Current Approaches With Recycle Treatment and Disposal of Flowback and Produced Water

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Safety Moment – Working at a Wastewater Treatment Locations

- When handling treatment chemicals, wear proper PPE protection – safety eye glasses, gloves

- Always be aware where the safety eyewash water bottles and or shower are located

- Wear a face mask when handling chemicals that generate dust
Discussion Overview

- Current recycle/reuse challenges
- Frac water chemistry
- Treatment methods flowback and produced water recycle
- Transferring the treated water
- Handling sludge waste
- TENORM
- Working with regulatory
- Summary
Current Recycle Treatment Challenges

- Current Operator recycle/reuse approaches varies
- Flowback and produced water chemistry varies
- Frac water chemistry requirement varies
- Cost of treatment – AFE and LOE budgets
- Cost of water transfer
- Drilling and completion logistics
- Regulatory considerations
**Water in Gas Well Development Process**

- Water inputs and outputs change throughout life cycle of each gas well
  - Mud drilling water
  - Top hole water
  - Flowback water
  - Produced water
  - Storm water

Operators in Marcellus and Utica are using varied recycle treatment approaches.
Flowback and Produced Water Handling

- Blend untreated flowback and produced water with fresh water
- Treat flowback and produced water to make a clean brine and blend with fresh water
- Add friction reducers, anti-scalant and biocides for hydraulic fracture water makeup
- Transfer flowback and produced water to permitted central treatment facilities for recycle and reuse
- Transfer flowback and produced water to permitted brine disposal wells
Recycle Flowback and Produced Water – Many Treatment Approaches

- Flowback water – water that returns to surface via wellbore after the fracturing treatment is complete

- Produced water – water produced along with oil and gas

<table>
<thead>
<tr>
<th>Parameter (mg/L or ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids (TSS)</td>
</tr>
<tr>
<td>Bacteria - SRB and APB</td>
</tr>
<tr>
<td>Iron (Fe²⁺)</td>
</tr>
<tr>
<td>Barium</td>
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<tr>
<td>Strontium</td>
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<tr>
<td>Calcium</td>
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<tr>
<td>Total Dissolved Solids (TDS)</td>
</tr>
<tr>
<td>Sulfates</td>
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<tr>
<td>Chlorides</td>
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</tbody>
</table>
Key Hydraulic Fracture Water Fluid Properties

- Low viscosity
- Non-reactive
- Non-flammable
- Minimal residuals
- Minimal potential for scale & corrosion
- Low entrained solids
- Around Neutral pH (6.5 to 7.5)
Water Impurities of Concern

- Scale Forming Constituents
- High Dissolved Solids (Chlorides, Sulfates & Calcium)
- Bacteria: Acid Producing (APB) and Sulfate Reducing Bacteria (SRB)
- Suspended Solids
- Hydrocarbons
- Acid Gases (CO₂ & H₂S)
- Friction Reducers
- Warmer season odor
Chlorides increase demand for Friction reducers and scale inhibitors

Controlling scale potential (Ca, Mg, Ba, S0₄, C0₃)

Suspended Solids (25 mg/l or less)

No bacterial growth (SRB and APB)

Scale & corrosive materials affect down hole and surface production facilities

Adding inhibitors affects friction reducers
Chlorides – reported up to 100,000 mg/l (even higher) is acceptable given the high cost of TDS removal

Ca++ level of 350 mg/l begins to increase friction reducer demand

Suspended solids - < 100 mg/l

Oil & Grease - < 200 mg/l

Bacteria, cells/100 ml < 100

Soluble gas removal – To non-problems levels for safety and corrosive specifications

Low levels of Ba++ - to avoid scale forming potential

High iron concentrations can cause problems with plugging

pH – neutral – around 7 to 8
# 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>
<td>✗ With pretreatment</td>
<td>✗</td>
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<tr>
<td>Metals</td>
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<td></td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
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<tr>
<td>Bacteria</td>
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<tr>
<td>Barium</td>
<td></td>
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<tr>
<td>Hardness (Ca)</td>
<td></td>
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<tr>
<td>Total Dissolved Solids</td>
<td></td>
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<tr>
<td>Limitations</td>
<td>Disposing of spent filter bags. Can be costly $</td>
<td>Can have large chemical usage and solids processing / landfilling $</td>
<td>Requires very consistent/stable raw water quality; Can have high ($) electrical requirements</td>
<td>Danger handling and generating chlorine dioxide. Can be costly. Have to pay close attention to system performance.</td>
<td>High Energy. High Cost. Rigorous Pre-Treatment.</td>
<td>High energy. Requires very consistent/stable raw influent water quality. High Cost.</td>
</tr>
</tbody>
</table>
No Treatment – Use all Flowback and Produced Water Being Generated

- Move the water quickly to the next hydraulic fracture
- Sludge generation and accumulation in pits and tanks – metals oxidize
- Does untreated flowback water with blended fresh water hydraulic fractures yield good gas well production?
- Defer on high treatment cost. Operators have tighter AFE budgets.
Bag Filtration Treatment

- Reduces TSS
- Easy to rig up and rig down
- Low to medium cost $
- Operating cost to replace bags and dispose of them to a permitted landfill
- Used by many Operators
- Many suppliers offer
Chemical Biocide Treatment

