Chemical Characteristics of Frac Flowback Water & Technologies Deployed to Recycle Water, Reduce Waste Volumes & Reduce Cost

Preston McEachern
Director, Research and Development
Tervita Manages Waste
Tervita Facilities
Water Supply & Use

- Oil and gas sector:
  - A small user of water relative to other segments
  - A large recipient of attention and regulatory scrutiny
- Industry’s water management critical to social license
- Regulations continue to tighten on industry & limit access

Percentage of Water Used by Market Segment in the U.S.

- Thermoelectric Power, 41%
- Public Supply, 12%
- Irrigation, 37%
- Industrial, Domestic, 5%
- Aquaculture, 2%
- Livestock, 1%
- Mining and Oil & Gas, 1%

Cubic meters used in Alberta

- Agricultural 2.213
- Industrial 0.186
- Municipal 0.146
- Petroleum 0.202
- Other 0.441

Source: USGS
Produced Water Volumes O & G

- Produced water volumes predicted to increase by 32% by 2025*
- Potential for water reuse exists to decrease freshwater use
- Produced water management is a major cost to industry and consumes resources otherwise slated for hydrocarbon production

![Production Water Volumes Chart]

* Source: Clarke & Veil, 2009
Addressing Environmental Concerns of Hydraulic Fracturing

• There has been a significant increase in frac’ing:
  • Between 2004-2009 US shale gas supply increased 5 times
  • In Canada, shale gas currently accounts for nearly 30% of natural gas production

• This has led to concerns about:
  • Aquifer and soil contamination
  • Unsustainable water use
  • Seismic activity
What The Frac?

Dilbert

We're going to start fracking under our biggest competitor's headquarters.

My plan is to pollute their water and generate earthquakes to destroy their campus.

The project code name is "fracking awesome."

Catchy
Aquifers are typically at much shallower depths than shale gas zones

Well constructed wellbore and casing prevent upward migration of frac fluid and produced water

- Old, poorly constructed existing wells are a significant contamination risk during frac’ing

- Pressure characteristics within the geology determine the extent to which vertical fracturing may exist
Fracs and Aquifer Contamination

• Pay zone frac typically separated from aquifers by thousands of feet and several impermeable layers, vertical frac propagation typically < 300 ft

• Contamination issues likely from surface operations and historic oil and gas wells in the area.

• Presence of methane in drinking water wells is prevalent and not associated with recent drilling.

• Disclosure and understanding of additives should be routine.

• A (federal) approach is required to deal with orphaned wells.
### Table 3  Incidents Investigated and Determined Cause of Problem (Kell, 2011)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio</td>
<td>26 yrs.</td>
<td>65,000</td>
<td>185</td>
<td>0</td>
<td>74</td>
<td>0</td>
<td>39</td>
<td>41</td>
<td>26</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Texas</td>
<td>16 yrs.</td>
<td>250,000</td>
<td>211</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>56</td>
<td>30</td>
<td>75</td>
<td>1</td>
<td>39</td>
</tr>
</tbody>
</table>

Aquifer and Soil Contamination
Risk mitigation leading practices

• Baseline aquifer data assessment allows accurate monitoring and real-time adjustment

• Comprehensive environment and geology assessment facilitates effective frac planning

• Appropriate pad development for drilling minimizes surface impact

• Improved frac and produced water storage and treatment to minimize contamination risk

• Improved isolation through cement additives
Understanding Additives

## Chemicals Commonly Used in Shale Fracturing and consequences of not using the chemical

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Use</th>
<th>Consequences of not using chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Removes near well damage</td>
<td>Higher treating pressure, slightly more engine emissions.</td>
</tr>
<tr>
<td>Biocides</td>
<td>Controls bacterial growth</td>
<td>Increased risk of souring the formation (H₂S gas from sulfate reducing bacteria growth) and increasing corrosion.</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>Used in the acid to prevent corrosion of pipe</td>
<td>Sharply increased risk of pipe corrosion from acid. Well integrity compromised.</td>
</tr>
<tr>
<td>Friction Reducers</td>
<td>Decreases pumping friction</td>
<td>Significantly increases surface pressure and frac pump engine emissions.</td>
</tr>
<tr>
<td>Gelling Agents</td>
<td>Improves proppant placement</td>
<td>Increased water use. Natural gas recovery may decrease in some cases by 30 to 50% where frac fluids must be gelled (conventional fracs).</td>
</tr>
<tr>
<td>Oxygen scavenger</td>
<td>Prevents corrosion of well tubulars by oxygen</td>
<td>Corrosion sharply increased and well integrity (containment) compromised.</td>
</tr>
</tbody>
</table>

