



Membrane Filtration

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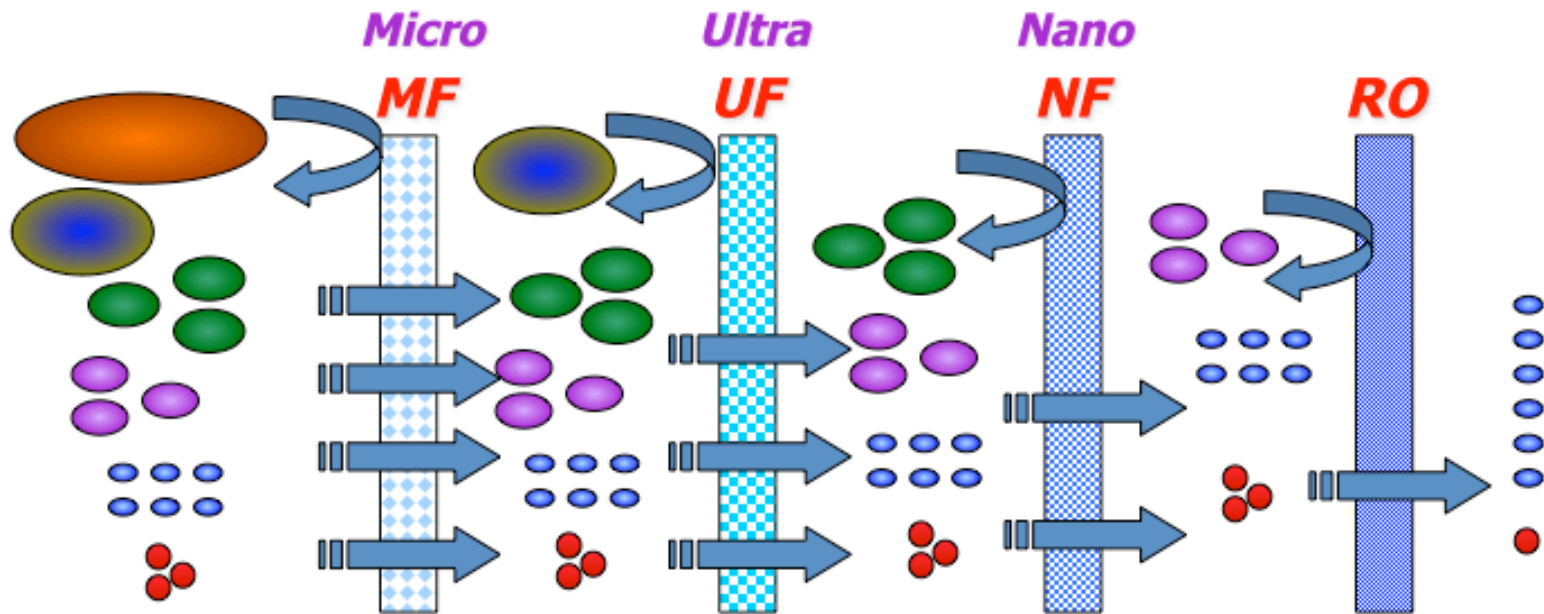
Membrane Types

- Pressure driven membrane processes
 - Low-pressure membranes
 - Microfiltration (MF) and ultrafiltration (UF)
 - High-pressure membranes
 - Reverse osmosis (RO) and nanofiltration (NF)
- Current driven membrane processes
 - Electrodialysis (ED) and electrodialysis reversal (EDR)

