Flowback and Produced Water Treatment for Recycle and Discharge to the Environment

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Outline

Project Background

Pilot Overview
  Pilot Approach and Treatment Options
  Pilot Results Summary

Focus on Field Sampling Methods

Conclusions
Project Background

Pilot required to permit fixed facility due to state regulatory requirements and stringent discharge water quality coupled with complex feed water quality:

- Treat produced and flowback water to discharge standards for the nearby river
- Treated water to be re-used in their operations
- Validate Monarch Separators proposed technologies’ ability to consistently meet discharge requirements
- De-risk and confirm inlet water quality for full-scale fixed facility
- De-risk cost of facility: CAPEX and OPEX
WS contracted to design and provide the pilot system capable of treating approximately 1,500 BWPD to treat for oil and dissolved organics removal, iron and metals removal, radionuclides and ammonia removal, and salinity reduction.

Project and pilot tests challenged by:

- Urban corridor setting
- Stringent regulatory requirements – Whole Effluent Toxicity (WET) tests
- Rigorous HSE requirements
- Piloting during winter conditions
- Greatly varying incoming water quality (fed from small tanks receiving daily truck deliveries)
- Need for cost-effective treatment scheme to provide high quality water
Pilot Approach

How To Develop the Most Cost-effective, Reliable Treatment System

- Conduct Bench-Scale Testing
- Develop Treatment Regime and Build-up Cost Structure to Ensure Cost Effectiveness
- Multi-prong approach for Removal of Difficult Constituents
  - Pilot to compare performance of different technologies
  - Determine if stand-alone or multi-barrier/Series
- Build Pilot Unit
- Develop Pilot Protocol, KPI’s and Experimental Design
- Conduct Pilot With Constant Vigilance Over Performance

Be Willing to Adapt (Quickly)!
Targeted Treatment Scheme

Measuring Performance Versus Cost for Different Treatment Options

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Technology Options Piloted</th>
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<tbody>
<tr>
<td>Free oil</td>
<td>Flocculant, Dissolved Air Flotation (DAF), Nutshell Filter (NSF)</td>
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<tr>
<td>Iron and metals</td>
<td>Oxidant, Flocculant, DAF, NSF</td>
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<td>TSS</td>
<td>Oxidant, Flocculant, DAF, NSF</td>
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<tr>
<td>BTEX</td>
<td>NSF, Granulated Activated Carbon (GAC), Advanced Oxidation Process (AOP), MBR, RO</td>
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<td>Bacteria</td>
<td>Oxidant</td>
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<td>Nitrogen</td>
<td>Ammonia, Nitrate, Nitrite at MBR, RO, AOP</td>
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<td>Radionuclides</td>
<td>Flocculant, DAF, RO</td>
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<td>Inorganic salts</td>
<td>RO</td>
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### Test Duration, weeks

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<th>Parameter</th>
<th>Instrument</th>
<th>Test Range</th>
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<td>Hach DR900</td>
<td>0.4 - 10.0 mg/L NH₃-N</td>
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<td>Total Dissolved Solids or EC</td>
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<td>pH</td>
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<td>10259 Powder Filters</td>
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<td>Turbidity (surrogate for TSS)</td>
<td>Hach 2100Q</td>
<td>0-1000 NTU</td>
<td>d</td>
<td>d</td>
<td>d</td>
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<td>d</td>
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<td>Biological Oxygen Demand (5 Days)</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td>Chemical Oxygen Demand</td>
<td>Hach DR900/DR8200</td>
<td>20 - 1500 mg/L</td>
<td>w</td>
<td>w</td>
<td>w</td>
<td>w</td>
<td>w</td>
<td>w</td>
<td>w</td>
<td>w</td>
<td>10260 Powder Filters</td>
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<td>Whole Effluent Toxicity</td>
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</table>
Focus: Managing Operations & Costs
Turbidity, Conductivity and ORP

Primary field measurement
- Influent samples
- DAF effluent
- Nutshell effluent
- MBR filtrate
- RO permeate

Average sample time ~ 2 minutes
Free Oil (TPH)

Field Measurement and Labs to verify field measurement
- Influent samples
- DAF effluent
- Nutshell effluent

Comparison of field solvent extraction method to labs (EPA 1664)
- MDL ~ 1.5 mg/L

Average sample time ~ 20 minutes, process requires filtering plenty of room for art

Frequency
- Two sets per day
Iron and Metals

Focus on iron, aluminum and manganese
- Influent samples
- DAF Effluent
- Nutshell Effluent
- MBR Effluent
- RO Effluent

3x daily samples
- Approximate time per sample: 5 minutes/sample
- Dilutions required
- Use of Hach DR900 methods (Waste Disposal)
Sample prep is critical.

Filter pad preparation, volumetric consistency. Verification of drying.

Issues with consistency of results both labs and fields for very salty waters (Permian Basin)
Ammonia, Nitrate, Nitrite and Phosphate

Focus on biological process performance
- Nutshell Effluent
- MBR Effluent
- RO Permeate

Heavily utilized during biological conditioning

Approximate time per sample:
- 30 minutes for color development for ammonia
- 5 minutes nitrate, nitrite

Use of Hach DR900 methods (Waste Disposal)
Focus on biological process performance

- Nutshell Effluent
- MBR Effluent
- RO Effluent

Heavily utilized during biological conditioning

Approximate time per sample:

- 30 minutes prep/measurement plus heating requires 2 hours.
- Different heating processes for COD and TOC
- Sample interreferences.
- Use of Hach DR900 methods (Waste Disposal)
Testing Lessons Learned

Cost effective analyzers are available to handle a lot analytes.

Very cost effective in comparison to lab data.

Very rapid results, better understanding of pilot performance.

Sample disposal costs need to be considered.

Need to evaluate sampling requirements of an upset.
Pilot Treatment Results

- Treating 300-650 NTU turbidity to less than 1 NTU
- Treating iron from 35 mg/L to less than 1 mg/L
- Alginate flocculent dosing of 5-7 mg/L for produced water
- Treating Oil in Water to less than 1 mg/L in DAF
- Flocculant/coagulant cost (dosing of 5 mg/L) less than $.05/bbl treated water
- Oxidant dosing of 10-25 mg/L, high dosing levels during upset conditions (cross-linked polymer slugs)
- 100% BTEX and TOC removal upstream of RO, 99+% salt removal in RO, 100% ammonia removal in RO
- Pass WET tests!!!
Pilot Conclusions

Cutting Costs with Conventional Treatment Combined with Novel Technologies

• The growing volumes of produced water and flowback, combined with restricted SWD usage, are driving operators to more creative disposal options

• Cost-effective treatment schemes are available which provide improved recycle water quality, and that can serve as the backbone for more rigorous treatment, if needed. For cost-effective discharge, target flowback/produced water under 50,000 mg/L salinity

• Keep it simple for recycle treatment but ensure ability to address large swings in flowback/produced water quality

• Minimize operator intervention to keep costs low, i.e. automation where practical

• For discharge option, water quality is not just what you can easily measure/monitor. Think like a fathead minnow and a daphnia.

• Last, but not least, a pilot of this level of optionality requires a multi-disciplined, experienced (and relentless) team!