Environmental and economic assessment of fertilizer drawn forward osmosis and nanofiltration hybrid system for desalination of mine impaired water for irrigation

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1. Background

As a driest continent on the earth, drought and water scarcity is a major issue in Australia. Like most parts of world, agriculture sector uses up to 60-70% of the total fresh water consumption in Australia. Coal mining is a globally significant industry in Australia and most coal mining activities involve massive volumes of produced water. With appropriate treatment, mine impaired water could be valuable source of irrigation water for growing food rather than simply dispose to the environment after treatment. Most produced water are however associated with high salinity, generally not fit for irrigation until salinity is lowered. Lately, forward osmosis (FO) process is seen as innovative low-energy technology for various applications including desalination for irrigation purpose [1]. One of the most promising applications of the FO process with potentially lower additional energy consumption is the fertilizer drawn FO (FDFO) process using fertilisers as DS in which the diluted DS containing fertiliser nutrients can be used as non-potable water for irrigation of crops [2, 3]. Recently a pilot-scale FDFO-NF desalination system with a capacity of 1000 - 4000 L/day was operated and tested at Centennial Coal Mine site at Newtan Colliary, Fassifern, New South Wales for the desalination of saline water [4]. Based on about six months pilot-scale operation in the field, it was observed that the FDFO-NF hybrid system could be a robust desalination technology in producing nutrient rich water for irrigation with the potential to support farming industry around the coal mining area.

FDFO-NF hybrid desalination technology is a relatively new technology and hence, the economic and environmental life cycle assessment (LCA) of the technology needs to be conducted for the FDFO-NF system to investigate not only the hot-spots of improving the whole process operation but also to understand the sustainability and economic viability of this new technology for commercial applications. In this study, we conducted an environmental impact assessment of the FDFO-NF hybrid system and compared with the two different conventional reverse osmosis (RO) hybrid scenarios for the desalination of mine impaired saline groundwater. The environmental impact assessment also aims to identify the major hot-spots that are responsible for the economic and environmental impacts including chemical consumptions for membrane cleaning, materials consumed for membrane replacement and energy consumption during process operation.

2. Methodology

A standard LCA was considered which generally consists of 4 stages; goal and scope definitions, life cycle inventory analysis (LCI), life cycle impact assessment, and interpretation. The three different hybrid desalination processes chosen for this goal includes MF-RO hybrid system for scenario A and UF-RO hybrid system for scenario B which was

then compared to the hybrid FDFO-NF process for scenario C. To aggregate primary data for each scenario, the inventory analysis has been carried out using the Ecoinvent LCA database version 3.0 and the Australian LCA database in the software Simapro version 8.0 [5-7] with several common considerations for economic and environmental life cycle assessment of the three scenarios. Life-cycle impact assessment (LCIA) stage of LCA was performed based on the six Australian relevant impact assessment categories Australian indicator set v.3.01 [6, 8]. An economic assessment in this study considered annual operational expenditure (OPEX) that includes three cost components: electricity (energy) cost, membrane replacement cost, and cost of chemicals for membrane cleaning. The FO OPEX data such as FO membrane module cost were based on membrane manufacturers data while for NF, the existing OPEX data from the RO and NF were adapted from the published literatures.

3. Findings from the study

The following are some of the brief findings from this study:

- Environmental LCA results showed that the overall environmental impact of both energy consumption and cleaning chemical usage is lower for FDFO-NF hybrid system using thin film composite FO membrane while that of membrane requirement is higher for FDFO-NF hybrid system (using cellulose triacetate FO membrane) compared to conventional MF-RO and UF-RO hybrid systems.
- The sensitivity analysis of the FDFO process under different considerations such as average FO water flux and NF feed concentration showed that a minimum average FO flux of 6 $Lm^{-2}h^{-1}$ is required to compete with conventional desalination processes (MF-RO and UF-RO).
- If the dilution of fertilizer draw solution by the FO process is economically achieved osmotic equilibrium, potential exists for energy savings in the NF process by nearly 50% thus resulting in the reduction the OPEX costs in the FDFO-NF hybrid system.
- However, in order to better understand the performances of a commercial level full-scale FDFO-NF hybrid system, more comprehensive and detailed analysis is important through rigorous simulation studies or confirm through design and operation of a full-scale FDFO-NF hybrid system especially to assess the practicality of achieving osmotic equilibrium within the practical module settings.

References

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