Brine/Concentrate Management
Technologies and Trends

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Acknowledgements

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Buddy Boysen
Hazen and Sawyer

Rick Stover
Gradiant
Agenda

- Introduction
- Current State of Market
- Concentrate Minimization
- Concentrate Disposal
- Salt Recovery
- Questions
Population Growth

Alternative Supplies Required

Fresh Water Reduction

Drought

Challenging water quality
Considerations for Sustainable Water

Simple Costs
- Traditional Recycled
- Imported
- Conservation
- Groundwater
- Advanced Reuse
- High Recovery
- Seawater
- Urban Runoff

Sustainable
- Conservation
- Traditional Recycled
- Groundwater
- Urban Runoff
- Advanced Reuse
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- Imported
Desalination (Salt Removal) Technologies

- Groundwater
- Advanced Reuse
- High Recovery
- Seawater
Solid Growth in Desalination Application
Salt Removal Technologies

Reverse Osmosis

Electrodialysis

Electrodialysis Reversal
Electrodialysis

Movement of ions in the electrodialysis process
What Do Technologies Have in Common?

• Low TDS (total dissolved solids) Product Water
• 75-85% of Flow
• Concentrated Saline Waste Stream
• 15-25% of Flow is concentrate waste
Why so much concentrate?

Scaling

Main culprits:
- Alkaline scales: CaCO$_3$ / Mg(OH)$_2$
- Non-alkaline: CaSO$_4$
- Sparingly soluble: BaSO$_4$/SrSO$_4$/CaF$_2$
- Silica (gel & colloidal)
- Ca$_3$(PO$_4$)$_2$ – (Water Reuse)

Control techniques:
- Antiscalant (threshold inhibitor)
- pH Control (usually acid dosing)
- Limit maximum recovery
For Inland Systems Disposal Can be Highest Cost

Inland desalination operating cost per 1000 gallons of RO permeate - RO with brine disposal to sewer at average US commercial sewage tariffs.
What do we do with Concentrate (Brine) in the USA?

- Zero Liquid Discharge, 1
- Evaporation Ponds, 3
- Deep Well Injection, 9
- Surface Discharge, 45
- Sewer Discharge, 42

US Concentrate Disposal

Mickley, 2003
Costs of Increasing Recovery

Normal
Up to 85%

Concentrate Minimization
Up to 98%

ZLD
No Brine

SYSTEM COMPLEXITY

Operating Cost

Capital Cost

Reverse Osmosis
EDR

CCD, Batch RO
Membrane Distillation
Controlled Scale RO,
Interstage Lime,
Many Others

Evaporation
Thermal – Brine
Concentrators and
Crystallizers
What Does Increasing Recovery Cost?

- Brine Flow Decreases
  - 1.2 MGD
  - 0.8 MGD
  - 0.4 MGD
  - 0.0 MGD

- Salt Concentration Factor
- Water Recovery
- Cost $
Minimizing the Concentrate

Strategies to Increase Recovery
Controlled Scaling RO

- Achieves 93% water Recovery – WRD Vander Lans, CA
- Scale is controlled by permeate flushing
- Dispose of membranes every 2 years
Hybrid Membrane NF

- Achieved 98% Recovery – Signal Hill, CA
- Scale is controlled by passing salts in stage 1,2
- Stage 3 concentrates silica and CaCO3
Signal Hill – Hybrid Membrane Approach
Closed Circuit Desalination (CCD)

- Achieving 96-97% Recovery on WW Effluent Conc.
- Pilots at Gila Bend, AZ, Padre Dam MWD
Interstage Lime

- Achieved 95% water Recovery – Phoenix Pilot
- Solids Contact Clarifier
- Silica Removal was better than predicted
Interstage Pellet Lime

- Crystalactor – Interstage Lime Pellet
- Installed at Chino Desalter Authority – Chino, CA
- $50M for 1.7 MGD of Treatment
Zero Discharge Desalination (ZDD)

- Veolia/Kruger
- Dr. Tom Davis
  UTEP

Capelle et al, AMTA 2013
Vibratory Shear Enhanced Process (V-SEP)

- Use proprietary vibration to reduce boundary layer
- Tested by USBOR in Tucson
Disc Tube Reverse Osmosis

Used currently in landfill leachate

Diagram of Disc Tube Reverse Osmosis system:
- Well Pump
- Cartridge Filter
- Reverse Osmosis
- Feed Pump
- Concentrate
- DTRO

Crosstek
Membrane Distillation

- Use Temperature Differential
Humidification - Dehumidification

Gradiant – Carrier Gas Extraction
High Efficiency RO HERO™ by Aquatech

- Remove Cations first, then Anions
- Caustic to keep silica in solution
- 98% or greater

