

TREATMENT OF SHALE GAS PRODUCED WATER FOR DISCHARGE

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- Part of NETL's program to promote domestic natural gas production by providing technologies to overcome the technical and environmental challenges associated with unconventional resources.

INTRODUCTION



- Managing produced water from shale gas wells can be a challenge
- Management and treatment decisions depend on many variables and are inter-related
- Treatment can alleviate some disposal issues
- Treatment options are limited by cost, treatment capabilities, and availability

PW MANAGEMENT OPTIONS

- Three Basic Options
 - Injection
 - Surface Discharge/Beneficial use
 - Reuse in HVHF
- All options have challenges
- All options may require some level of treatment

TREATMENT GOALS

- Three primary treatment goals
 - Reduce TDS (desalination) for discharge/beneficial use
 - Reduce volume for disposal
 - Reduce TDS, scaling, and/or bio-fouling for reuse or UIC

TREATMENT CHALLENGES

- Shale gas produced water quality varies
 - Between plays
 - Within plays
 - Over time
- High Total Dissolved Solids (TDS) concentrations limit treatment options
- All treatment processes result in a waste stream – may be liquid, solid, or both
- Treatment in the field is very different than the lab
- All of the PW management options and treatment goals may be inter-related

SHALE GAS PW QUALITY/VARIATION

<u>Play</u>	<u>Range of TDS (mg/L)*</u>
Barnett	500 – 200,000
Fayetteville	3,000 – 80,000
Haynesville	500 – 250,000
Marcellus	10,000 – 300,000

** TDS Concentrations gathered from a combination of various published reports and personal conversations with operators.*

LOGISTICS/PRACTICAL CONSIDERATIONS

- Sources of PW change over time as new wells are drilled and development expands over an operator's lease-holdings
- Treatment facility location:
 - Mobile?
 - Permanent?
 - Semi-permanent? - Most common
- Treatment facility ownership:
 - Commercial?
 - Owned and run by operator?
 - Contracted by operator? - Most common

MANAGEMENT/TREATMENT DRIVERS

- Social/Community
- Environmental
 - Conservation of Resources
 - Aquatic Impacts
- Regulatory
- Economic
 - Cost of withdrawals
 - Cost of transportation
- Technical
 - Lack of injection capacity
 - Treatment limitations
 - Treatment availability
- Company policies



INJECTION

Benefits:

- Can be a low-cost option
- Well-established and (mostly) widely accepted disposal method
- Several States encourage as the preferred option

Challenges

- Limited UIC well capacity/locations in some shale plays
- Lack of near-by wells creates transportation issues

DISCHARGE/BENEFICIAL USE BENEFITS

- Returns water to the local ecosystem
- Reduces disposal volume
- Can help community relations
- Can be a cost-effective management option

DISCHARGE/BENEFICIAL USE CHALLENGES

- Treatment required
- Shale gas produced water not conducive to most beneficial uses
 - Small volume/well with scattered sources
 - Water production is episodic and moves over time
- Disposal of treatment concentrate
- Changing regulatory requirements
- Potential environmental/liability issues

REUSE

Benefits:

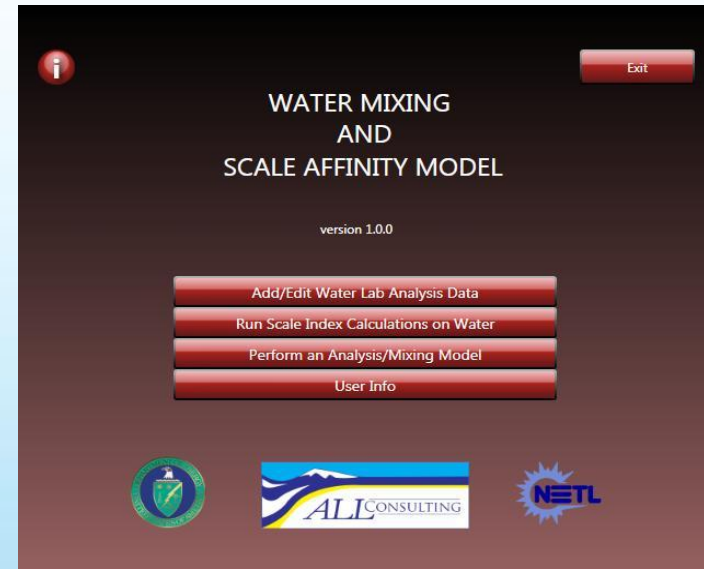
- Reduced withdrawals (and associated concerns)
- Reduced Disposal needs
- Reduced environmental concerns

