Desalination needs and opportunities in the oil & gas industry

Samer Adham

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Produced Water – Volumes, Management and Challenges

Historical PW Treatment

Application of Desalination Technology:
  - Gas/LNG Operations
  - Oil Sands
  - Conventional
  - Unconventional

Final remarks
Water touches most segments of the petroleum industry
Exploration & Production Water Sources

- Fresh Water: 7%
- Ocean: 25%
- Non Fresh Water: 3%
- Produced Water: 65%

Refining Water Sources

- Fresh Water: 7%
- Ocean: 25%
- Process Fresh Water: 25%
- Cooling Water - non fresh: 47%
- Cooling Water - fresh: 25%
Yearly Volume Estimates – Produced Water (PW)

- 3 to 4 barrels of water for every barrel of oil produced

- PW beneficial reuse
  - Water flooding
  - Maintain reservoir pressure
  - Drilling and completion of wells

- Future innovative options??

Non-conventional Resources

Oil Sands

Unconventional Reservoirs

Steam-Assisted Gravity Drainage

Water is critical for unconventional oil production
Oil Sands

- ~2 to 4 bbl of water required per barrel of oil produced
- ~90% of the water recycled back through the process
- ~0.5 bbl make-up water added to produce each barrel of oil

Unconventional

- 50 K – 150 K bbl of water required for hydraulic fracturing
- 15 to 80% of volume recovered as flow back water
- 10 – 1000 bbl/day of PW from each production well

http://albertainnovates.ca/media/20420/sagd_technologies_ogm_lightbown.pdf
http://www.epa.gov/ogwdw000/uic/pdfs/hfresearchstudyfs.pdf
## Sample PW Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Oil field(^{(a)})</th>
<th>Gas field(^{(b)})</th>
<th>SAGD(^{(c)})</th>
<th>Coal bed methane field(^{(d)})</th>
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<tbody>
<tr>
<td>TDS, mg/l</td>
<td>40,000-193,000</td>
<td>5,000-50,000</td>
<td>1500-3000</td>
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<td>TOC, mg/l</td>
<td>~100</td>
<td>100-800</td>
<td>300-350</td>
<td>~200</td>
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<tr>
<td>Oil/Grease, mg/l</td>
<td>2-565(^{(e)})</td>
<td>6-60(^{(e)})</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>pH</td>
<td>7</td>
<td>3.8</td>
<td>7.9(^{(f)})</td>
<td>8.2</td>
</tr>
</tbody>
</table>

Produced water characteristics are variable

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\(^{(a)}\) SPE 126910  
\(^{(b)}\) Qatar Gas waste water treatment reuse scope of work  
\(^{(c)}\) [http://albertainnovates.ca/media/20420/sagd_technologies_ogm_lightbown.pdf](http://albertainnovates.ca/media/20420/sagd_technologies_ogm_lightbown.pdf)  
\(^{(d)}\) Oil & Gas Journal, 2009  
\(^{(e)}\) Journal of Hazardous material, pp. 530-531, 2009  
\(^{(f)}\) [http://www.tundrasolutions.ca/files/Evaporators%20in%20SAGD%20DP.pdf](http://www.tundrasolutions.ca/files/Evaporators%20in%20SAGD%20DP.pdf)
Historical PW Treatment

- PW treatment – limited to suspended solids & dispersed oil/grease removal

- Common technologies adopted:
  - API separators
  - Coalescers
  - Hydrocyclone

- Usage of treated PW limited to
  - Disposal to reinjection wells/discharge to sea
  - Recycling limited to water flooding

* Oil and gas: Water treatment in oil and gas production - does it matters, Filtration + Separation Magazine, 2010
Specific Drivers for Advanced Treatment of PW

➤ Gas/LNG Operations
  ▪ Geological conditions or regulations may limit reinjection

➤ Oil Sands
  ▪ Strict water sourcing and recycling requirements

➤ Conventional Assets – Offshore (Seawater)
  ▪ Scale & souring control or enhance oil recovery

➤ Unconventional Reservoirs
  ▪ Recycling/reuse or volume reduction of PW
Challenges to Treat Produced Water

