World Academy of Science, Engineering and Technology
International Journal of Chemical and Materials Engineering
Vol:10, No:06, 2016

A Novel Nanocomposite Membrane Designed for the Treatment of Oil/Gas Produced Water

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Abstract : The onshore production of oil and gas (for example, shale gas) generates large quantities of wastewater, referred to be 'produced water', which contains high contents of oils and salts. The direct discharge of produced water, if not appropriately treated, can be toxic to the environment and human health. Membrane filtration has been deemed as an environmental-friendly and cost-effective technology for treating oily wastewater. However, conventional polymeric membranes have their drawbacks of either low salt rejection rate or high membrane fouling tendency when treating oily wastewater. Recent years, forward osmosis (FO) membrane filtration has emerged as a promising technology with its unique advantages of low operation pressure and less membrane fouling tendency. However, until now there is still no report about FO membranes specially designed and fabricated for treating the oily and salty produced water. In this study, a novel nanocomposite FO membrane was developed specially for treating oil- and salt-polluted produced water. By leveraging the recent advance of nanomaterials and nanotechnology, this nanocomposite FO membrane was designed to be made of double layers: an underwater oleophobic selective layer on top of a nanomaterial infused polymeric support layer. Wherein, graphene oxide (GO) nanosheets were selected to add into the polymeric support layer because adding GO nanosheets can optimize the pore structures of the support layer, thus potentially leading to high water flux for FO membranes. In addition, polyvinyl alcohol (PVA) hydrogel was selected as the selective layer because hydrated and chemically-crosslinked PVA hydrogel is capable of simultaneously rejecting oil and salt. After nanocomposite FO membranes were fabricated, the membrane structures were systematically characterized with the instruments of TEM, FESEM, XRD, ATR-FTIR, surface zeta-potential and Contact angles (CA). The membrane performances for treating produced waters were tested with the instruments of TOC, COD and Ion chromatography. The working mechanism of this new membrane was also analyzed. Very promising experimental results have been obtained. The incorporation of GO nanosheets can reduce internal concentration polarization (ICP) effect in the polymeric support layer. The structural parameter (S value) of the new FO membrane is reduced by 23% from 265 ± 31 μm to 205 ± 23 μm. The membrane tortuosity (τ value) is decreased by 20% from 2.55 ± 0.19 to 2.02 ± 0.13 μm, which contributes to the decrease of S value. Moreover, the highly-hydrophilic and chemically-cross-linked hydrogel selective layer present high antifouling property under saline oil/water emulsions. Compared with commercial FO membrane, this new FO membrane possesses three times higher water flux, higher removal efficiencies for oil (>99.9%) and salts (>99.7% for multivalent ions), and significantly lower membrane fouling tendency (<10%). To our knowledge, this is the first report of a nanocomposite FO membrane with the combined merits of high salt rejection, high oil repellency and high water flux for treating onshore oil/gas produced waters. Due to its outstanding performance and ease of fabrication, this novel nanocomposite FO membrane possesses great application potential in wastewater treatment industry.

Keywords : nanocomposite, membrane, polymer, graphene oxide
Conference Title : ICNME 2016 : International Conference on Nano and Materials Engineering
Conference Location : San Francisco, United States
Conference Dates : June 09-10, 2016