Membrane Technologies for Water Treatment

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• Some History
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  – Tubular membranes
• Classifications
  – Microfiltration
  – Ultrafiltration
  – Nanofiltration
  – Reverse Osmosis
• Configurations
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  – Spiral wound
  – Hollow fine fiber
• Test Configurations
• Lake Arrowhead Demonstration Project
• Applications
Loeb-Sourirajan invented the Cellulose-Acetate membrane at UCLA in early 1960’s. With UCLA they had the original patent, but it was never licensed due to its poor writing.

Originally used in a plate and frame apparatus.

Discovered accidentally that it was asymmetric.
- One-half of the time, their experiments worked, one-half of the time they failed.
- Only after analysis did they learn to orient the membrane correctly.

Later produced a tubular membrane that was commercially viable, and used in some small production facilities and several pilot plants.
Classifications

- Microfiltration – cutoff 0.15 to 50 μm, ~ 200 kPa operation
- Ultrafiltration – 0.003 to 0.2 μm, > 3000 mw ~ 700 kPa
- Nanofiltration – 0.001 to 0.003 μm, 200–10,000 MW, ~ 700 kPa
- Reverse osmosis – 0.0005 μm, < 200 MW, ~3000 kPa for reclamation, ~ 10,000 kPa for seawater
Sharper Cutoff Allows More Control

Coagulated, granular filter

Membrane microfilter

95% rejection of 1.5 um particles
Tubular Membranes

- Rarely used today due to low packing density
- Applications for special recovery, such as concentrating oil/water mixtures
- Applicable when intense fouling occurs
- Approach used for ceramic membranes in membrane bioreactors
- Full-scale applications in the 1960s for reducing TDS of groundwater in remote San Joaquin Valley towns
Tubular Schematic Diagram

Water Flow

3 m

2.5 cm

Connector

O-ring seal
Tubular Membranes at Las Gallinas
End Connections and Product Recovery

Product Water
Membrane End Connection

Connection nut
Tube End
CA membrane
Ceramic Membranes
Spiral Wound Membranes

- High packing density
- Standard holders and configurations
- Many membrane alternatives (CA, thin-film composite, PA, etc.)
- RO, Nano and Ultra membranes available
- Some manufacturers make micro filters in spiral wound configurations
- Most common configuration in use today
Spiral Wound Configurations

- Outer wrap
- Alternating layers of spacers, membranes, and permeate collectors
- Perforated central tube
- Concentrate
- Permeate
- Feed Water
Spiral wound cutouts
Commercial Installation, West Basin in Calif.
End Configuration
Hollow Fine Fiber

- Highest packing density
- Fewer membrane alternatives
- Requires high quality feed water
- Rarely found in water reclamation
- Exception - configuration used for the most successful micro filter, as of today.
Hollow Fine Fibers
(Memcor Microfilter)
Pilot and Test Apparatus

• Pilot studies usually performed before full scale plants are constructed
• Small test cells used for initial work, theoretical studies and membrane development
• Larger cells and pilot plants using a small number of full scale membranes often used for process evaluation
Multipurpose Test Apparatus

Plate and Frame

2.5 cm household units, serving as test cells
Lake Arrowhead Pilot Plant
## Some Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sec. Effl.</th>
<th>Product</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>pH</td>
<td>7.5 ± 0.4</td>
<td>6.3 ± 0.3</td>
<td>-</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>78 ± 16</td>
<td>7.0 ± 3.0</td>
<td>mg/L</td>
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<tr>
<td>Hardness</td>
<td>90 ± 13</td>
<td>5.0 ± 2.0</td>
<td>mg/L</td>
</tr>
<tr>
<td>Turbidity</td>
<td>6.3 ± 2.8</td>
<td>&lt; 0.1</td>
<td>NTU</td>
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<tr>
<td>TSS</td>
<td>12 ± 6.8</td>
<td>&lt; 0.2</td>
<td>mg/L</td>
</tr>
<tr>
<td>Total Coliform</td>
<td>1.1 x 10^6</td>
<td>&lt; 2.2</td>
<td>#/100 mL</td>
</tr>
<tr>
<td>E. Coli (Fecal)</td>
<td>-</td>
<td>&lt; 2.2</td>
<td>#/100 mL</td>
</tr>
<tr>
<td>Streptococcus</td>
<td>-</td>
<td>&lt; 2.2</td>
<td>#/100 mL</td>
</tr>
</tbody>
</table>
Applications

- MF – replacement of granular media filters
- MF - in water treatment plants, filter conventional backwash to prevent recycling protozoans
- NF, RO - primary treatment method in reclamation for higher uses, provides disinfection
- NF – water softening, phosphate removal
- RO – brackish water treatment
- RO – desalination – beginning to compete with distillation, especially for smaller plants
- RO – high quality water for semiconductors
- RO - pretreatment for ion exchangers
Pilot Tests

• Generally pilot tests of specific membranes for a specific application are recommended.
• The science is still has some “black art” aspects which can cause problems
• Manufacturers tend to have a wealth of unpublished but important data and results
Predictions

• Membranes will gradually replace a number of existing technologies, such as granular media filtration
• In reclamation plants in California, we have already seen RO replace high-lime coagulation, carbon adsorption, granular filtration, and reduce disinfection requirements.
• They easily fulfill the double barrier concept for water reclamation
• Research in membranes is “tricky.” Manufacturers have a lot of proprietary information, as well as control over the product. We will be moving from “open” technology to a “closed” technology as membranes are adopted for more applications
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