Application of ceramic membranes for seawater reverse osmosis (SWRO) pre-treatment

J.Z. Hamada,*, C. Ha, M.D. Kennedy, G.L. Amy

a King Abdullah University of Science and Technology (KAUST), Saudi Arabia
b UNESCO-IHE, Institute for Water Education, West vest 7, AX Delft 2611, The Netherlands

ABSTRACT

Low-pressure (microfiltration/ultrafiltration (MF/UF)) membranes are being increasingly used as pre-treatment, prior to seawater reverse osmosis (SWRO). The objective of pre-treatment before reverse osmosis (RO) membranes is to remove undesirable and particulate fouling materials (algae, suspended and colloidal particles). Also, a pre-treatment barrier reduces organics and provides better feed water quality for RO membranes. MF and UF pre-treatment prior to SWRO provides Low Silt Density Index (SDI) values recommended for RO operation. Ceramic membranes are more attractive as they made of more chemically resistant materials, which allow for more stable operation and aggressive backwashing (BW) and cleaning.

A pilot plant with a monolith ceramic MF membrane (0.1 μm pore size) from METAWATER was used to carry out the study. Red Sea water pumped from a distance of 700 m offshore from Thuwal (Kingdom of Saudi Arabia) was used as feed water. The pilot plant was operated automatically at constant flux of 150 LMH that involved BW, air flushing and forward flushing at the end of filtration cycle. Seawater permeates were used for hydraulic BW, while sodium hypochlorite, citric acid and sodium hydroxide were used for chemical cleaning (CIP) to restore the membrane permeability after use. Filtration cycles of 2.5 h were adopted for initial experiments. Aggressive BW flux of 1,800 LMH for 15 s, air flushing of 4 bars for 10 s and forward flushing of 300 LMH for 40 s were applied for regular membrane hydraulic cleaning. The increase of membrane resistances over time was monitored. Further studies were also performed by using Anopore ceramic membranes AAO100 (pore sizes of 0.1 μm) using a constant pressure bench-scale set-up. The feed water and permeate were analysed using an SDI unit, flow cytometre (FCM) and liquid chromatography with organic carbon detection (LC–OCD).

The results showed that ceramic membrane filtration reduced the SDI15 of seawater from 6.1 to 2.1 which conform to the requirement of SDI<3 needed for SWRO feed. The removal of bacteria corresponded to 3.7 log removal, while turbidity improved from 0.6 NTU (feed) to 0.05 NTU (permeate). However, ceramic membranes showed low recovery after BW and significant increase of trans-membrane pressure (TMP) during operation with the membrane.

*Corresponding author.

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alone, without coagulation. This increase of TMP can be related to the presence of sticky polysaccharide-like material called transparent exopolymers particles (TEP) that are known to be in abundance in seawater and contribute to organic fouling and eventually bio fouling. TEP showed resistance and stickiness on the membrane surface (AAO100) even after aggressive BW. This may be responsible for the low flux recovery observed after BW in both bench-scale and pilot experiments.

To improve membrane filtration, coagulation was performed by using iron III chloride. Continuous addition of iron III chloride (4 mg/L Fe) through inline coagulation showed almost complete control of irreversible fouling and reduces reversible fouling after 30 h of operation, based on 2.5 h intervals of filtration cycle. Also, biopolymers removal improved to 51–71%, with improved removal at low pH, while for stabilization of flux, a dose of 1 mg/L Fe$^{3+}$ was sufficient. Reduction of high molecular weight Natural organic matters (NOM) is essential for controlling or reducing irreversible fouling. Therefore, coagulation is recommended for smooth operation of ceramic membranes and for provision of low-fouling feed water, prior to SWRO membranes.

**Keywords:** Ceramic membranes; Membrane resistance; Silt Density Index (SDI); Fouling and flux recovery