Aeration, pH Adjustment, and UF/MF Filtration for TSS Reduction of Produced Waters from Hayneville

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Haynesville Shale

Shale straddles Arkansas, Louisiana and Texas

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Haynesville - General Characteristics

- Depth: 10,500 to 13,600 ft.
- Lateral reach about the same
- Fracturing Pressure > 10,000 psi
- Bottom Hole Temperature: 100 to 350 F
- Fracturing fluids used: slick water, linear gel and cross linked
- Water sources: rivers, bayous, ponds, lakes, wells, flow back and produced water

Source: Chesapeake Energy

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Haynesville - Produced Waters Characteristics

- Recycled water utilized per well fractured : 0-35%
- Common water contaminants: TSS, Calcium Magnesium, Iron, Bacteria
- Key treatment targets: TSS, Scale Forming Ions, Bacteria
- This discussion will focus on TSS removal and fluid clarification via membrane filtration

Source: Chesapeake Energy

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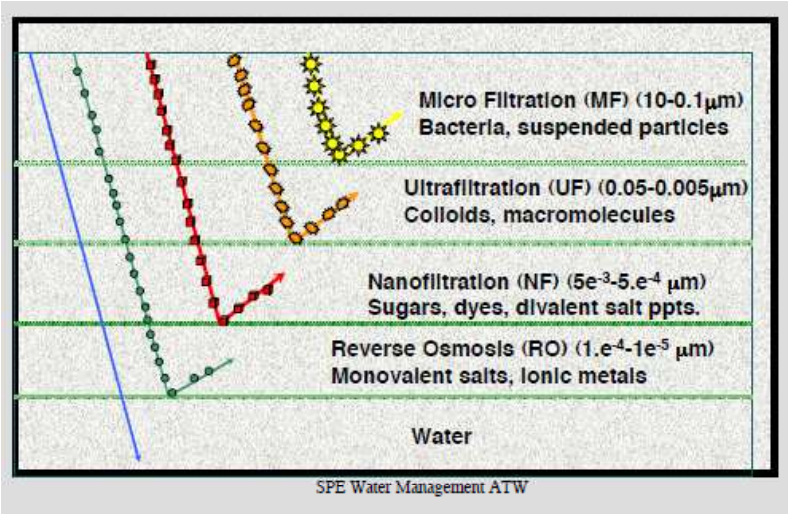
Four Common Membrane Processes



Process Name	Approximate Useful Particle Size Removed	Permeate
Microfiltration	0.5 - 50 µm	Clarified water
Ultrafiltration	0.2 µm	Clarified water
Nanofiltration	0.5 - 0.7 nm	Softened water
Reverse Osmosis	0.1 -1 nm	Low salinity water

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Filters Used in this Study

Filter	Manufacturer	Micron Rating (µm)
Polyester bag filter	Pentair	10
PVDF Hollow fiber membrane	Koch	0.1 – 1.0
Stainless steel membrane	Graver	0.5
Ceramic filter	Pall	0.2

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Texas A&M 2 GPM Mobile Water Filtration Trailer

Capable of low and high pressure membrane testing, from MF to RO

Pictures from David Burnett, Texas A&M GPRI

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10 Micron Polyester Bag Filter

