November 2nd 2012

Challenges and Emerging Practices for the Treatment of Natural Gas Fluids

Paul Hart, President
Hart Resource Technologies, Inc.
Pennsylvania Brine Treatment, Inc.
HRT Management
Trained and Experienced

• Active members in:
  • West Penn Energy Association
  • Independent Oil and Gas Association
  • Member of Marcellus Shale Coalition
  • Chairman of Environmental Committee (Paul Hart ‘99-’03)

• Management Team Members each have over 20 years experience in the Oil and Gas Industry

• Three treatment facilities currently in operation; processes millions of gallons of the water disposed of in PA

• Successfully crystallized brine water 1986-1992
• Patent on mobile Frac/Pit water treatment system
• Patent for on-site brine water treatment system
• Owner of Ohio disposal well
HRT CREEKSLIDE, PA
PA BRINE JOSEPHINE, PA
Company History

- 1984 – Cabot opened Franklin facility
- 1985 – HRT renovated AMD facility in Creekside, PA
- 1986 – Castle Gas opened Josephine facility
- 2003 – PBT purchased Franklin and Josephine facilities
- 2007 – Acquired rail cars to transport water
History of Water Disposal
(Pre 1984 VS Post 1984)

- **Pre 1984-** Discharge to blow box, surface pit, stream
- **Post 1984-** Approved Methods
  1. Centralized treatment facility with NPDES stream discharge
  2. Disposal/injection well UIC; seven wells in PA are currently in use (Appalachian brine is more concentrated)
  3. Road spreading for dust control and deicing (Beneficial uses)
  4. Sewage treatment facilities
  5. Reuse
  6. On site treatment/Recycle
Types of Waste Fluids

- **Top hole fluid** – freshwater encountered during drilling

- **Drilling fluids**

- **Stimulation “flow back” fluids, Frac water**
  (major source of waste fluids from Marcellus wells)

- **Production fluids - Brine**
Brine and Drilling/Frac Fluids Disposal 1997

Volumes
Brine 58,594,960 gallons
Fluids 30,862,822 gallons
Total 89,457,782 gallons

Source: Department of Environmental Protection
Bureau of Oil and Gas
Brine and Drilling/Frac Fluids Disposal in PA 2007

Estimated Volumes
Brine  82,000,000 gallons
Frac/Pit  100,000,000 gallons
Total  182,000,000 gallons/Day

Source: Hart Resource Technologies, Inc.
Marcellus operations in PA generated 232.1 million gallons of fluids during July 2009 thru July 2010

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Value (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reused</td>
<td>25.6%</td>
<td>59.5</td>
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<tr>
<td>Stored</td>
<td>36.5%</td>
<td>84.7</td>
</tr>
<tr>
<td>Unspecified</td>
<td>9.6%</td>
<td>22.2</td>
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<tr>
<td>OH disposal wells</td>
<td>18.6%</td>
<td>43.3</td>
</tr>
<tr>
<td>OH POTW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OH CTW</td>
<td></td>
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</tr>
<tr>
<td>WV CTW</td>
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<tr>
<td>PA POTW</td>
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<tr>
<td>PA CTW</td>
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<tr>
<td>WV CTW</td>
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</table>
Variable Nature of Waste Fluids
(one example)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>First 1/3</th>
<th>Second 1/3</th>
<th>Last 1/3</th>
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<tbody>
<tr>
<td>TDS</td>
<td>23,978</td>
<td>142,095</td>
<td>245,987</td>
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<tr>
<td>Chloride</td>
<td>12,098</td>
<td>64,598</td>
<td>134,065</td>
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<tr>
<td>Barium</td>
<td>432</td>
<td>4,786</td>
<td>6,784</td>
</tr>
<tr>
<td>Iron</td>
<td>12</td>
<td>27</td>
<td>67</td>
</tr>
<tr>
<td>Benzene</td>
<td>BD</td>
<td>BD</td>
<td>18</td>
</tr>
</tbody>
</table>

All concentrations in mg/L except benzene (µg/L)
“BD” = below detection
Challenges for Water Disposal

