Water Treatment and Related Research

DOE/NETL Oil & Gas Program

September 18, 2017

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NETL Natural Gas Team

Solutions for Today | Options for Tomorrow
Outline

• Current water management challenges
• Industry approaches
• Related DOE research
• Questions
Key Points

• NETL Oil & Gas research in ‘water space’ > 10 Years.

• Industry success in reuse and recycle. NETL/DOE recognizes this success by industry. EIA forecasts that US will soon be an exporter of oil & gas. It will be CRITICAL that we develop more advanced solutions for water management. Urgent need to develop improved (low cost, lower energy penalty) water solutions.

• Solution:
  • Advanced manufacturing, optimization (water networks), modularization make it is possible to pursue ‘transformational produced water treatment technologies’ and DOE will contribute to making it happen.
Oil and Natural Gas “Water” Challenges

Fracturing Water
- Find Non-Freshwater Alternatives
- Reduce Freshwater Requirements
- Lower Treatment Costs
- Ensure Safe/Economic Disposal

Produced Water
- Reduce Produced Water Volumes
- Lower Treatment and Disposal Costs
- Support Beneficial Reuse

Fresh Water Protection
- Follow Drilling and Well Completion Best Practices to Protect Fresh Water Sources
- Improve Methods for Locating and Plugging Abandoned Wells

Water Disposal
- Reduce Risk of Induced Seismicity
Oil & Gas Water Treatment

Methods Used

- Recycling (Floc, Metals, Evaporation)
- Deep Well Injection
- HDH Systems (e.g., AltelaRain®)
- Crystallizer
- Ceramic Filtration
Disposal Fees Vary Widely ($/bbl)

Does not include hauling costs which can range from $2 - $10/bbl
# Recycle Treatment Options

<table>
<thead>
<tr>
<th>Technology</th>
<th>Bag Filtration</th>
<th>Physical/Chemical Separation</th>
<th>Electro-Coagulation</th>
<th>Chlorine Dioxide Treatment</th>
<th>Evaporation/Distillation (MVR)</th>
<th>Crystallization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
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<tr>
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<td></td>
<td></td>
<td>With pretreatment</td>
<td>With pretreatment</td>
</tr>
<tr>
<td>Metals</td>
<td>×</td>
<td>×</td>
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<td>×</td>
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<td></td>
<td></td>
<td>With pretreatment</td>
<td>With pretreatment</td>
</tr>
<tr>
<td>Bacteria</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
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<td></td>
<td></td>
<td>With pretreatment</td>
<td>With pretreatment</td>
</tr>
<tr>
<td>Barium</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
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<td></td>
<td></td>
<td></td>
<td>With pretreatment</td>
<td>With pretreatment</td>
</tr>
<tr>
<td>Hardness (Ca)</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>With pretreatment</td>
<td>With pretreatment</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>With pretreatment</td>
<td>With pretreatment</td>
</tr>
</tbody>
</table>

**Limitations**

- **Disposing of spent filter bags. Can be costly.**
- **Can have large chemical usage and solids processing/landfilling.**
- **Requires very consistent/stable raw water quality; can have high electrical requirements.**
- **Danger handling and generating chlorine dioxide. Can be costly. Have to pay close attention to system performance.**
- **High energy. High cost. Rigorous Pre-Treatment.**
- **High energy. Requires very consistent/stable raw influent water quality. High cost.**
Fracturing Water Costs
For Three Scenarios

Cost (USD/bbl)

- Traditional
- Reuse with Treatment
- Water-Flexible System

Sourcing, Transport, Treatment, Storage, Fracturing Fluid, Transport, Disposal, Total Spend

Industry Solutions to Fracturing Water Issues

• Recycle as much fracture flowback as possible using new chemical additives, low cost filtration, and dilution procedures

• Reduce costs of freshwater supply by centralizing storage and using flexible distribution systems

• Apply water treatment options to solve specific problems in the most cost-effective manner possible

• Continue to dispose of waste water that cannot be re-used via Class II UIC wells

Fracturing flowback water before and after filtration and dilution
Areas of Research Support
For Water Treatment

- Stray Methane Gas Migration – Hydraulic Fracturing Regions
- Support for Online Tools – Environmental/Chemical
  - FracFocus and RDBMS
- Induced Seismicity and Deep Well Injection
- Produced Water Treatment
- Mine Water Treatment
- Renewable and Waste Heat as a treatment option
  - Solar, Compressor Heat, and Geothermal
DOE Fossil Energy Water Research Program