- Removes the bacteria
- Easy to rig up and rig down and move to next hydraulic fracture
- Inexpensive and reliable treatment approach
- Low to medium cost $
- Regulatory concern of using biocides
- Many suppliers offer
Physical/Chemical Recycle Treatment

- Reduces TSS, metals, bacteria, hardness and barium

- Provides wide treatment capability with additional chemistry. Low to medium cost $

- Most common recycle technology with Operators who currently use recycle treatment

- Higher treatment chemical cost

- Generates sludge which requires handling and disposal

- Regulatory concern sludge higher in NORM that exceeds background.
Electrocoagulation Recycle Treatment

- Reduces TSS, metals and bacteria
- Does not reduce hardness and barium
- Low to medium cost $
- Easy to deploy with rig up and rig down
Chlorine Dioxide Recycle Treatment

- Removes TSS, metals and bacteria
- Handling of chlorine dioxide requires attention and good safety
- Medium cost $
- Easy to deploy with rig up and rig down
- Several suppliers
Brine Concentrator Treatment

- Reduces TDS and bacteria
- Requires pretreatment to reduce TSS, metals and barium
- High cost $
- Consumes a lot of energy
- Long term produced water treatment approach
- How to handle brine concentrate and dispose of
- Easy to deploy with rig up and rig down
Crystallization Treatment

- Reduces TDS and bacteria
- Requires pretreatment to reduce TSS, metals and barium
- Consumes a lot of energy
- High cost $
- Long term produced water treatment approach
- How to develop and handle salt byproduct for beneficial reuse?
Water Transfer

- Challenges of steep terrain in PA, WV and OH
- Portable water temporary lines – HDPE pipe most often use by Operators
- Permanent lines – reduce truck traffic and cost
- Cold weather climate logistics. Water cannot sit on cold nights with temporary lines
- Landowner Right of Way considerations and relations
- Regulatory restrictions
- Stream and wetlands crossing challenges.
Sludge Handling and Disposal

- Metal hydroxide sludge – non hazardous can be disposed at permitted landfills
- Solid waste landfills can only accept TENORM wastes for disposal at concentrations less than 5 picocuries per gram above natural background.
- Sludge with NORM that exceeds to background – directed to permitted radiological waste disposal sites.
- Need to carefully monitor and control sludge that exceeds background
Radioactivity: TENORM

- Technologically-enhanced NORM (TENORM)
- Scale
  - Group IIA elements (barium, strontium, calcium, radium) form pipe / tank scales
  - Acidity, temperature, and pressure contribute to scale build-up
  - Gas transportation (radon)
- Sludge
  - Produced water
  - Water treatment- barium extraction inadvertently concentrates radium in filter cake sludge
## Radioactivity: TENORM

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Radiation Level</th>
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<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
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<tr>
<td>Produced Water</td>
<td>0.1</td>
<td>9,000</td>
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<tr>
<td>[pCi/liter]</td>
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<tr>
<td>Pipe/Tank Scale</td>
<td>0.25</td>
<td>100,000</td>
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<tr>
<td>[pCi/g]</td>
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<tr>
<td>WWTF Ra Sludge</td>
<td>2</td>
<td>450</td>
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<tr>
<td>[pCi/g]</td>
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Ionizing Radiation

- Radiation that possesses enough energy to cause ionization of the atoms with which it interacts

- Types of Ionizing Radiation
  - alpha ($\alpha$)
  - beta ($\beta$)
  - gamma/x-ray ($\gamma$, $x$)
  - neutron ($\eta$)
Penetrating Power

Relative Penetrating Power of Alpha, Beta, and Gamma Radiation

Type of Radiation

Alpha
Beta
Gamma

One Meter of Concrete
Oil and gas deposits exist in geologic formations that contain naturally-occurring radioactive materials (NORM)

- Uranium (U-238)
  - Parent + 13 radioactive progeny
  - Alpha, beta, gamma radiation

- Thorium (Th-232)
  - Parent + 10 radioactive progeny
  - Alpha, beta, gamma radiation

- Secular Equilibrium in the rock
Radiological Elements In Gas Development

Condensate $^{222}\text{Rn}$ and particulate scale

Gas

Particulate scale and $^{40}\text{Rn}$

Oil

Water

$^{222}\text{Rn}$, $^{210}\text{Pb}$, $^{210}\text{Po}$ plates tubular

$^{238}\text{U}$, $^{232}\text{Th}$

$^{226}\text{Ra}$, $^{228}\text{Ra}$, $^{224}\text{Ra}$, $^{222}\text{Rn}$

Mobilise with hydrocarbons and produced water

$^{222}\text{Rn}$ migrates with gas

Ra isotopes precipitate as mineral scale
Radioactive material is a material containing an “excess” of radioactive atoms.
Radioactive contamination is uncontained or uncontrolled radioactive material

- Radiation is *energy*
- Contamination is *material*
- Exposure of the worker to radiation does not result in contamination
Implement NORM/TENORM Management Programs

- Basic radiation safety practices
- Reduce occupational and public exposures
- Worker Training
- Reduce environmental liability
Managing Regulatory Requirements

- Continue to work with the regulators
- Understand what is required with permit processes and control
- Follow best design practices and methods
- Provide proper plans and permit application packages
- Communicate
- Regulatory requirements will continue to evolve as shale gas develops
Questions?

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