Dynamic modelling of electrodialysis with bipolar membranes at industrial scale for the sustainable production of chemicals from brines

Giovanni Virruso[1], Calogero Cassaro[1], Andrea Culcasi[1], Andrea Cipollina[1], Alessandro Tamburini[1], Giorgio Micale[1]*

[1] Dipartimento di Ingegneria, Università degli studi di Palermo (UNIPA) – Viale delle Scienze, Ed 6, 90128 Palermo, Italy;

**Corresponding author e-mail: alessandro.tamburini@unipa.it*

Introduction

Valorisation of industrial brines represents a crucial step towards a sustainable society. To this purpose, novel processes are required to recover high-value compounds from these wastes. ElectroDialysis with Bipolar Membranes (EDBM) is an innovative and effective process for the production of acids and bases solutions from salty solutions. The repetitive unit of EDBM is named *triplet* and is composed of three channels (hosting the three different solutions) and three ionic exchange membranes, which are: monopolar anionic, monopolar cationic and bipolar. Several repetitive units are arranged in parallel between two electrodes, forming the EDBM stack. A power supply is adopted to create an electric field leading ions to migrate in opposite directions, depending on their charge, and to promote water dissociation in the bipolar membranes. Protons and salt anions are transported to the acid channel, while hydroxide and salt cations are transferred to the base channel, thus allowing the formation of acid and base.

Recently, the EDBM process has been proposed for the valorisation of brines, produced by desalination plants. These brines contain mainly sodium chloride ions with a concentration about two times higher than the seawater one. The resulting streams of hydrochloric acid and sodium hydroxide, produced by the EDBM, can be beneficially re-used in the desalination plant itself or in downstream units devoted to recovering other valuable minerals. The reliable adoption of such an approach at industrial scale requires a preliminary economic feasibility assessment. To this aim, the present work deals with the development of a phenomenological model able to predict the behaviour of an EDBM unit operated both under transient and steady-state mode (i.e., continuous and discontinuous).

Method

A comprehensive multiscale model with distributed parameters, able to predict also non-stationary conditions, was developed for the simulation of EDBM processes. The model was validated with experimental data purposely collected at pilot plant scale (19.2 m^2 of total membrane area). Industrial scale EDBM units were simulated in different scenarios by varying: (i) the configuration mode (i.e. either Fed & Bleed (continuous) or Closed-loop (discontinuous)), (ii) the chemicals target concentration and (iii) the operating conditions (i.e. flow rate and current density).

Results and discussion

The simulations suggested that Feed & Bleed configuration should be preferred at moderate and high current densities (300-500 A/m^2), whilst Closed-Loop configuration is more appropriate at lower current densities . Moreover, the achievement of high concentration of acid and base (i.e. much higher than 1M) was found to be too energy-demanding. Rather, targeting a lower concentration (c. 1M) results to be an efficient method for producing such chemicals, thus reducing the environmental impact of seawater reverse osmosis brines.

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