Pressure Driven Membranes

Low-pressure Membranes

High-pressure Membranes



 **Suspended Solids (Particles)**

 **Macromolecules (Humics)**

 **Multivalent Ions (Hardness)**

 **Monovalent Ions (Na⁺, Cl⁻)**

 **Water Molecules**

 **Low Molecular Weight Organics**

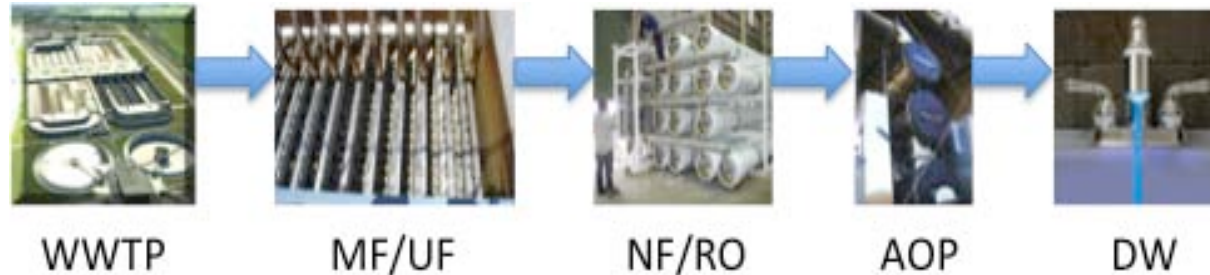
Membranes Available for Waste Recycling

- Water with moderate solids (up to 5%), high COD/BOD and high TOC
 - Ceramic MF and UF membranes
 - Certain polymeric MF membrane systems
- Low solids, high TOC
 - Polymeric MF and UF
- Water with variable salinity and moderate TOC
 - Low-pressure reverse osmosis
 - Nanofiltration