Pentair website

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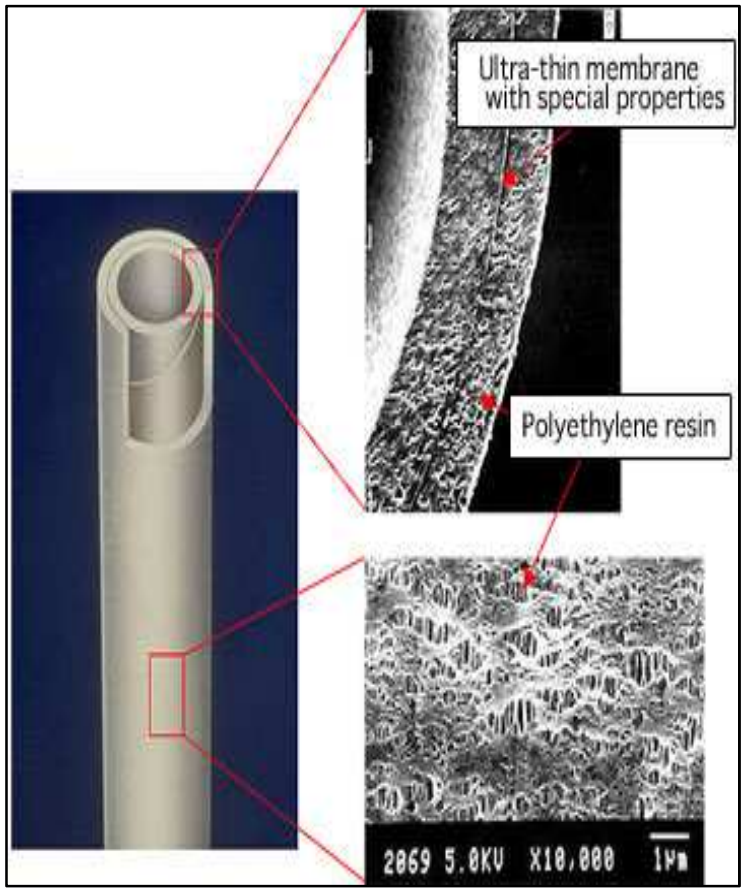
Hollow Fiber Cross Flow Membrane



Koch Membranes web site

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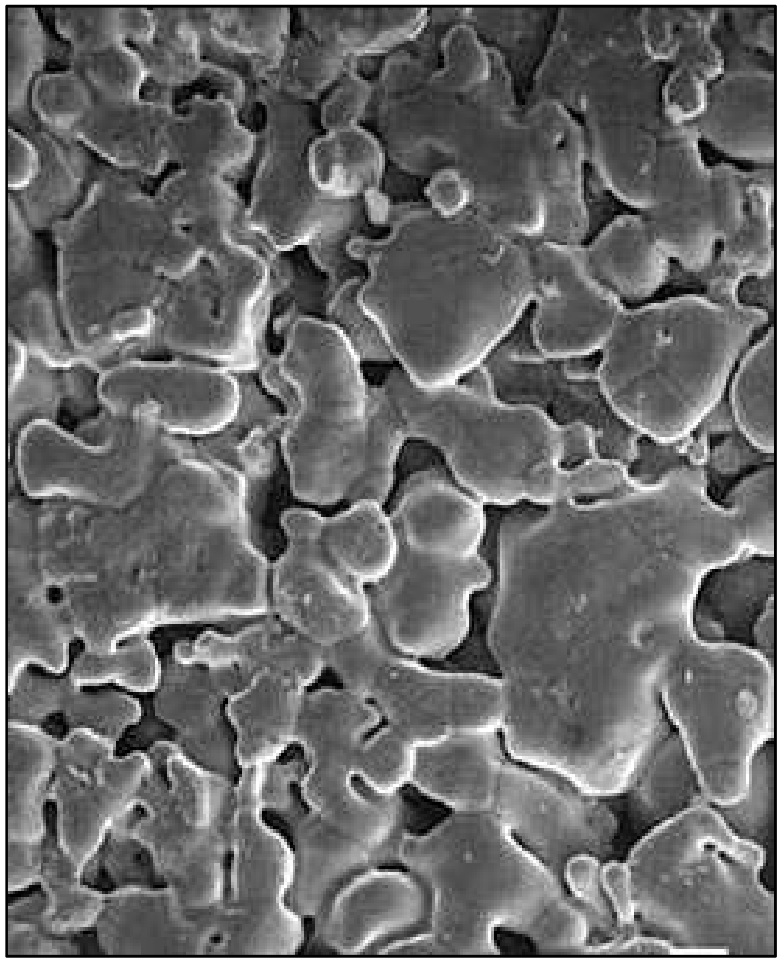
Stainless Steel Cross Flow Membrane



Graver Web site

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Ceramic Cross Flow Membrane

Pall web site

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Characteristics of Water Tested

- Haynesville gas shale waters are clear to yellow at the time of collection.
- Water becomes deep orange upon standing due to mixing with air resulting in iron oxidation.
- The orange color is due to formation of insoluble ferric oxide and hydroxide.