• 59 projects initiated since 2008 with a total value of more than $104 million

• All projects were completed before September 2017

• Major focus has been on water treatment technologies, accounting for about 40% of projects and a third of funding

• Program covers a broad range of water-related issues (e.g., improved cementing technology to protect aquifers)

• NETL-RIC in-house research is focused on risk assessment and basic science surrounding a host of water issues
## DOE Fossil Energy Water Project Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Projects</th>
<th>Total Value* (MM$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water treatment technology development</td>
<td>25</td>
<td>33.4</td>
</tr>
<tr>
<td>Basic science and risk assessment (NETL ORD in-house research)</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>Water management tool development</td>
<td>6</td>
<td>8.4</td>
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<tr>
<td>Improved annular isolation</td>
<td>5</td>
<td>19.2</td>
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<tr>
<td>Environmental impact reduction</td>
<td>3</td>
<td>14.3</td>
</tr>
<tr>
<td>Alternatives to water as fracturing fluid</td>
<td>3</td>
<td>7.6</td>
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<tr>
<td>Enhanced water disposal options</td>
<td>2</td>
<td>2.1</td>
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<tr>
<td>Other (e.g., beneficial use, water chemistry, induced seismicity, volume reduction)</td>
<td>7</td>
<td>19.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>59</td>
</tr>
</tbody>
</table>

* Average partner cost share is about 30%, DOE funding about 70%
DOE Fossil Energy Water Project Performers

- University: 44%
- Industry: 20%
- Research Org.: 13%
- NETL: 14%
- Non-Profit: 2%
- State Agency: 7%
Research objectives were to evaluate current sampling methodologies and analytical technologies, conduct field trials in multiple shale plays, and develop recommended practices for:

- **Baseline Sampling for Dissolved Methane:**
  - Develop recommendations for improved sample collection and data interpretation for pre-drill and post-drill sampling programs.

- **Advanced Analytical Air Monitoring:**
  - Develop a protocol for measurement of air emissions from production facilities and open impoundments using OP-FTIR spectrometer, sensors, and imaging camera.

- **Flowback/Produced Water Characterization:**
  - Test and evaluate on-site analytical technologies to characterize flowback and produced water from unconventional oil and gas operations and support cost-effective reuse, treatment, or disposal of produced waters.
FracFocus Website
Developed and Maintained via DOE Funding to GWPC

• Contains publicly-available data on fracturing treatments for more than 127,000 wells fractured after January 1, 2011

• More than 1,200 companies have contributed data as of July 2017.

• New website features will facilitate data downloads and analysis by any interested stakeholder

• Many producing states are incorporating FracFocus into reporting requirements
Marcellus Wastewater Treatment Facilities

Open with DOE-Tested Technology

• Located in Clarion County and McKean County, Pennsylvania

• Energy-efficient AltelaRain® thermal distillation process captures heat from condensation to use during evaporation

• Capacity = 12,000 barrels of wastewater per day per plant

• Discharge water exceeds Pennsylvania Department of Environmental Protection requirements
Future Possibility for Water Treatment
3D Printing of WWTP Membranes

- 3D printing should allow rapid designing and building of various configurations of materials and membrane structure/geometrics that are capable of treating wastewater
- Pressure drops, biological and chemical fouling, and membrane damage pose tough challenges in 2017, due to vintage technologies
Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Program Administration

FINAL REPORT

Reporting Period Start Date: January 4, 2007
Reporting Period End Date: January 3, 2017
Principal Authors: Thomas E Williams, (RPSEA President), James Poppas, and Karl Parry
Date Report was Issued: December 10, 2016
DOE Award Number: DE-AC26-07NT42107

December 30, 2016
Research Partnership to Secure Energy for America
www.rpsea.org
P.O. Box 960729
Houston, TX 77098

Links to Water-Related Topics
For Oil & Gas
Questions?
Backup Slides
Oklahoma Produced Water Disposal

SWD well volumes (bbl/mon) in 2014

- up to 150,000
- 150,000 - 500,000
- greater than 500,000

Regional Faults

Prepared by:
Kyle E. Murray
OGS Hydrogeologist

Murray 2014, OGS OF5-2015
Recycling into Scheduled Drilling and Frac Work
Deep Well Injection
Crystallizers
Waste Heat, Humidification/Dehumidification and Evaporation
Ceramic Filtration
What is Water Recycling in HR Operation?

• Before moving produced water to the next well being fracked…
  • Settle, Floc, Chemical Treatment, and Filtration - sometimes done on site or can be done at centralized treatment facility

• Trucks, trucks, and more trucks