- High Volume
- Changing level of contaminants
- Oil
- Solids
- Salt
- White Brine
Disposal Facilities Prior to 2010
30 Facilities
(Not Injection Wells)

* Franklin
* Creekside
* Josephine
* Warren
* Clairton
* Harmarville
* Johnstown
* Phillipsburg
* Clearfield
* Sunbury
* Masontown
* Brockway
* Ridgeway
* President Township
* Franklin
* Ridgway
* Lafayette Township
* Warren
* Reynolds Township
* Lafayette Township
* Franklin
* Ridgeway
* President Township
* Franklin
* Ridgeway
* Lafayette Township

Source: Hart Resource Technologies, Inc
Current Disposal Facilities
(Excluding Disposal Wells)

12

- Franklin
- Creekside
- Josephine
- Warren
- New Castle
- Williamsport
- Brockway
- Lafayette Township
- President Township
- Franklin
- Punxsy
- New Castle
- Cranberry Township
- Josephine
- Henderson Township
- Brokenstraw Township
Pennsylvania Disposal Capacity

Gallons per day

1997: 200,000
2007: 600,000
2010: 1,600,000
2012: 200,000

Source: Hart Resource and Technologies, Inc.
Impacts on Water Disposal

- High TDS in Monongahela River, falsely blamed on Natural Gas industry, led to revision of Chap 95 and 500 TDS requirement for discharges
- POTW Restriction – 500 mg/l influent
- Industry was falsely accused of excessive use of fresh water
- Contamination of Dunkard Creek falsely blamed on Natural Gas industry
- Contamination of Dimick water wells falsely blamed on Natural Gas industry
- Notice to producers to cease taking water to 16 identified facilities, due to bromide levels in river
Oil & Gas review of bromides from industry water

- Zero treatment plants in the Allegheny River Basin are discharging treated Marcellus flowback/produced water

- Treatment/discharge of conventional water has been reduced by over 50%

- Effectively reducing the Bromide loadings from Oil & Gas industry below 2005 levels
Treatment of NORM:
Industrial Treatment Facilities

- Naturally Occurring Radiological Material (NORM) in geological formations such as Marcellus Shale return during flowback process

- Previous inspections showed no threat to environment or public health, continued monitoring in place

- Industrial treatment processes reduce NORM levels in water between 85-95 percent

- Discharges meet state in-stream regulatory criteria

- New and planned facilities coming on line are likely to have stricter requirements. Current discussions focus on radium 226
Casing The Well

Groundwater Protection

- Surface casing - 50 feet below deepest aquifer
- 20” casing, (200-500 feet) cemented to surface
- 13-3/8” casing, (up to 1,000 feet) cemented to surface past coal seams
- 9-5/8” casing, if necessary to seal off shallow oil, gas or brine bearing zones
- Casing for vertical and horizontal wells identical to this point
- 5-1/2” casing, cemented to 500 feet above Marcellus

Fresh water aquifers

Coal-bearing interval

Shallow sandstones and shales (gas & brine)

Marcellus Shale
Water Supply Complaints

For the first 6 months of 2009, 148 water supply complaints were filed to DEP related to oil and gas well activities.

- 48% were found not to be related to the oil and gas well activity
- 36% of the complaints are still under investigation
- 16% of the cases were found to have been impacted by activities related to the oil and gas industry
- No impacts were due to hydraulic fracturing
- EPA Study concludes testing of 47 water sources in Dimock, PA. Limited contamination is not due to Natural Gas Development
Water Management Options

- Recycle/Reuse at the well site
- Recycle at centralized facility
- Evaporate, with or without pretreatment
- Crystallizer
- Injection Well disposal
Dilution and Reuse

- Frac flowback – approx. 1 million gallons per well
  - Immediate re-use of relatively clean initial return fluids

- Remaining fluids may undergo limited treatment to get to a moderate TDS and hardness

- The 1 million gallons of untreated or partially treated fluids are then diluted with 3 million gallons of freshwater for use on the next well

- Advantages
  - Potentially zero discharge
  - Low cost – no need for additional infrastructure
  - Less transportation of waste fluids

