Development of Advanced Membranes for Produced Water Treatment

Daniel Wandera, Scott M. Husson
CHEMICAL & BIOMOLECULAR ENGR.
CLEMSON UNIVERSITY
Ranil Wickramasinghe
CHEMICAL ENGR.
UNIVERSITY OF ARKANSAS

Introduction

• Produced water (PW) is oily water co-produced during oil and gas exploration and production**.**

• Contains dispersed oils and suspended solids.

• Estimated 21 billion barrels of PW generated from active oil and gas wells in the US in 2007.

• Normally, PW is re-injected in geologically isolated wells or is surface discharged with adverse environmental effects.

• Membrane filtration is an option but is affected negatively by fouling and concentration polarization.

Objectives

• Graft poly(N-isopropylacrylamide)-*block*-poly(oligoethylene glycol methacrylate) by surface-initiated atom transfer radical polymerization (ATRP) from ultrafiltration membranes to limit foulant accumulation and provide an easy, chemical-free way to remove any attached foulants.

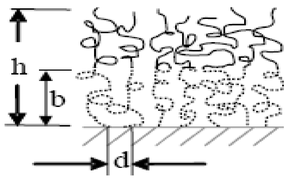
• Characterize the physiochemical and performance properties of modified membranes.

Experimental Methods

Surface-initiated ATRP

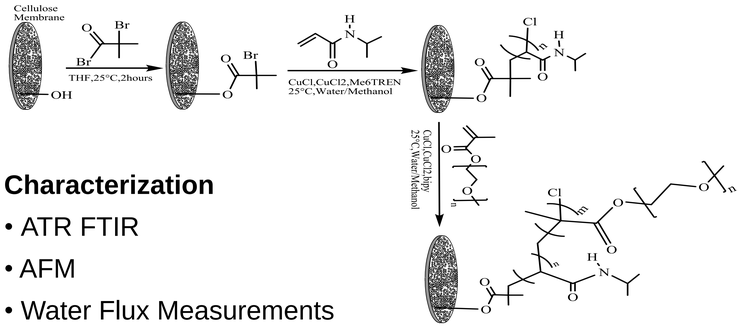
• Potential for independent control over grafting density and chain length at low polydispersity.

• Straightforward to graft block copolymers.



Membrane Modification

Regenerated Cellulose (RC) membranes



Characterization

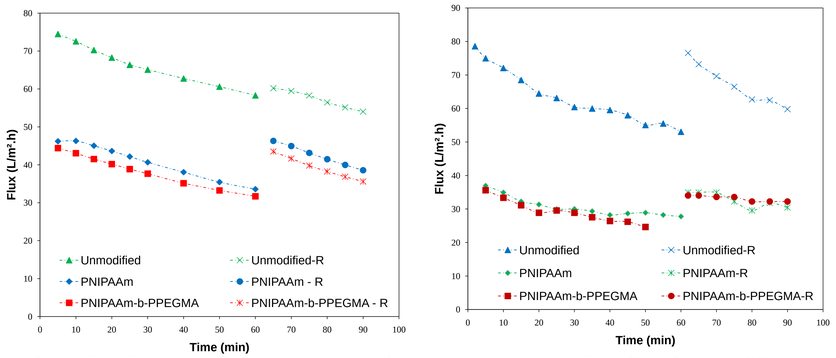
• ATR FTIR

• AFM

• Water Flux Measurements

Results and Discussion

Water Flux Measurements



Direct-flow filtration with model synthetic PW (Left) and actual oilfield PW (Right) at 30 psi.

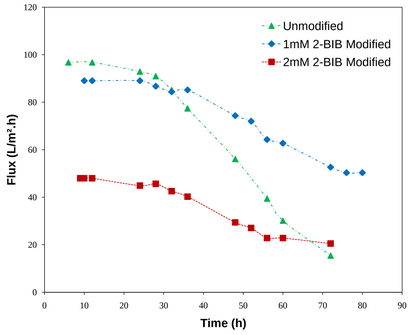
Characteristics of model synthetic produced water

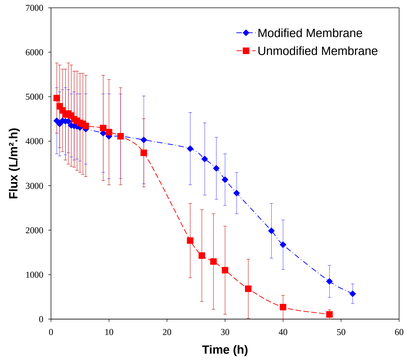
Parameter	Value
Dispersed oil	5000 mg/L
Conductivity	1108 µs/cm
Total Dissolved Solids (TDS)	543 mg/L
Total Organic Carbon (TOC)	82.23 mg/L

