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Pressure-assisted osmosis (PAO)–RO hybrid: impact of hydraulic pressure on fouling and economics

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ABSTRACT

The use of forward osmosis (FO) is of growing interest for water desalination due to its potential energy savings. However, its industrial implementation is still limited by its current limitation in performance in terms of water permeation and reverse salt diffusion, mainly due to the membrane properties. Pressure-assisted osmosis is a new concept, aiming at pressurising the feed solution to enhance water permeation through synergistic osmotic and hydraulic driving forces that have demonstrated promising results in tackling current limitations of FO.

Keywords: Forward osmosis; Hydraulic pressure; Water desalination; Fouling

One attractive concept for the implementation of forward osmosis (FO), or pressure-assisted osmosis (PAO), is to combine it with desalination by reverse osmosis (RO), whereby an osmotic dilution of the seawater is implemented as a pre-treatment of RO using impaired water as feed. Such a process offers the benefit of combining water reuse while decreasing energy needs of the RO separation step [1–3]. The wastewater composition is expected to impact the process efficiency through potential external concentration polarisation and fouling (organic and inorganic pollutants), which is of key importance for industrial implementation. Primary studies for FO–RO hybrids demonstrated significant energy savings and economic viability [3], while limited fouling was observed due to the absence of hydraulic pressure [4].

The aim of this study is to evaluate the economic viability of a PAO–RO hybrid and to compare it with existing RO and FO–RO reference systems. Therefore, an energetic and economic model has been developed to consider the impact of the pressurisation of the PAO feed on the overall system, considering both operational and investment costs. Additionally, experiments are conducted on fouling behaviour in PAO mode to better evaluate potential fouling as well as anti-fouling strategies to implement and their implication on the system sustainability.

Experimental results confirmed a higher permeation flux in PAO mode than in FO mode even when highly fouling feed waters were used. However, on a

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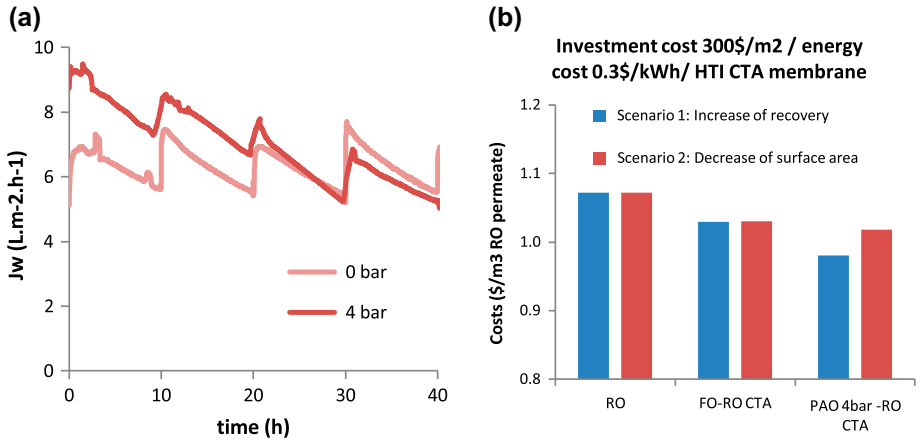

Fig. 1. Impact of PAO implementation using 4 bar hydraulic pressure (a) on long-term fouling and (b) desalination costs.

long-term experiment basis, significant decrease of permeation flux had been observed when 4 bar hydraulic pressure was applied using a pulsation dampener on the feed pump (Fig. 1(a)). It is assumed that the implementation of hydraulic pressure led to more severe fouling in all cases as a consequence of the compaction of the foulant cake on the membrane active layer, affecting the efficiency of the high cross-flow velocity (CFV) cleaning strategy normally efficient in FO [4]. Among the tested anti-fouling strategies for PAO, osmotic backwashing in combination with high CFV water flushing afterwards provided the most promising results, completely removing the foulant cake from the membrane active layer.

Interestingly, the developed model demonstrated that, thanks to the improved permeation flux, higher recovery of the PAO system was observed, leading to better use of the impaired water in term of water recovery. By osmotic dilution, more than 30% energy savings were observed in the RO system due to the lower required feed pressure. These energy savings should be balanced with the additional capital costs of the FO/PAO systems. Finally, despite the additional energy input in the PAO process, the overall hybrid PAO/RO system has proven to decrease the energy demand further than FO/RO hybrids, if the impact of membrane deformation is considered in the model. Alternatively, PAO implementation could be considered as a way to decrease membrane surface area and save capital costs. Both options should be considered depending on local energy or capital costs (Fig. 1(b)).

As a conclusion, more severe fouling is observed in PAO mode than in FO mode, but it is expected that this will not significantly affect its economic viability, since simple and adaptive anti-fouling strategies have successfully been implemented to recover initial performance.

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