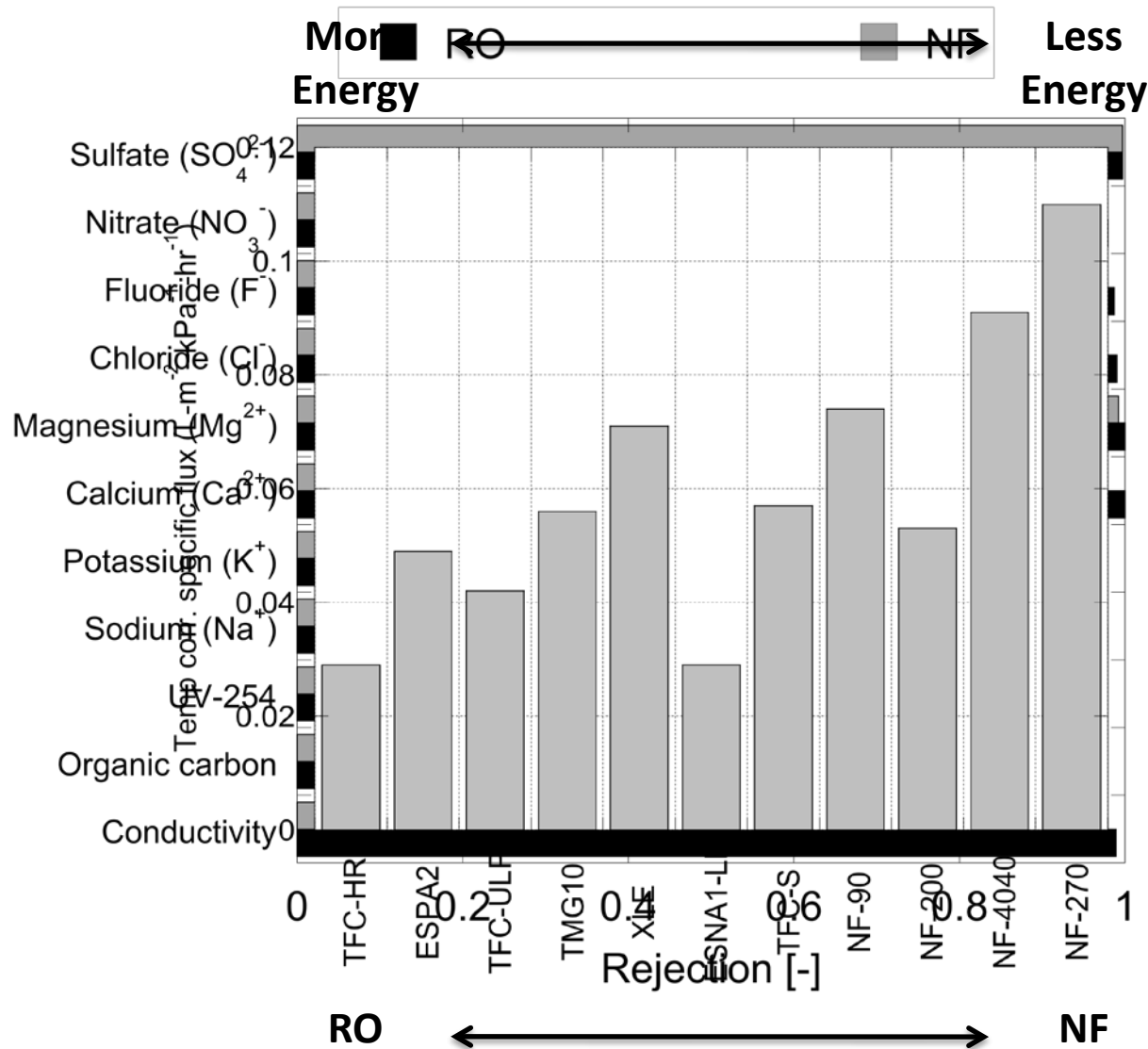
Past and Current Research

- Past research focus has been on municipal wastewater reuse using membrane technology:



- Current research includes use of membranes for separation of components in waste streams
- Membrane bioreactors
- Optimization of membrane systems:
 - Reducing energy consumption
 - Mitigating fouling
 - Modeling membrane separations

Comparing RO to NF



Example Application

- Paper manufacturer using surface (river) water for process water:
 - Low total dissolved solids concentration and conductivity
 - Moderate TOC with relatively high color (tannins)

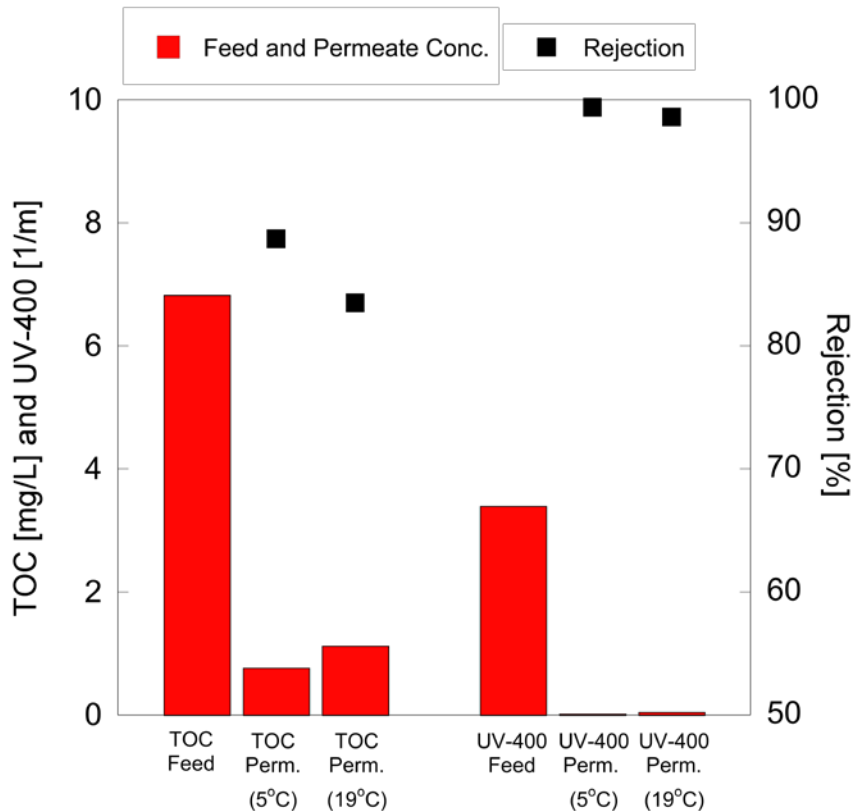
Parameters	Units	Average	Average deviation
pH	-	7.40	0.09
Conductivity	us/cm	81.49	1.93
TOC	mg/l	6.83	0.082
UV-400 ¹	1/m	3.4	0.267