Permeate Quality Specifications for 5 kDa membranes

Membrane	Conductivity (µS/cm)	TDS (mg/L)	TOC (mg/L)	TOC Removal (%)
Unmodified	1038	508	4.91	94.02
PNIPAAm	1024	502	3.30	95.99
PNIPAAm-*b*-PPEGMA	1021	500	2.02	97.54

Model PW (A), Unmodified 5 kDa membrane permeate (B) and Modified 5 kDa membrane permeate (C).

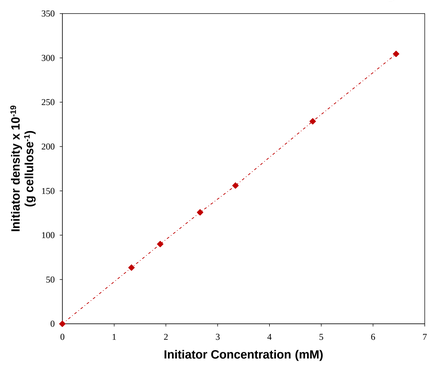




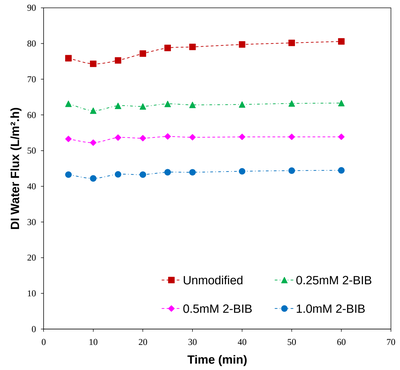
Cross-flow filtration results for 1000 kDa unmodified and modified membranes using model PW at 60 psi and 50 C (Top)

Cross-flow filtration results for 5 kDa unmodified and modified membranes using model PW at 40 psi and 50 C (Left).

Variation of Initiator Density

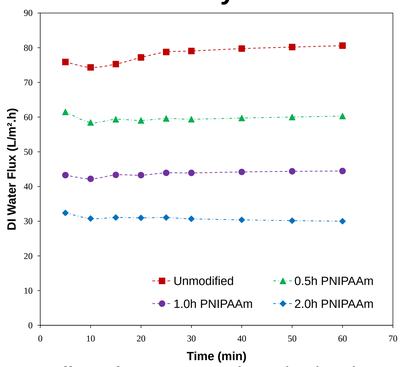


Systematically varied initiator density by changing initiator (2-BIB) conc.

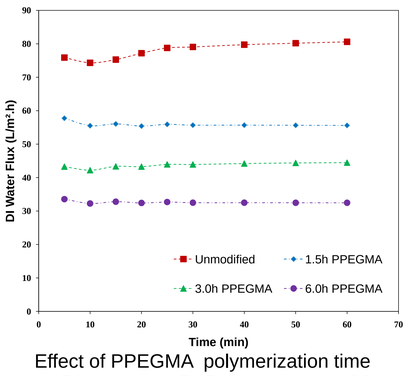


Effect of varying initiator density on DI water flux, 5 kDa membranes, 30 psi. Higher Initiator density leads to lower flux.

Variation of Polymerization Time



Effect of PNIPAAm polymerization time on DI water flux, 5 kDa membranes, 30 psi. Longer time leads to lower flux.



Effect of PPEGMA polymerization time on DI water flux, 5 kDa membranes, 30 psi. Longer time leads to lower flux.

Conclusions

• Developed membranes for PW treatment with good anti-fouling properties that can be cleaned well by water rinse

• Poor salt rejection but excellent TOC removal in all membranes

• General decline in flux post modification; flux recovery better for modified membranes

• Modified membranes allow higher cumulative volumes of water to be processed over time prior to cleaning

• Initiator density and polymerization time impact water flux, so can be used to tune membrane performance

Current Work

• Developing an effective self-cleaning protocol

Acknowledgements: *This work was supported by the National Science Foundation (CBET 0651646). Thanks to Heath Himstedt, Colorado State University.*

Reference: *D. Wandera et al., J. Membr. Sci. 373 (2011) 178–188*