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BOOK OF ABSTRACTS

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Modelling of colloidal fouling in electro-membrane processes

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Introduction. Fouling is one of the main hurdles that hinders the performance of membrane-based processes. It is defined as the formation of an additional layer on membrane surfaces or spacers. Different types of fouling have been classified in the literature, such as bio-, colloidal and organic fouling. Colloidal fouling is often one of the most affecting phenomena in electro-membrane processes. Colloidal fouling is the attachment of suspended charged solid particles, with size lower than 1 μm. Few works have been presented in the literature to describe the colloidal fouling phenomena in electro-membrane processes. De Jaegher et al. [1] developed a neural network-based model to describe fouling, although a simplified fluid flow description inside the channel was adopted. In this work, a simulative platform for the prediction of colloidal fouling phenomena in electro-membrane-based systems is introduced. A Computational Fluid Dynamics (CFD) model, able to solve flow field and mass transfer inside spacer-filled channels, was coupled with an ad-hoc developed 3-D modelling tool able to quantify colloids deposition rate.

Methodology. A fluid channel bounded by two membranes was the numerical domain. Flow field and mass transfer were solved by the finite volume method implemented in the Ansys®-CFX 23 software. To reduce computational costs, the "unit cell approach" was adopted, thus considering only a periodic portion of the whole channel [2]. Wall shear stresses and salt concentration data were the outcomes of the CFD simulations. Data were used as input for fouling prediction. Specifically, the deposition rate and the migration transport of colloids were computed by an in-house 3D code implemented in the Matlab® software. Salt concentration was used to determine the deposition rate of colloids [1], while wall shear stresses values provided information regarding the probability of attachment of the colloids. The predicted fouling layer was then transported into the CFD model to take the fouling layer growth into account: a pseudo-solid phase was imposed in the regions where fouling was predicted, thus altering the fluid channel geometry and eventually the fluid flow conditions. Simulations (coupled CFD-fouling interactions) ended when the final simulation time was reached. The performance of the developed simulative platform was tested by simulating the same Electrodialysis (ED) unit investigated by Guo et al [3].

Results and discussion. Numerical predictions of the simulative platform were compared to experimental data reported by Guo et al. [3]. The authors investigated the impact of colloidal fouling growth in an ED unit considering current density from 20 to 30 A/m^2 and adopting an anion polyacrylamide (APAM) compound with concentrations up to 300 mg/L to accelerate fouling growth phenomena. Numerical results of the coupled CFD-fouling model were used to estimate ohmic resistance of the ED unit. Numerical data were compared to experimental ones. A very good agreement between numerical and experimental ED unit resistance as function of time was observed. However, due to complex nature of fouling, some discrepancies were observed due to the numerous phenomena occurring in real applications that were not considered by the model. The developed model was also able to provide pressure drops estimation due to fouling layer formation. Model predictions allow a deeper understating of the impact of fouling phenomena on the operating costs and operating parameters of electro-membrane-based units. Therefore, the model represents a useful tool for process control and optimization.

References

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