Method and System for Purifying Produced Water

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Summary

In the United States, for every barrel of oil, approximately seven barrels of water are produced. Produced water consists of various amounts of organic and inorganic constituents from the source geologic formation and associated hydrocarbons. Produced water handling has become a major effort for all waterflood operations. The overall objective of this innovation is to develop and demonstrate the performance and cost-effectiveness of a portable two-Stage, antifouling hollow fiber membrane (TS-af-HFM) nanofiltration process to convert produced water into a clean water product for a reused fluid or direct discharge.

Super hydrophobic PVDF/Si-R hybrid HFM was first prepared for organics removal from produced water. The organics removal efficiency of the PVDF/Si-R membrane was three times higher than that of the neat PVDF membrane. The organics removal of hybrid membranes increased with the increase of operating pressure; however, it decreased with the increase in feed rate, and was not influenced by temperature in the range of 0-80°C. With membrane collecting velocity of 424 cm/min, the PVDF/Si-R membrane exhibited organics removal of 94.5% and 96.7% for benzene and octanoic acid, with membrane adsorption capacities of 208.1 mg/g and 173.9 mg/g. respectively. The hybrid membrane also showed high regeneration ability.

Then, PES/SiO_2 based thin film composite (TFC) hollow fiber membrane (HFM) was prepared for the desalination with low-pressure nanofiltration process. The effects of operating parameters including pressure, salt concentration and time, on the salt rejection were investigated. The results showed that the salt rejection increased linearly with an increase in operating pressure from 50 psi to 80 psi, decreasing slightly with a further increase in pressure to 100 psi. The increased salt concentration resulted in a decrease in salt rejection.

A novel TS-af-HFM system was established with the super hydrophobic PVDF/Si-R HFM and the super hydrophilic PES/SiO_2 based TFC HFM for oilfield produced water remediation. The effects of operating parameters on the performances of the TS-af-HFM system were investigated. The PVDF/Si-R membrane can effectively remove dissolved organics from the produced water in the first stage, with the organics rejection efficiency up to 98.7%. The PES/SiO_2 TFC membrane showed good desalination ability in the second stage, with the salt rejection efficiency of 64.1%, 71.8% and 73% for NaCl, $MgCl_2$ and $CaCl_2$, respectively. The effective removal of dissolved organics in the first stage effectively eliminated the organics fouling occurred during the desalination process in the second stage. The variation of feed rate (0.05-0.2ml/min) and operating pressure (0-30 psi) in the first stage has no significant effect on the performances of the TS-af-HFM system. With the increase of operating pressure from 50 psi to 80 psi in the second stage, the permeate water flux and salt rejection efficiency linearly increased. The system showed attractive regeneration ability and exhibited high potential for the oil-field produced water treatment.

Large amounts of PVDF/Si-R HFMs and PES/SiO_2 HFMs were fabricated to assemble the pilot-scale hollow fiber membrane modules for the installation of the TS-af-HFM nanofiltration system. The system was installed and tested in a production facility located at Carlsbad, New Mexico. Clean water flux and water recovery was proportional to the feed rate. The optimal feed rate for a single hollow fiber membrane module was in the range between 10.96 bbl/day to 12.95 bbl/day, with the clean water recovery around 60%. The TS-af-HFM system exhibited a good antifouling ability during a continuous filtration process. A comprehensive cost analysis reveals that the TS-af-HFM system can help generate $61,468 of capitals compared to without the system.