EMERGING CHALLENGES IN PRODUCED WATER MANAGEMENT

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PRESENTATION OVERVIEW

- Oil and gas production background
- Environmental impacts of oil and gas production
- Challenges associated with produced water reuse and recycling
- Produced water treatment technologies
WHAT IS PRODUCED WATER?

- Energy resource extraction processes use water for drilling and other purposes.
- Petroleum formations are a complex mixture of oil, natural gas, and brackish water.
- Wastewater from operations and the formation is generated along with oil and gas.
- Produced water: All water that is returned to the surface from an oil and gas well.
OIL AND GAS FORMATION

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

http://2.bp.blogspot.com/-cdtGjsLHegE/Vbj8k1qGU5I/AAAAAAAABPs/Xef6n4bKmWU/s1600/oil_gas_formation.jpg
OIL AND GAS RECOVERY

https://4.bp.blogspot.com/-mODI8R-hry0/VyXxGZyy2ZI/AAAAAAAAADR0/8WUOAaPDew4YHvwpNSElluHQu9E1tuXWgCLcB/s320/x.jpg
PETROLEUM RECOVERY LIFE CYCLE

- Primary Recovery—formation under pressure (<10%)
- Secondary Recovery—water used to drive petroleum to production wells (majority of production)
- Enhanced Recovery—other technologies sometimes used
HYDRAULIC FRACTURING

- Uses water at high pressure to create fractures in the source rock
- Proppant (sand) is carried by the water to keep fractures open
- Large quantities of water used to increase reservoir conductivity/economic viability of the operations

http://www.goldmanprize.org/blog/lois-gibbs-leads-national-anti-fracking-campaign/
UNCONVENTIONAL RECOVERY

- Source rocks have low permeability
- Hydraulic Fracturing—increases permeability
- Horizontal Drilling—decreases drilling costs
- Hence, the Shale Gas and Tight Oil Boom
RESURGENCE IN OIL & GAS PRODUCTION

- Natural gas sources
  - Co-produced with oil and coal
  - Conventional gas wells
  - Shale gas wells
- Tight oil and shale gas production resulting from new technology has dramatically increased US production
ENVIRONMENTAL IMPACTS OF OIL AND GAS PRODUCTION

- Energy is needed by our economy, but oil and gas production present many environmental and technical challenges

- Water consumption for secondary recovery/hydraulic fracturing

- Leaky well bores and spills (groundwater contamination)

- Air pollution

- Climate change

- Seismicity

- Produced water management

http://www.nofrackingway.us/2014/06/05/canadians-scientists-discover-that-old-gas-wells-leak-a-lot-forfrackingever/
The recent increase in oil and gas production in Oklahoma has coincided with an uptick in seismic activity.
CLASS II INJECTION WELLS/SEISMICITY?

How the Disposal of Salty Wastewater from Oil Extraction Can Trigger Earthquakes

PRODUCED WATER MANAGEMENT

- NOT a new problem, but exacerbated by recent boom in production
- Produced water is separated from fuels at the surface and initially stored in tanks before disposal
- Characteristics vary significantly
  - Salinity 1,000 to 400,000 mg/L (seawater ~35,000 mg/L)
  - Naturally-occurring radioactive materials
  - Heavy metals
  - Oil and Grease
  - Organic contaminants (BTEX, PAHs, etc.)
- Currently, most produced water is disposed of by trucking followed by deep well injection (Class II wells)
PRODUCED WATER RECYCLING?

- Alternative approaches are needed to reduce injection volumes/seismicity concerns
- Numerous sociological, legal, and technologies issues
- Alternatives likely to require treatment
- Oklahoma Water for 2060 Produced Water Working Group
  - Investigating challenges associated with treating produced water for beneficial uses, such as industrial use or crop irrigation
PRODUCED WATER RECYCLING?

- Recycling for oil and gas production
  - Alleviates stress on water consumption and production
  - High salinity water is not a major issue
  - Issues with proprietary technologies

- Agriculture
  - Salinity is prohibitive
  - Public acceptance is unlikely
  - Groundwater is a cheap alternative in Oklahoma

- Release to surface and groundwater (permitting requirements)
- Alternatives likely to require treatment
- Salinity is the biggest technical challenge
WATER DEMAND FOR OIL AND GAS


~13,200 acre-ft
PRODUCED WATER RECYCLING?

