High recovery, energy efficient wastewater desalination using highly permeable and anti-fouling hollow fiber membrane: scaling-up from lab to pilot

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Abstract:

Desalination of brackish water and seawater has been increasingly implemented across the globe to overcome global water scarcity. Among different desalination technologies, reverse osmosis (RO) is most widely used as a space-saving and energy-efficient process. To further improve the energy efficiency of RO, many efforts are devoted to enhancing the membrane performances in recent years, in particularly in terms of higher permeability and anti-fouling coating [3]. Careful process design by thermodynamic analysis is also required to maximize both the energy efficiency and freshwater output.

Here, we show that high permeability and good fouling resistance can save substantial energy and maximize freshwater output for reverse osmosis (RO) desalination of low-salinity wastewater, via both theoretical and experimental demonstrations. First, module-scale modelling revealed that at reasonably low feed salinity, the specific energy consumption (SEC) drops by > 60% when water permeability is increased from 2 to 7 L m^{-2} hr^{-1} bar^{-1}. Optimization of different operating parameters was further performed to maximize the energy efficiency and process capacity, and suitable salt rejection to maintain permeate quality was evaluated. Next, we synthesized zwitterionic copolymers of different molecular weight and fabricated hollow fiber membranes with a pure water permeability of 8.6 L m^{-2} hr^{-1} bar^{-1}, 98.5% rejection to NaCl, and excellent fouling resistance. 85% water recovery, 56% energy saving and 25% reduction of membrane area were demonstrated for treating membrane bioreactor (MBR) filtrate from a local water reclamation plant. 1-inch hollow fiber membranes were fabricated and 3-months long term test were conducted which confirmed the long term stability of the current membranes. Finally, 4-inch hollow fiber membrane modules were successfully fabricated and sent to the local water plant for pilot test. The whole process demonstrates the upscaling and commercialization possibility of the current technology.

Keywords: energy efficient, anti-fouling, highly permeable membrane, upscaling