Challenges

- Blended water must be suitable for fracture fluid
- May require treatment for TDS, scale, microbes
- Not necessarily a “no-treatment” option

MIXING AND SCALE AFFINITY MODEL

- Predicts chemical composition of mixed waters, allowing the user to see how waters will react when mixed
- Analyzes the mixing of multiple source waters, identifies the affinity for scale formation and the potential species of scale that will be formed
- Identify the most favorable mix ratio of available waters to meet specified targets for quality parameters – create an engineered water
- www.all-llc.com/projects/produced_water_tool/



TREATMENT FOR DISCHARGE

Available Technologies

- Thermal Distillation
- Reverse Osmosis
- Will also briefly mention Thermal Evaporation



Pre-Treatment/Conditioning

- Remove suspended solids and organics, adjust pH, etc.
- Each of these technologies require some pre-treatment
 - Handled by vendors as part of their system
 - Discussed in other presentations

THERMAL DISTILLATION

- Mechanical Vapor Recompression (MVR)
- Condenses steam for reuse
- Corrosion/scale can be problems
- TDS up to about 200,000 mg/L
- Fresh water recovery rates of 50 – 90 %
- Costs range from \$3.00 to \$5.00/Bbl



REVERSE OSMOSIS (RO)

- Force water through an osmotic membrane
- Pre-treatment to prevent premature membrane fouling is critical
- Membrane replacement costly
- TDS up to about 50,000 mg/L
- Fresh water recovery rates of 40 – 90%
- Costs range from \$0.42 to \$3.50/Bbl



VENDOR COSTS AND CAPABILITIES

- Vendors have limited operating experience/data for shale gas produced water
- Cost and capability data developed in the lab or in other industries may not be valid
 - Produced water quality variability
 - High TDS
 - Field Conditions
- Even when there is no intent to deceive, lack of consistent information on what is included in a quoted cost makes cost comparisons difficult
 - CAPEX/OPEX, Transportation, Disposal of reject water, etc.
- Vendors are constantly improving their processes as they gain experience

VOLUME REDUCTION

May want to reduce the volume that must be transported to UIC wells

- Thermal Distillation
- Reverse Osmosis
- Thermal Evaporation
 - Reduce liquid volume
 - Dispose of concentrate
- Crystallization
 - No limit on TDS
 - Zero Liquid Discharge
 - Dispose of solids



TREATMENT AVAILABILITY



- Availability varies by basin
- New vendors entering the market almost daily
- Several pilots underway/planned



- Treatment for shale gas PW remains in it's infancy

THERMAL AVAILABILITY

Treatment Vendor	Thermal Distillation/ Evaporation	Shale Gas Play				
		Marcellus	Barnett	Haynesville	Fayetteville	Woodford
212 Resources		✓	✓			
Fountain Quail		✓	✓		✓	
<u>Aquatech</u>		✓	✓		✓	
Veolia		✓				
INTEVRAS		✓	✓			
GE Water & Process Tech.			✓		✓	
Total Separation Solutions				✓		

RO AVAILABILITY

Treatment Vendor	Reverse Osmosis	Shale Gas Play				
		Marcellus	Barnett	Haynesville	Fayetteville	Woodford
GeoPure			✓			
Siemens	✓				✓	
GPRI			✓			
Auxsol			✓		✓	
Veolia	✓					
MI SWACO	✓					
Ecosphere			✓		✓	✓
GE Water & Process Tech.			✓		✓	
Innovative Water Solutions			✓			

KEY POINTS

- The decision to treat shale gas produced water for surface discharge is based on many inter-related considerations
- Shale gas PW has high TDS concentrations that require desalination prior to discharge
- Treatment for discharge options are effectively limited to Thermal Distillation and Reverse Osmosis.
- Cost data for many vendors is limited/unproven
- Technology Availability is limited/unproven
- Treatment technologies are advancing and changing