¹UV-400 is UV absorbance at 400 nm wavelength and is a surrogate for color

- Interested in RO for color removal but evaluated NF (NF270, Dow/Filmtec) because conductivity removal not an issue

NF for Color Removal

- Evaluated TOC and color removal by NF:
 1. Effect of temperature (5 and 19°C)
 2. Membrane fouling propensity (operation for 30 hours)



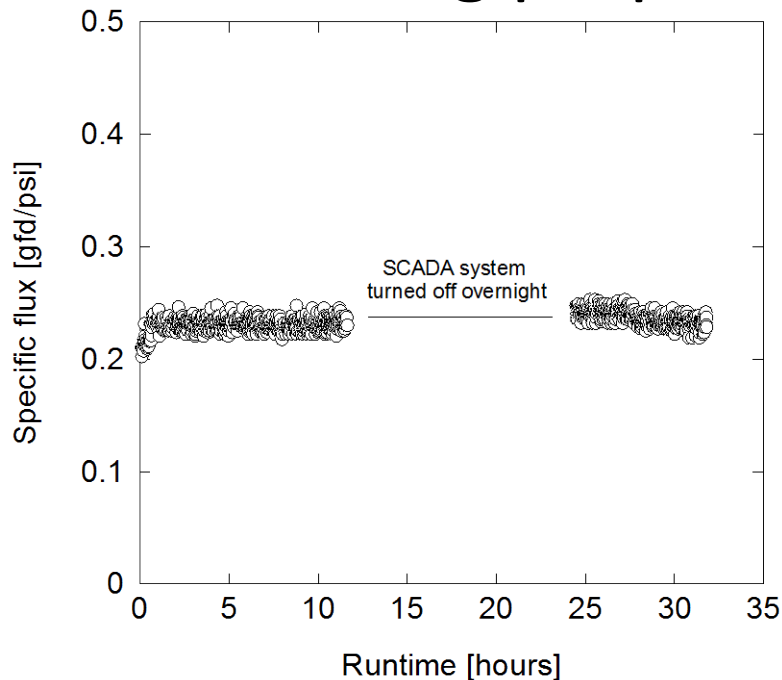
NF for Color Removal

- Relatively low-pressure requirements:

	Average Temp (°C) ¹	Average permeate flux (GFD) ²	Average Pressure (psi)	Specific flux (GFD/psi)
Cold Water Experiment	5.88	12.15	84.67	0.14
Warm Water Experiment	18.87	12.08	56.30	0.21

¹Three separate experiments were conducted for each water temperature, ²The desired permeate flux set-point was 12 gfd

- Low fouling propensity:



NF for Color Removal

- Conclusions
 - NF is a viable alternative to RO for certain applications
 - Low pressure and energy requirements compared to RO
 - Good organic compound removal
 - Preferential removal of divalent ions over monovalent ions
 - Proper membrane selection important
 - Selection of low fouling membranes or measures to mitigate fouling
 - Selection of proper membrane and operating conditions to achieve desired separation performance

Clarkson Research Group

- Past and Current Research:
 - Modeling and optimizing membrane separations
 - Evaluating membrane fouling and filterability
 - Testing novel membrane systems
- Capabilities
 - Bench- and laboratory-scale membrane testing systems
 - Wide range of analytical capabilities
 - Metal analysis (ICP, AAS)
 - Organic analysis (GC-ECD, GC-FID, GC-MS/MS, etc.)
 - Surface analysis (SEM microscopy, XRD analysis)



Thank You

Feel free to contact me:

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