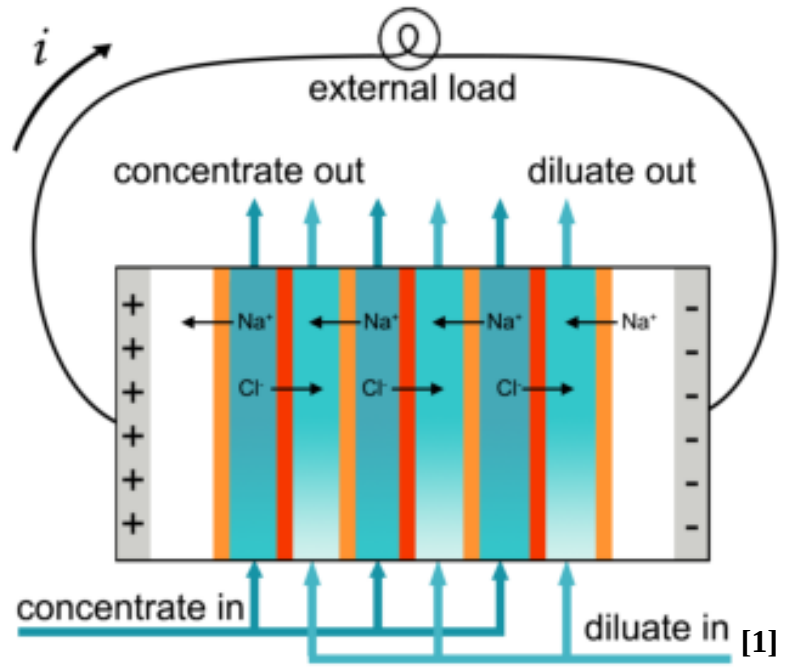
Ion Exchange Membranes (IEMs) based processes play a crucial role in the transition from a fossil-fuel based economy to a sustainable one. Fouling is a critical issue worsening the performances of these processes. Fouling is usually identified as the deposition of undesired (ion)organic species on membranes or spacers. Numerical tools able to predict fouling deposition can help to control and mitigate fouling phenomena. On the other hand, the implementation of predictive models is challenging due to the complex nature of fouling.
This research project focuses on the fouling characterization and modelling in technologies devoted to valorizing waste-process streams such as: Electrodialysis (ED), where an electric field is applied to desalinate a salty stream and Reverse Electrodialysis (RED), where a salinity gradient is exploited to produce electric energy. Notably, converting a waste-stream in a resource is the classical scheme of circular economy, which can be pursued only if fouling issues are suitably tackled.

Scientific approach

Fouling layers growth affects IEMs processes performance in 3 main ways: increasing pressure drop, increasing electric resistance and lowering selectivity of membranes. The time-variation of these variables will be evaluated through long-run experimental tests carried out with real or "ad-hoc prepared" solutions.
Moreover, different set-ups (lab and pilot-scale) and electric configurations (e.g. electrodes segmentation) will be tested.
Membrane autopsy will be carried out through Scanning Electron Microscope (SEM) analysis for fouling characterization.
Data from experimental activity will be also employed to build a database for models' validation.
Modelling activity will follow two paths: (i) mechanistic models will be implemented through a simulative platform, coupling Computational Fluid Dynamics (CFD) simulations and in-house developed models; (ii) Artificial Neural Networks models will be developed to highlight hidden connections between operating conditions and fouling impact.

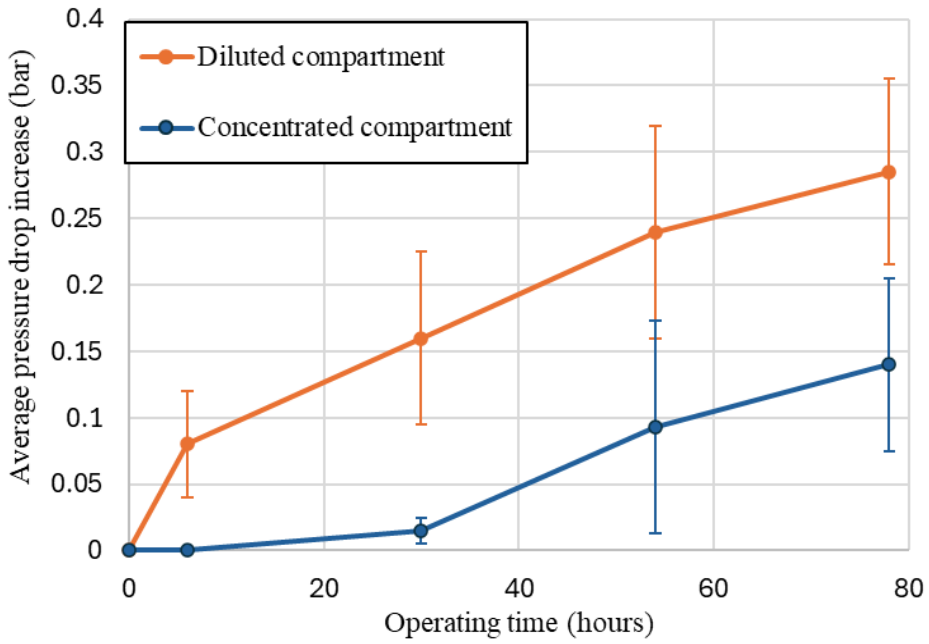
Research objectives

- Experimental investigation on operating conditions and solutions composition in RED and ED performance and fouling deposition magnitude;
- Evaluation of the influence of electrodes' segmentation and pilot-scale on performance parameters;
- Development of CFD mechanistic models for the prediction of specific mechanisms of fouling deposition (colloidal fouling, biofouling etc…);
- Implementation of Neural Networks models to describe the complexity of fouling nature in IEMs processes.

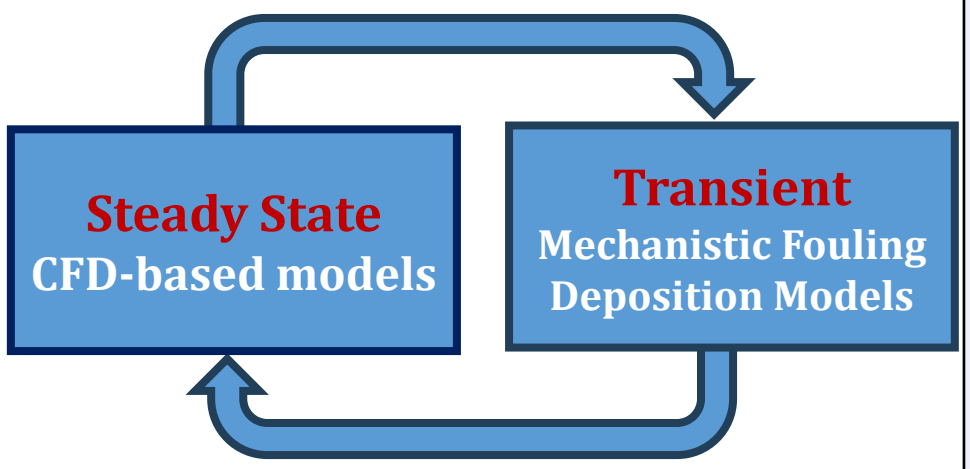


[1]

RED Process Schematic Representation



Average pressure drop increase in RED long run tests performed



General scheme of the simulative platform

[1] Tedesco, Michele & Hamelers, H.V.M. & Biesheuvel, Maarten. (2016). Nernst-Planck transport theory for (reverse) electrodialysis: I. Effect of co-ion transport through the membranes. Journal of Membrane Science. 510. 10.1016/j.memsci.2016.03.012.