Desalination Technology Overview

James C. Lozier, P.E.

CH2M HILL, Tempe, AZ
Presentation Outline

• Introductory Concepts
• Desalination Processes
• Reverse Osmosis
  – Components
  – Costs
  – Recent Developments
• Concentrate Disposal
• Looking Forward
Desalination

• The process of removing salt (dissolved solids) from an impaired water supply (brackish water, seawater or wastewater) in order to put the source to beneficial use (drinking, irrigation, industrial needs, etc)
Desalting Spectrum

**Desalination**
*Salinity Removal*

- **Seawater**
  - High Salinity
  - 20,000-50,000 mg/L

- **Brackish**
  - Moderate Salinity
  - 1,000-20,000 mg/L

- **Fresh**
  - Low Salinity
  - > 1,000 mg/L
Desalination Processes

Thermal Processes

- Multi-Stage Flash (MSF)
- Multi-Effect Distillation (MED)
- Vapor Compression (VC)

Membrane Processes

- Reverse Osmosis (RO)
- Electrodialysis (ED/EDR)
- Nanofiltration (NF)

Pressure Driven

Electrical Driven

Seawater

Brackish Water

Freshwater
Pressure-driven membranes

The higher the salt content, the greater the pressure required to desalinate.
Spiral wound RO element
Brackish Groundwater RO Plant

- Wells
- Scale inhibitor
- Sulfuric acid
- RO feed pumping center
- RO trains (two stage)
- To concentrate disposal
- Degasifiers
- Product transfer pumps
- Clearwell
- Chlorine
- Caustic
- Ground storage
- High service pumps
- To distribution system
Seawater RO Plant

- RAW WATER PUMPS WITH SUBMERGED INTAKE SCREENS
- COAGULANT
- STRAINERS
- BLOWERS
- BREAK TANK
- RO FEED PUMPING CENTER
- RO TRAINS (SINGLE STAGE)
- PRODUCT TRANSFER PUMPS
- CLEARWELL
- CHLORINE
- CAUSTIC
- GROUND STORAGE
- TO DISTRIBUTION SYSTEM
- TO CONCENTRATE DISPOSAL
- MF/UF BACKWASH SETTLING
- MF/UF SYSTEM
- ENERGY RECOVERY CENTER
- BREAK TANK
- HIGH SERVICE PUMPS
Advanced Water Reclamation Plant

EFFLUENT PUMPS WITH SUBMERGED INTAKE SCREENS

TO HEADWORKS

STRAINERS

MF/UF SYSTEM

SCALE INHIBITOR

ACID

BREAK TANK

ACID

ACID

RO FEED PUMPING CENTER

RO TRAINS (THREE STAGE)

TO CONCENTRATE DISPOSAL

H₂O₂

UV/AOP

TO AQUIFER INJECTION

HIGH SERVICE PUMPS

GROUND STORAGE

CAUSTIC CHLORINE

Effluent Channel

TO AQUIFER INJECTION
General Comparison- Brackish vs. Seawater RO

- SWRO requires higher feed pressures
- SWRO requires more expensive materials of construction
- SWRO generally requires more pretreatment (except in beach wells)
- SWRO generally doesn’t require scale inhibition
- SWRO may require more RO cleaning (except in beach wells)
- SWRO may have shorter membrane life
Desalination Costs

• Capital Costs (CAPEX)
  – physical infrastructure, land, professional services etc
• Operating Costs (OPEX)
  – power, labour, chemicals, maintenance, replacement etc
• Total Water Cost (TWC)
  – Annual Operating Cost + debt service on capital
  – most commonly quoted
BWRO CAPEX Models

1 acre-ft = 325,851 gallons = 1233.48 m³
SWRO CAPEX Models

1 acre-ft = 325,851 gallons = 1233.48 m³
**Total Water Costs**

- Brackish RO: $1.50 - $3.00/1000 gals
- Seawater RO: $3.00 – 8.00/1000 gals
Advancements in RO Desalination
Performance Improvement – Seawater RO Element

- Rejection (%): 99.0% to 99.9%
- Flow (gpd): 3000 to 12000

Chart showing productivity and rejection over time from 1985 to 2005.
## Evolution of Membrane Element Costs