- 3.7 barrels of water produced per barrel of oil
- Supply/demand mismatch
  - 13,000 acre-feet per year used for hydraulic fracturing
  - 105,000 acre-feet per year of produced water
  - Water is also used for secondary recovery, but not quantity is not clear (recycling exists already)
- Additional logistical challenges exist for recycling (transportation is expensive)
- Oil and gas uses less than 1% of Oklahoma’s water
- Conclusion: other alternatives to reuse for oil and gas will eventually be needed
PRODUCED WATER WORKING GROUP REUSE ANALYSIS

- Preliminary study of short-term possibilities (CH2M)
- Did not consider agriculture or discharge to groundwater for aquifer recharge (regulatory issues)
- Investigated potential for reuse infrastructure (i.e., pipelines)
- Estimated costs for 10 cases including:
  - Existing injection case (baseline)
  - Reuse by oil and gas with minimal treatment (no desal)
  - Evaporation (no recovery)
  - Desalination for electric power generation
  - Desalination for surface discharge
- Cost estimates based on quotes from companies
Locations of Main Oil and gas formations in Oklahoma.

Mississippi Lime

PRODUCED WATER WORKING GROUP
REUSE ANALYSIS
Color intensity corresponds to salinity based on Oklahoma Corporation Commission data.
Produced water from Mississippi Lime is very saline.
Other formations need water for hydraulic fracturing.
Marker size shows water requirements based on wastewater discharge permits.
County color intensities correspond to produced water volumes.
Local oil and gas reuse assumes someone builds the infrastructure, and that reuse is in the Scoop and Stack (water needed for shale)

Intra-county transfer: Mississippi Lime (lots of salty water) to Stack

Evaporation doesn’t depend much on salinity, no reuse

Desalination costs are heavily dependent on salinity; low TDS case in Granite Wash (SW OK); high TDS is Mississippi Lime
PRODUCED WATER WORKING GROUP REUSE ANALYSIS

- Challenges to adoption of produced water reuse
  1. Cost to transport and treat water
  2. Ownership of produced water
  3. Legal custody of water as it relates to potential spills
  4. Right-of-Way and landowner negotiations
  5. Discharge permit challenges including timing

- Pipelines are much more cost and energy efficient than trucks, but create a potential “not in my backyard issue”

- Long-term risks of capital investments for oil and gas industry (price volatility)
PRODUCED WATER WORKING GROUP REUSE RECOMMENDATIONS

- Reduce the challenges to water re-use through targeted regulations and legislation
- Continue to consider how to facilitate the re-use of produced water in oil and gas operations.
- Continue detailed study of transferring Mississippi Lime produced water to the Stack play
- Continue a detailed evaluation of evaporation as an alternative to injection
- Encourage companies and regulators to consider all environmental and stakeholder impacts
- Engage with university experts to develop longer-term alternatives (I added this one, but it was mentioned!)
PRODUCED WATER TREATMENT

- Produced water is salty and may contain high levels of pollutants and salts
- Alternatives to reinjection are energy-intensive (salt and water like each other/hard to separate)
- Pretreatment is needed before desalination
- Thermal Processes
- Membranes
- Ion exchange (more for polishing than primary)
- Other major issues revolve around concentration of dilute species (e.g., scale formation)
- Treatment concentrates pollutants, but doesn’t eliminate them (still have some water to manage)
A possible produced water treatment train
THERMAL DESALINATION PROCESSES

- Don’t depend as much on salinity (depend on the thermal characteristics of water)
- Multi-stage flash (MSF) desalination
- Multi-effect distillation (MED)
  - Capture waste heat in successive stages

http://www.separationprocesses.com/Distillation/Fig078b.htm
Membrane processes use the differences in the size of constituents relative to water for separation.

<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>Pore Size (nm)</th>
<th>Typical Pollutants Excluded</th>
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</thead>
<tbody>
<tr>
<td>Microfiltration</td>
<td>50-500</td>
<td>Bacteria, Emulsions</td>
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<tr>
<td>Ultrafiltration</td>
<td>2.0-50</td>
<td>Colloids, Proteins, Humic Acids</td>
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<tr>
<td>Nanofiltration</td>
<td>0.6-2.0</td>
<td>Antibiotics, Metals</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td>0.3-0.6</td>
<td>Inorganic Ions</td>
</tr>
</tbody>
</table>

http://www.theenergyofchange.com/water-treatment-membrane
REVERSE OSMOSIS

Osmosis (natural process): the water follows the salt

Reverse Osmosis: force the water in the opposite direction


MEMBRANE DESALINATION CHALLENGES

- Two streams are generated: concentrate (salty) and permeate (fresh)
- Energy is needed to drive the process
- Energy requirements increase with the amount of concentration that is achieved
- Low-solubility ions in the concentrated solution precipitate and cause scaling and fouling (Mg and Ca species in particular, “hard water”)
- Bacteria may grow on the membrane
- I’m looking for students to investigate these issues!
SUMMARY

- Oil and gas production is critical to Oklahoma and the global economy.
- Produced water is generated with oil and gas.
- Managing produced water is not a new issue, but it is growing with other water challenges and the Oklahoma oil and gas resurgence.
- Recycling produced water provides a way to reduce the impacts of oil and gas production.
- Social, legal, and technical expertise is needed to solve emerging problems in produced water management.
- Multidisciplinary research teams are needed to overcome challenges associated with reuse.