- Emulsified oils
- High Salinity
- Dissolved Organics
- Trace Metals
- Production Chemicals

New “TOOL BOX” with Advanced Water Treatment Technologies (AWTTs)
Application of Desalination Technology

- **Gas/LNG Operations**
  - Reverse Osmosis (RO)
  - Evaporators

- **Oil Sands**
  - Evaporators

- **Conventional**
  - Reverse Osmosis (RO)
  - Nanofiltration (NF)

- **Unconventional**
  - Evaporators
  - Traditional / Novel Technologies
Application of Desalination Technology

Gas/LNG Operations

- Reverse Osmosis (RO)
- Evaporators
Qatargas

- Process water generated during gas clean-up & liquefaction
- Produced water mixed with process water & injected to disposal wells
- Regulation require reduction of injection water volume for sustainability of reservoir
- Advanced water treatment technologies – MBR, GAC, RO are currently being deployed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Feed</th>
<th>MBR Permeate (Irrigation)</th>
<th>RO permeate (Desal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD, mg/L</td>
<td>710</td>
<td>100</td>
<td>Neg</td>
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<tr>
<td>TSS, mg/L</td>
<td>15</td>
<td>25</td>
<td>Neg</td>
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<tr>
<td>TDS, mg/L</td>
<td>850</td>
<td>2000</td>
<td>23</td>
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</table>
Qatargas – Advanced Wastewater Treatment Scheme

Process Water (4 ML/day)

- De-oiler
- H₂S removal
- Membrane Bioreactor
- Granular Activated Carbon
- Reverse Osmosis

Effluent

Irrigation

Permeate

Boiler Feed

Produced Water

RO Concentrate 40%

Deep well Injection
Qatargas – Bench Scale Investigation

- Characterized water streams & provided recommendation for design
- Installed 4 parallel MBRs to assess water biodegradability (QNRF Fund)
- Tested process water at various operating conditions
- Initial bench-scale data showed 50 - 65% COD removal
- MBR permeate was fed to bench scale RO system
- >97% salt rejection with stable flux of 24 LMH
Australia - APLNG

- In Coal Seam Gas (CSG) production, large volume of water are generated
- Regulations prevent salt water disposal wells
- RO technology is used for desalination & concentrate discharged to evaporation ponds
- Evaporators are under consideration to increase recovery

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RO Feed</th>
<th>RO Permeate</th>
<th>RO Concentrate</th>
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<tr>
<td>Sodium, mg/L</td>
<td>1645</td>
<td>32.9</td>
<td>16450</td>
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<tr>
<td>Chloride, mg/L</td>
<td>1317</td>
<td>26</td>
<td>13170</td>
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<tr>
<td>Alkalinity, mg/L as CaCO₃</td>
<td>1871</td>
<td>37</td>
<td>18710</td>
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<tr>
<td>TDS, mg/L</td>
<td>4137</td>
<td>83</td>
<td>41370</td>
</tr>
</tbody>
</table>

Salt rejection: 98%, Recovery = 90%, CF = 10
Australia – APLNG Project Locations

Spring Gully
12 ML/d

Reedy Creek
40 ML/d

Talinga
20 ML/d

Condabri
40 ML/d
APLNG – Treatment Schemes

Disk Filter → Microfiltration → Ion Exchange → Reverse Osmosis → Evaporation Ponds

Permeate
Irrigation / Aquifer Recharge

* Evaporators Under consideration in COP, installed by other operators
APLNG – Reedy Creek Treatment Facility
Application of Desalination Technology

Gas/LNG Operations
- Reverse Osmosis (RO)
- Evaporators

Oil Sands
- Evaporators
Oil Sands – Surmont

- Water in the form of steam is used to heat the bitumen
- Hot oil & produced water are then separated
- Following treatment schemes are used to treat deoiled PW:
  - Lime softener (silica removal, partial Ca & Mg removal)
  - Weak acid cation exchange (Complete Ca & Mg removal)
  - Once through steam generator (OTSG)
- The blow down of OTSG is sent to vapor liquid separator & recycled
Oil Sands – Conventional Treatment Schemes