Contact Information

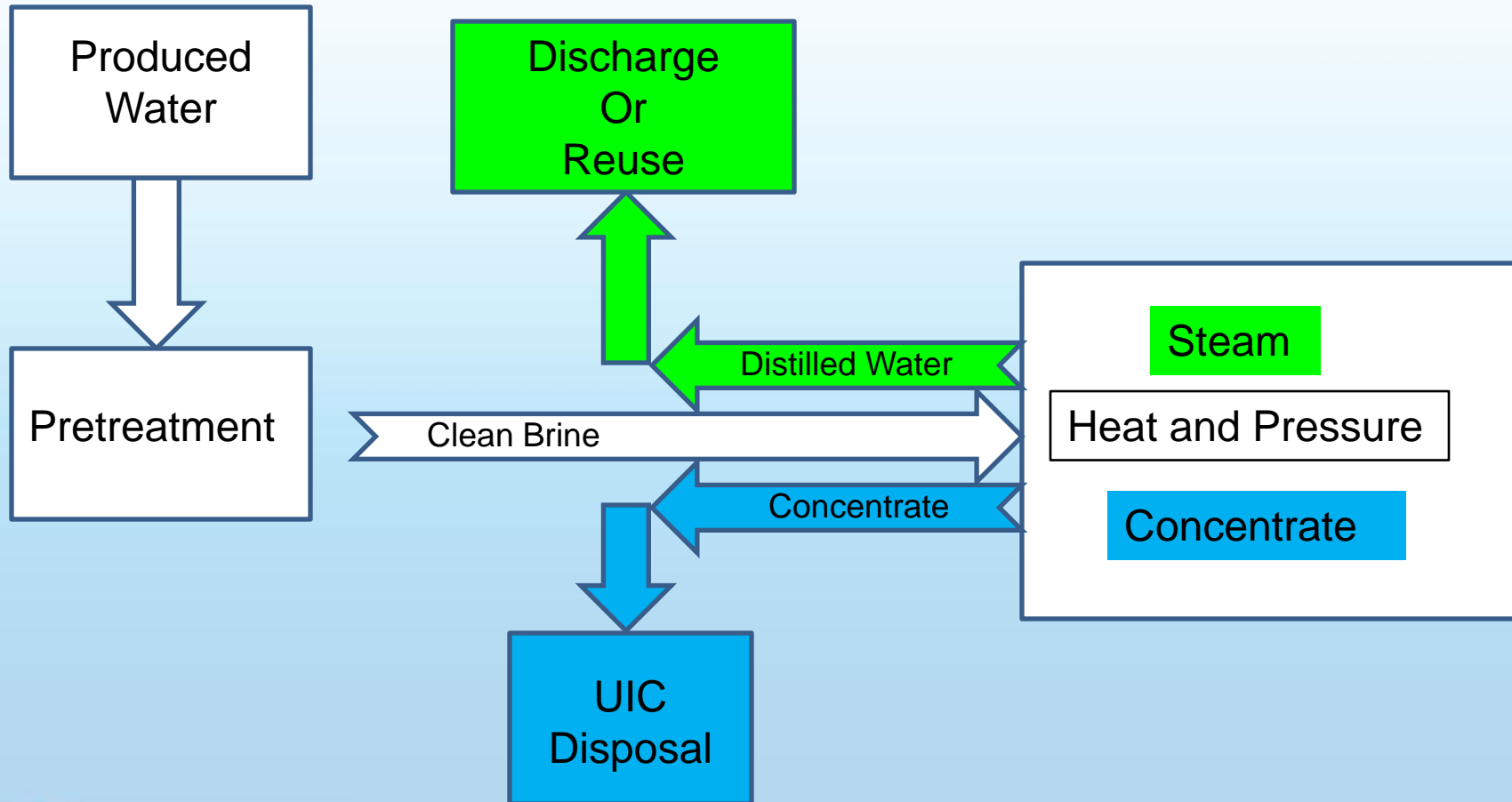
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THERMAL DISTILLATION



REVERSE OSMOSIS (RO)

