Experimental and Numerical Investigation of Feed Pressure Optimization in Photovoltaic-Driven Reverse Osmosis Systems for Green Hydrogen Water Production

Abderrahim Maftouh[1], Omkaltoume El Fatni[2], Ilias Kacimi[3], Tarik Bahaj[3]

[1]Laboratory of Materials, Energy and Environment (LaMEE), Faculty of Science Semlalia, Cadi Ayyad University, UCA, Marrakech, BP 2390, Morocco. Email: a.maftouh@uca.ac.ma

[2]LPHE-Modeling & Simulations, Faculty of Science, Mohammed V University in Rabat, Rabat, Morocco.

[3]Geosciences, Water and Environment Laboratory, Faculty of Science, Mohammed V University in Rabat, Rabat, Morocco.

Abstract:

The growing demand for sustainable freshwater and green hydrogen production has increased interest in energy-efficient desalination technologies powered by renewable energy systems. In this study, a combined experimental and numerical investigation was conducted to evaluate the influence of feed pressure on the performance of a photovoltaic-driven reverse osmosis (RO) pilot plant treating high-salinity groundwater from the Ain El Atti region, Morocco. A FORTRAN-based mathematical model was developed using membrane transport equations derived from the Kedem–Katchalsky framework and validated against pilot-scale experimental data under varying feed pressures ranging from 10 to 20 bar. The model demonstrated strong predictive capability with an average relative error of only 2.687%. Results showed that increasing feed pressure significantly enhanced permeate productivity, increasing permeate flow rate from 187 to 250 L h^{-1}, while improving water recovery from 55% to 63% and salt rejection from 93.7% to 95.0%. Simultaneously, permeate salinity decreased from 330 to 295 mg L^{-1}, confirming improved desalination efficiency. However, higher operating pressures also increased the specific energy consumption from 1.24 to 1.67 kWh m^{-3}, highlighting the trade-off between permeate quality and energy demand. The study further demonstrates the strategic importance of RO desalination as a pre-treatment stage for producing electrolysis-grade water required in proton exchange membrane (PEM) hydrogen systems. The proposed experimental–numerical framework provides an effective tool for optimizing renewable energy-powered desalination systems dedicated to sustainable hydrogen production and decentralized water treatment applications.

Keywords: Reverse osmosis, Feed pressure optimization, Photovoltaic desalination, Green hydrogen production.