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Reverse osmosis (RO) and pressure retarded osmosis (PRO) hybrid processes: Model-based scenario study

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HIGHLIGHTS

- A model-based scenario study assessed the RO–PRO hybrid processes.
- A cost analysis evaluated RO–PRO hybrid systems.
- RO plays a crucial role to determine water and energy production (WERR).
- PRO plant size plays a minor role to determine WERR value.
- The use of RO as PRO draw solution is beneficial to augment power generation.

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ABSTRACT

We conducted a scenario study on a promising RO–PRO hybrid system to alleviate water and energy demands. We utilized a previously validated reverse osmosis (RO) process model and modified a model of a pressure-retarded osmosis (PRO) process to properly consider the spatial distribution of concentration and velocity based on a mass balance principle. Using the models, we compared four different RO–PRO hybrid configurations based on the water and energy return rate (WERR). Subsequently, the comparison of the water production rate and energy production rate confirmed the results that RO plays a dominant role to determine the WERR value. Hybrid systems that use seawater as a feed water for RO are more energy price sensitive. That is, a decrease in the RO plant size considerably diminishes the WERR values; however, the PRO plant size plays a minor role to determine the WERR value. Research and available literature on RO–PRO hybrid processes are in a relatively early stage; this study is a preliminary step to evaluate further advances in hybrid systems that can eventually alleviate water and energy demands.

1. Introduction

Climate change may affect precipitation levels and alter the global hydraulic cycle [1]; subsequently, aggravate regional freshwater accessibility could face drastic changes. Membrane technology, such as reverse osmosis (RO), forward osmosis (FO), and membrane distillation (MD), is widely recognized as a promising potable water-production process due to its ability to desalinate saline water (such as seawater and brackish water), which is the most abundant global water source [2]. Among the membrane processes, RO is one of the most dominant technologies in the seawater desalination and water treatment market since it has the lowest geographical restrictions as well as is a proven, reliable, and established process [3,4]. Relatively high energy consumption (due to pressurizing and environmental pollution by concentrated brine disposal) hinders the further development of RO [5]. Therefore, maximizing the efficiency of RO processes would tremendously alleviate freshwater demands.

Membrane technology can reduce energy demands as well as alleviate water demands. Pressure-retarded osmosis (PRO) has re-emerged as an energy production process that uses the chemical potential difference of two solutions [6]. The theoretical feasibility of electricity generated by mixing fresh and salt water was proposed in the 1950s [7] and the PRO process was suggested in the 1970s [8,9]. However, at the beginning of the PRO process, studies revealed that the PRO membrane was insufficient to produce water to operate a hydro turbine because the porous support substrate of the PRO membrane had a higher internal resistance against the solute transport within its inside and

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