Assessment of Performance Recently Developed Acriflavine Thin Film Composite Nanofiltration Membrane for Seawater Treatment and RO Brine Concentration

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Seawater covers over 75% of the Earth’s surface.

As global population grows to over 6 billion by 2050, the ultimate source of sustainable potable water is DESALINATION.
Introduction

The membrane can be described as “interphase between two adjacent phases acting as a selective barrier, regulating the transport of substances between the two compartments.”

The driving force:
- Pressure gradient $\Delta P$
- Concentration gradient $\Delta C$
- Electrical potential gradient $\Delta E$, or a temperature gradient $\Delta T$. 
Application of Membrane Technology

- **Life**: Purifying water, Manufacturing salt from sea water
- **Environment**: Sewage disposal, Re-use by removal of unnecessary material
- **Factory**: Gas separation, Semiconductor, Electronic paint coating
- **Energy**: Fuel cell, Nuclear power plant, Hydrogenous production
- **Foods**: Dairy product, Protein elimination from honey, Condensed fruit juice
- **Health**: Artificial dialysis, Artificial muscle, Artificial lungs, Medical water

Diagram showing the applications of membrane technology in various sectors.
Types of membranes

- Reverse Osmosis:
  - Desalination of seawater
  - Hemodialysis
  - H₂O, Ions, Serum Albumin

- Nano-Filtration:
  - Water purification
  - Colloidal silica, Viruses

- Ultra-Filtration:
  - Wine

- Micro-Filtration:
  - E. coli, Bacteria

Small molecular ions: 10⁻¹⁰ to 10⁻⁹
Colloids: 10⁻⁸ to 10⁻⁷
Small particles: 10⁻⁶ to 10⁻⁵
Size of substances to be filtered out [m]
Good membrane material and characteristic

- Polysulfone (Psf)
- Cellulose Acetate (CA)
- Poly(acrylonitrile) (PAN)
- Poly(vinylidene difluoride) (PVDF)

- **Film forming** nature.
- **Mechanical strength** to overcome high pressure during performance.
- **Thermal stability** i.e. Glass transition temperature (tg) of the polymer should be higher than the process temperature.
- **Chemical stability** i.e. Resistance of the polymer at extreme pH values and other chemical conditions.
- **Hydrophilicity-hydrophobicity balance** in order to achieve better flux, low fouling.
Membrane Fouling

Fouling may be due to
- adsorption
- pore-blocking
- concentration polarization
Assessment of Performance Recently Developed Acriflavine Thin Film Composite Nanofiltration Membrane for Seawater Treatment and RO Brine Concentration
The chemical reaction of acriflavine and Trimesoyl chloride

TEA: Triethylamine
The reaction mechanism of interfacial polymerization of acriflavine and trimesoyl chloride monomer.
Characterization

FT-IR spectra of acriflavine, PSf, TFC, and TiO₂TFC

¹H NMR spectra of acriflavine and TFC Polymer
Preparation of PSf Substrate and Acriflavine Thin Film Composite (TFC) Membranes

Substrate membrane was prepared by Immersion precipitation method.

- Preparation of Acriflavine Thin Film Composite (TFC) Membranes

- 2 Wt % of acriflavine was dissolved in DI water and added 1.1 eq of triethyl amine (TEA),
- 0.01, 0.05 and 0.1 Wt% of TiO2 nanoparticles were dispersed in acriflavine aqueous solution,
- 0.1 Wt% of Trimesoyl chloride (TMC) was dissolved in hexane,
- nanoparticle-dispersed acriflavine solution was poured and kept for two min to penetrate solution to pores of the substrate,
- The excess solution was drained off,
- 0.1 % Wt% TMC solution in hexane was added and kept for one min to interfacial polymerization, then TMC solution was drained off,
- The unreacted TMC was removed by hexane washing and kept inside the oven at 60 ℃ for 10 min to complete polymerization.

<table>
<thead>
<tr>
<th>SL No</th>
<th>Code</th>
<th>Acriflavine Wt%</th>
<th>Trimesoyl chloride Wt%</th>
<th>TiO2 Wt%</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>TFC1</td>
<td>2</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>TFC2</td>
<td>2</td>
<td>0.1</td>
<td>0.01</td>
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<tr>
<td>3</td>
<td>TFC3</td>
<td>2</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>TFC4</td>
<td>2</td>
<td>0.1</td>
<td>0.1</td>
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</tbody>
</table>
Characterization

The magnified surface, cross-sectional FESEM images of TFC 4
The three-dimensional AFM images of; a) TFC 1, b) TFC 2, TFC 3 and c) TFC 4
Nano filtration performance study

The pure water flux of the membranes at 0.9 MPa pressure

The water flux of the TFC 4 membrane at 0.9 MPa pressure for AGS and RO brine feed
## Nano filtration performance study

Physicochemical parameters of permeate water and reject from the desalination of AGS and RO brine

<table>
<thead>
<tr>
<th>Parameters / Unit</th>
<th>AGS Acridine TFC membrane Permeate</th>
<th>AGS Acridine TFC membrane Reject</th>
<th>RO brine Acridine TFC membrane Permeate</th>
<th>RO brine Acridine TFC membrane Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity (mS/cm)</td>
<td>0.027</td>
<td>62.856</td>
<td>0.071</td>
<td>85.11</td>
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<tr>
<td>Magnesium, mg/L</td>
<td>3.8</td>
<td>2.039</td>
<td>197</td>
<td>3.013</td>
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<td>Calcium, mg/L</td>
<td>6.0</td>
<td>1.006</td>
<td>407.2</td>
<td>1,507</td>
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<td>Sodium, mg/L</td>
<td>12,051</td>
<td>13,316</td>
<td>12,051</td>
<td>30,520</td>
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<tr>
<td>Potassium, mg/L</td>
<td>100</td>
<td>340</td>
<td>688</td>
<td>1,223</td>
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<tr>
<td>Chloride, mg/L</td>
<td>20,230</td>
<td>26,086</td>
<td>41,176</td>
<td>68,603</td>
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<tr>
<td>Sulfate, mg/L</td>
<td>3.9</td>
<td>6,433</td>
<td>6.84</td>
<td>21,704</td>
</tr>
</tbody>
</table>

### Percentage salt rejection

![Percentage salt rejection graph](image)
Conclusions

- The TiO$_2$ nanoparticle incorporated acriflavine TFC membranes were fabricated on PSf support by IP method,
- The TFC membranes were characterized using FT-IR, NMR, AFM, and FESEM,
- The addition of TiO$_2$ nanoparticle in acriflavine TFC active layer improved the morphology of the membrane and contact angle,
- The membrane with 0.1 wt% TiO$_2$ nanoparticle content achieved water flux of 67.1 LMH against deionized water, and 53 LMH and 44.5 LMH against Arabian Gulf Seawater and Reverse Osmosis brine respectively,
- The acriflavine TFC membranes showed excellent antifouling characteristics and rejection > 99% for magnesium (Mg$^{2+}$), calcium (Ca$^{2+}$), and sulfate (SO$_4^{2-}$) ions,
- The study concluded that TiO$_2$ nanoparticle incorporated acriflavine TFC membranes are having the high capability of rejecting divalent ions and suitable for desalination pre-treatment and RO brine concentration applications.
Thank you