HERO is a registered trademark of Debasish Mukhopadhyay
OPUS™ - Kruger Process
Forward Osmosis

Pendergast, 2018 (Oasys) mostly Oil and Gas
Concentrate Disposal
Concentrate Pipelines

- Menifee/Perris I Desalter
- Perris II Desalter
- SJVRWRP IPR
Deep Well Injection

- El Paso has injection for K. Bailey Hutchison RO Plant
- 22 miles from plant
- 3 mgd
- 3,800 ft deep
- $19 M construction (20%)
Pond Evaporation

- 1-2 inches per day in Arizona
- Intel – Chandler since 1996
Semi Enhanced Evaporation

- 6 inches per day in Arizona
- Maintained by Equipment Vendors
Fully Enhanced Evaporation

- Up to 30 times evapotranspiration
Wind Aided Evaporation

- Up to 20 time Eto
- Considering at Intel in Arizona
Concentrator Technologies

- Single Effect Evaporators/Multi-Effect Evaporators
- Thermal Vapor Recompression
- Mechanical Vapor Recompression
Typical Costs

![Bar chart showing typical costs for different processes. The chart compares Brine Concentration, DTRO, VSEP, RO with Brine Precip, High Recovery RO, CCD, SWRO, FO, HDH, and Membrane Distill. The y-axis represents the total cost per 1000 gallons, ranging from 0 to 50, and the x-axis lists the processes.]
Recovery of Products
## Potentially Recoverable Salts

<table>
<thead>
<tr>
<th>Salt</th>
<th>Price</th>
<th>Basis (Year)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Sulfate (gypsum)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Salt</td>
<td>60</td>
<td>$/ton (2011)</td>
<td>Kostick, 2012c</td>
</tr>
<tr>
<td>Brine</td>
<td>8</td>
<td>$/ton (2011)</td>
<td>Kostick, 2012c</td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Capelle (UTEP) et al 2013.
## Purity Requirements for Sale

<table>
<thead>
<tr>
<th>Salt</th>
<th>Purity Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Carbonate</td>
<td>• 96% as CaCO₃</td>
</tr>
<tr>
<td></td>
<td>• Less than 0.5% by weight of SO₄, Cl, and other constituents</td>
</tr>
<tr>
<td>Calcium Sulfate (gypsum)</td>
<td>• 75-85% as CaSO₄ for use in cement</td>
</tr>
<tr>
<td></td>
<td>• ≤ 0.3% by weight of Na₂O, K₂O, and Mg₂O for use in wallboard</td>
</tr>
<tr>
<td></td>
<td>• ≤ 100 ppm Cl</td>
</tr>
<tr>
<td>Sodium Sulfate</td>
<td>99% by weight as Na₂SO₄ for use in detergent</td>
</tr>
<tr>
<td>Sodium Carbonate</td>
<td>• 99% pure for use in glass industry</td>
</tr>
<tr>
<td></td>
<td>• No Cl or Fe</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>• 96% pure for use in rock salt</td>
</tr>
<tr>
<td></td>
<td>• No SO₄, Ca, or Mg for use in chlor-alkali process</td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>• ASTM Standard D98</td>
</tr>
<tr>
<td></td>
<td>• Other limits are specific to the user</td>
</tr>
</tbody>
</table>
Enviro Water Minerals – El Paso

- Add in three more from memo.

**Exisitng EPWU Kay Bailey Hutchison Desalination Plant**

- Brackish Wells
- BWRO Desalination
- BWRO Brine 13,000 mg/l dissolved salts
- 85% recovery
- Disinfection, Blending and Distribution
- Chlorine
- Potable Water
- 99% well water recovery with full brine flow to EWM
- Waste Brine to Disposal Wells

**Enviro Water Minerals El Paso Plant**

- Heater
- Nano-Filtration
- Degasifier
- Electrodialysis
- Softener
- 125% flow
- 80% recovery
- Air+CO2
- 100 F
- 90% recovery
- Desalinated Water 91% Recovery (based on 3m3 of seawater)
- 700 mg/l dissolved salts
- HCl
- Caustic
- Sodium Chloride Brine 10 Mineral Production
- Magnesium Chloride, Calcium Chloride Brine 10 Mineral Production

* NSF 60 certified acid provides additional product water and silica desaturation

**Images:**

- Agricultural Gypsum
- Caustic Solution
- Milk of Magnesia
- Potash Liquid Fertilizer
- Bromide Rich Brine
- High-Purity Salt

**Courtesy Enviro Water Minerals**
Significant Facility

Enviro Water Minerals

Brackish Well Water

Concentrate

Potable Quality Water

El Paso Water Utilities
KBH Desal Plant

Courtesy Enviro Water Minerals
Questions?

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