Deoiled produced water → Warm Lime softening → Filter → Weak Acid Cation Exchange → Once Thru Steam Generator → Vapor Liquid Separators

- Sludge Disposal
- Filter waste
- Regeneration waste
- Makeup water
- Blow down Recycle
- Blow down
- Steam
Oil Sands – Advanced Treatment Schemes

Falling Film Evaporators

Drum Boilers

Deoiled produced water

Makeup water

Blow down

Steam

Blow down disposal
Evaporators - Advantages

- Reduced footprint
- Distillate quality water for boilers
- High efficiency drum boilers
- Physical chemical process is eliminated
- Elimination of vapor-liquid separators
Application of Desalination Technology

Gas/LNG Operations
- Reverse Osmosis (RO)
- Evaporators

Oil Sands
- Evaporators

Conventional
- Reverse Osmosis (RO)
- Nanofiltration (NF)
Sulfate Removal

- Seawater is used for water flooding to maintain reservoir pressure
- Scaling may form due to barium sulfate formation
- Presence of sulphate reducing bacteria can lead to reservoir souring
- Desulfating of seawater by nanofiltration (NF) membranes
- DOW had major market share for NF - patent expired 2011
Salinity Adjustment

- Based on core studies in clay, injection of low salinity water increases oil recovery
- In Clair Ridge (UK), full scale low salinity injection project is underway
- Combination of RO and NF membranes are used
- Reservoir specific application:
  - Low salinity, low hardness, low sulfate
  - Low salinity, medium hardness, low sulfate
  - Medium to high salinity, low hardness, low sulfate
  - High salinity, ultra-low hardness, low sulfate
Clair Ridge Treatment Scheme

Seawater $\rightarrow$ Coarse Filters $\rightarrow$ UF Membrane Pretreatment $\rightarrow$ Membrane Desalination $\rightarrow$ De-aeration $\rightarrow$ Well Injection

$\text{Cl}_2$
Application of Desalination Technology

- Gas/LNG Operations
  - Reverse Osmosis (RO)
  - Evaporators

- Oil Sands
  - Evaporators

- Conventional
  - Reverse Osmosis (RO)
  - Nanofiltration (NF)

- Unconventional
  - Evaporators
  - Traditional / Novel Technologies
- New frontier field development to unlock oil/gas resources by horizontal drilling and hydraulic fracturing

- Site specific challenges:
  - Access to fresh or saline water sources
  - Volume of flowback & PW after fracking
  - PW quality & salinity
  - Availability of salt water disposal wells
  - Trucking - traffic control & spillage concerns

- Fit for purpose water solutions
Evaporators gained share in Marcellus play (PA) as potential desalination technology – PW volume reduction

COP addresses following concerns for PW recycle (TX):
  - H$_2$S (souring)
  - Iron (solids)

H$_2$S removal by H$_2$O$_2$/ClO$_2$ followed by filtration

Iron removal by either H$_2$O$_2$ or caustic followed by precipitation
PW Recycle – Texas

Produced Water

- Oxidant addition
- Caustic addition

Reaction tank → Clarification → Filtration → Frac tank

Biocide

Pad
PW/Hypersaline Groundwater Treatment

- Advanced treatment technologies were evaluated:
  - Ion Exchange: selective boron removal from hypersaline GW
  - Membrane Distillation: salinity removal of hypersaline GW
  - Humidification – Dehumidification (HDH): minimize volume of PW and/or MD brine
Membrane Distillation - Qatar

Pretreatment/Chemicals

Sea water

Thermal Desalination Plant

Fresh water

Hot Brine

Membrane Distillation

Brine

Sea water
Forward Osmosis - Qatar

- Volume reduction of produced/process water by osmotic dilution
- Concentrated brine from thermal desalination plants serves as draw solution
- Bench-scale testing at GWSC (QNRF- Fund)
Final Remarks

Water management is an integral part of successful O&G production

- PW volumes will continue to increase and regulations/water scarcity will drive more advanced treatment/desalination

- Reverse osmosis & thermal evaporators are currently installed for PW treatment

- Fit for purpose treatment solutions are required based on site specific challenges for shale play

- Novel technologies (e.g., MD, FO, HDH, etc.) may be feasible for niche applications