### How Much Chemical is Used? Examples:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Common in a Shale Frac?</th>
<th>Normal Concentration Ranges (actual minimum set by testing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid (15% HCl)</td>
<td>Yes</td>
<td>1500 to 2500 gallons total</td>
</tr>
<tr>
<td>Bacteria Control</td>
<td>Yes</td>
<td>0.0 to 0.001%</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Yes</td>
<td>0.01 to 0.025%</td>
</tr>
<tr>
<td>Oxygen Scavenger (ammonium bisulfite)</td>
<td>Yes</td>
<td>0.005%</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>Yes</td>
<td>0.001% in the frac to 0.2% in acid</td>
</tr>
<tr>
<td>Surfactants (multiple products – similar to products in dish washing soaps)</td>
<td>Common, but often over used</td>
<td>0.005 to 0.01%</td>
</tr>
<tr>
<td>Gelling Agent (guar gum or cellulose product)</td>
<td>Only in Hybrid fracs</td>
<td>10 to 20 lb/1000 gallons</td>
</tr>
<tr>
<td>Cross Linker (borax base is laundry detergent)</td>
<td>In some hybrid fracs</td>
<td>Varies, but very low conc.</td>
</tr>
<tr>
<td>KCl (potassium chloride is table salt substitute)</td>
<td>Uncommon in shale</td>
<td>2%</td>
</tr>
<tr>
<td>Gel Breaker (ammonium persulfate)</td>
<td>Only with gel</td>
<td>0.01%</td>
</tr>
<tr>
<td>pH adjusting agent (sodium carbonate)</td>
<td>Only with gel</td>
<td>0.01%</td>
</tr>
<tr>
<td>Scale Inhibitor (5% to 10% active phosphate ester, or polymer or 0.02 to 0.4% ethylene glycol)</td>
<td>Rare</td>
<td>1 to 2 gallons per 1000 gallons</td>
</tr>
<tr>
<td>Iron Control (Citric Acid)</td>
<td>Rare</td>
<td>0.001 to 0.004%</td>
</tr>
</tbody>
</table>

Sustainable Water Use
Risk mitigation leading practices

• Re-use of flowback and produced water
  • Tervita is developing “Closed Loop” systems to re-use flowback water

• Treatment of flowback and produced water
  • Tervita water treatment technologies minimize environmental impact

• Understanding resource availability
  • Brackish water can be treated for use to minimize freshwater use
Frac Water Example

• A typical frac may require 10 to 20,000 m³ of water¹

• This recovers about 11,000 person years of energy²

• Typical 100,000 ppm TDS with variable non-carbonate and carbonate hardness depending on region

• Cost for on site treatment and recycle breaks even at about 55 bbl/hr compared to trucking
Closed Loop Drilling

- Rig Equipment
- Tervita Equipment

- WELL
- DRILLING FLUIDS
- CENTRIFUGE (High G)
- RIG TANK S
- RIG TANK S
- FLUID MAKE UP TANK
- CENTRIFUGE FEED
- POLYMER UNIT
- POLYMER
- CENTRIFUGE (High G)
- CENTRATE

- CUTTINGS
- RIG SHAKERS
- UNDERFLOW
- RIG TANK S
- RIG TANK S
- DRYING SHAKER
- UNDERFLOW
- SOLIDS BINS
- SOLIDS

- Polymer Injection Unit
- Mixing Tank
- Control Cabin & Laboratory
Fracturing Flowback Water

Shale Fracturing Flowback Water Chemistry (Various North American Basins)

Sources: Canadian Shale Basins, Bakken, Haynesville, Marcellus, Barnett flowback water chemical analysis
Tervita Mobile Water Treatment

H₂O In → Stablflote ® → Softened H₂O → VRU (Vertical Reactor Unit) → Clarifier → Centrate Re-Cycle → Centrifuge → Dry Solids Out

Portable RO Unit (optional)
## Haynesville Water

<table>
<thead>
<tr>
<th>Flowback Water</th>
<th>Raw Water</th>
<th>Product Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In</td>
<td></td>
</tr>
<tr>
<td>Total Hardness (ppm)</td>
<td>10,200</td>
<td>40</td>
</tr>
<tr>
<td>Calcium (ppm)</td>
<td>3,780</td>
<td>16</td>
</tr>
<tr>
<td>Barium (ppm)</td>
<td>1,050</td>
<td>1</td>
</tr>
<tr>
<td>Strontium (ppm)</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td>Magnesium (ppm)</td>
<td>178</td>
<td>ND</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>93</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Seismic Activity
Risk mitigation leading practices

• Assessment of fault location to minimize fault risk during frac planning

• Reduce frac flowback and produced water disposal to minimize seismic activity related to disposal caverns

• Careful monitoring to minimize risk
  • Pressure monitoring
  • Frac propagation monitoring
Increasing Industry Response

- The industry is responding to growing awareness around impacts and mitigating strategies

- CAPP together with industry partners established newly created *Guiding Principles and Operating Practices for Hydraulic Fracturing*

- Guidelines impact:
  - Use and disclosure of frac fluid additives, groundwater testing, wellbore construction quality, water sourcing, fluid management
Questions or Comments?

Preston McEachern
Director, Research and Development
Tervita Corporation
(403) 718-1266
pmceachern@tervita.com