- Disadvantages
  - Quality c – changing chemistry
  - Still may need treatment for long-term production fluids
Deep Well Injection

- EPA Underground Injection Control (UIC) program

- Requirements
  - Porous formation to accept fluid (limited in PA)
  - Confining layer free of faults or fractures
  - Plugged or absent orphan gas wells
  - Controlled injection pressure
  - Double containment – casing

- Unlike other states, very few in PA

- Some Marcellus waste fluids go to surrounding state’s UIC wells for disposal

- Costly to develop – some expected in PA
Pennsylvania water to Ohio disposal

Ohio – 172 disposal wells

PA – 7 disposal wells

- Marcellus Shale footprint

Waste-disposal wells in Ohio

Geologists are studying earthquakes reported in recent years in Arkansas, Texas and West Virginia to determine if they were triggered by the drilling of waste-disposal wells. The map shows the locations of 10 industrial waste-disposal wells and 170 oil and gas waste-disposal wells. Several locations include more than one well.

Source: Ohio Geological Survey
Hydraulic Fracturing

Hydraulic fracturing often involves the injection of more than a million gallons of water, chemicals, and sand at high pressure down the well. The depth and length of the well varies depending on the characteristics of the hydrocarbon-bearing formation. The pressurized fluid mixture causes the formation to crack, allowing natural gas or oil to flow up the well.

Water Use in Hydraulic Fracturing Operations

Water Acquisition - Large volumes of water are transported for the fracturing process.
Chemical Mixing - Equipment mixes water, chemicals, and sand at the well site.
Well Injection - The hydraulic fracturing fluid is pumped into the well at high injection rates.
Flowback and Produced Water - Recovered water (called flowback and produced water) is stored on-site in open pits or storage tanks.
Wastewater Treatment and Waste Disposal - The wastewater is then transported for treatment and/or disposal.
Hydraulic Fracturing Ingredients

Frac Water Chemistry (disclosed by FracFocus)

**Fring reducer:** organic polymer or potassium chloride

**Wetting agent:** non-ionic surfactant (soap)

**Biocide** – toxic compound to control micro-organism growth

**Scale inhibitor:** organic polymer or phosphonate

<table>
<thead>
<tr>
<th>Parameter</th>
<th>untreated</th>
<th>treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>barium mg/l</td>
<td>4,300</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>calcium mg/l</td>
<td>31,300</td>
<td>2.15</td>
</tr>
<tr>
<td>iron mg/l</td>
<td>134.1</td>
<td>1.60</td>
</tr>
<tr>
<td>magnesium mg/l</td>
<td>1,630</td>
<td>1.10</td>
</tr>
<tr>
<td>manganese mg/l</td>
<td>7.0</td>
<td>0.14</td>
</tr>
<tr>
<td>strontium mg/l</td>
<td>2,000</td>
<td>1.60</td>
</tr>
<tr>
<td>total hardness mg/l (as CaCO3)</td>
<td>90,633</td>
<td>14.9</td>
</tr>
<tr>
<td>total dissolved solids mg/l</td>
<td>248,428</td>
<td>150,520</td>
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</table>
Closed-Loop Reuse Of Flowback Water

1. Fresh Water
2. Frac
3. Store Flowback
4. Analyze and Treat Flowback
5. Store Treated Water
6. Determine Chemical Loading for Frac Fluids.
7. Reuse Treated Flow Back Water
The relation between geography, geology and frac water treatment and disposal in the profile of the well and shale play.
New Treatment Options
Various Advanced Treatment Processes

- Evaporators, crystallization technologies (distillation)
- Membrane technologies (reverse osmosis)

Advantages
- Produce effluent that will meet new proposed state regulations on discharges
- Treated water reusable (zero discharge?)

Disadvantages
- Costs greatly increase over traditional treatment ($0.25 or more per gallon)
- Large solid waste residue – composition and disposal?
Salt manufactured from natural gas well brines.

15 tons per day of 99.4% NaCl crystals.
Changing Treatment and Disposal of Gas Drilling Wastewaters

Data source: Paul Hart, Hart Resource Technologies