<table>
<thead>
<tr>
<th>Year</th>
<th>Element Price</th>
<th>Price/ft²</th>
<th>Normalized Price/Area</th>
<th>CPI</th>
<th>1978=1 CPI</th>
<th>Norm 78 Price/Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>$950</td>
<td>$6.33</td>
<td>$1.00</td>
<td>71</td>
<td>1.00</td>
<td>$1.00</td>
</tr>
<tr>
<td>1989</td>
<td>$875</td>
<td>$2.92</td>
<td>$0.46</td>
<td>124</td>
<td>1.75</td>
<td>$0.26</td>
</tr>
<tr>
<td>1995</td>
<td>$750</td>
<td>$2.27</td>
<td>$0.36</td>
<td>152</td>
<td>2.14</td>
<td>$0.17</td>
</tr>
<tr>
<td>2000</td>
<td>$645</td>
<td>$1.79</td>
<td>$0.28</td>
<td>172</td>
<td>2.42</td>
<td>$0.12</td>
</tr>
<tr>
<td>2002</td>
<td>$435</td>
<td>$1.18</td>
<td>$0.19</td>
<td>180</td>
<td>2.54</td>
<td>$0.07</td>
</tr>
<tr>
<td>2006</td>
<td>$550</td>
<td>$1.38</td>
<td>$0.22</td>
<td>200</td>
<td>2.82</td>
<td>$0.08</td>
</tr>
</tbody>
</table>

J. Birkett & R Truby, 2007
SWRO Energy Use Reduction

- Diminishing return for additional investment

- 91% reduction

- Minimum theoretical: 0.8 kWh/m³

- 1970: 20 kWh/m³
- 1980: 10 kWh/m³
- 1990: 5 kWh/m³
- 2000: 2 kWh/m³
- 2007: 1 kWh/m³
Large-Diameter Elements Reduce RO Costs

From Industry Consortium Analysis of Large RO/NF Element Diameters (Reclamation, 2004)
Large-Diameter Element Commercialization

Dow FilmTec (16”)

Toray (16”)

Hydranautics (16”)

Koch (18”)

CSM (16”)
not shown

~20 large-diameter plants currently in operation
YDP Pioneered Use of Large-Diameter Elements

50-mgd of Fluid Systems (Koch) nominal 12” dia. elements
Desal Residuals – Concentrate Mgmt
Concentrate Treatment – Fort Irwin, CA

Water Distribution

Groundwater → EDR (92% recovery) → ZLD

Cost Distribution ($/ac-ft)

EDR → ZLD

ZLD → precipitative softening, RO, mech. Evaporator, evap. ponds
Oxnard, CA Concentrate Treatment Wetlands Demo Project

- Demonstrate ability of engineered natural treatment system to utilize RO concentrate for environmental benefit
- Utilize salt-tolerant, brackish marsh species to remove nutrients, heavy metals and provide volume reduction
- Restore or create new wetlands habitat using concentrate as sustainable source water
Looking Forward
Nano-particle RO Membranes

- Manufactured by NanoH2O, El Segundo CA
- Developed at UCLA
- Reduced feed pressure or increased flow
- Focus on SW desal market
Membrane Distillation (MD)

- Components of MD
  - Warm feed
  - Porous hydrophobic membrane
  - In Direct Contact MD (DCMD), cold fresh water on the permeate side

- Driving force
  - Partial vapor pressure gradient
Forward Osmosis (FO) – Oasys Concept

Saline Water → Membrane → Draw Solution NH$_3$/CO$_2$ → Draw Solute Recovery → Product Water → Brine

Heat Input

Biomimetric Membranes

• Biomimicry – emulating nature to solve human problems sustainably

• Aquaporins - membrane water channels that control the water contents of cells
  – Very high rate of water transport
  – complete selectivity to H2O molecules only

• Companies are now working to construct membranes using aquaporins (e.g, Aquaporin A/S)
Renewable Energy and Desalination

- Multi-Effect Distillation
- Multi-Stage Flash
- Membrane Distillation
- Reverse Osmosis
- Electrical Separation
- Mechanical Vapor Compression
- Solar Distillation
- Humidification/Dehumidification
- Multi-Effect Distillation
- Multi-Stage Flash
- Membrane Distillation
- Electrical Separation
- Reverse Osmosis
- Mechanical Vapor Compression
Thank You!

• “I believe that water is the only drink for a wise man.”
  ~Henry David Thoreau (1817 – 1862)

• “A man who drinks only water has a secret to hide from his fellow men.”
  ~Charles Baudelaire (1821-1867)

jlozier@ch2m.com