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Treatment Overview

Consolidated produced water

Untreated

pH adjusted and aerated

Filter or Membrane

Filter or Membrane

Permeate

Permeate

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Raw and Pre-Treated Feed Water before Filtration

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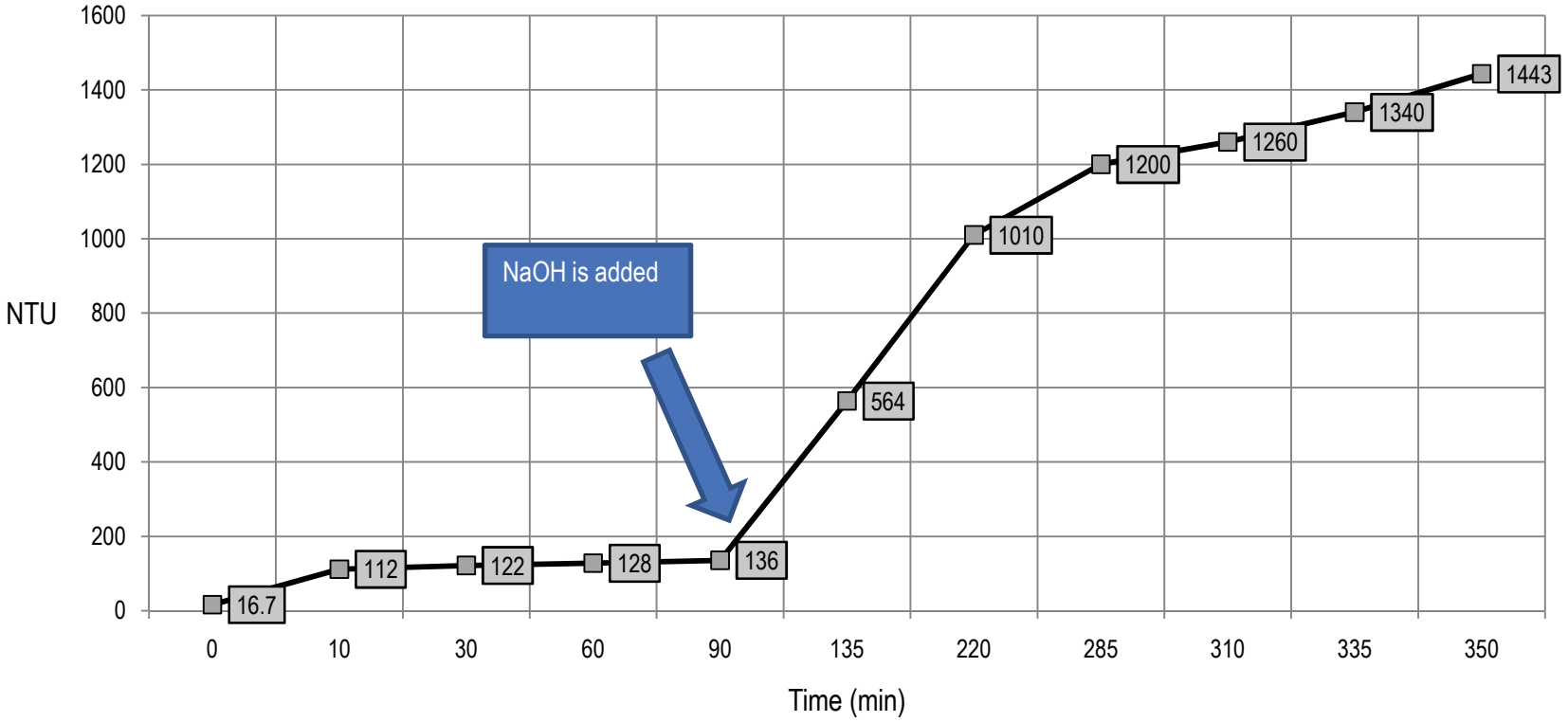
Effect of pH Adjustment on Ferric Oxide Production

pH-adjusted from 5.7 to 7.6 under continuous aeration



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Haynesville Produced Feed Water

Results for Feed Waters

Field (Warehouse)data	Raw water	pH-adjusted continuously mixed water after aeration	Untreated continuously mixed water
pH	5.7	7.6	5.6
Turbidity (NTU)	16.7	1443	125
Total Iron (mg/L)	160	150	170
TSS (mg/L)	550	1,400	680
Particle counts (/cc)	131,300	653,000	330,500

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Haynesville Produced Water Permeate

Filtration Results for untreated water : no pH adjustment and no aeration

Field (Warehouse)data	Untreated water	10 micron bag filter	KOCH hollow fiber membrane	Graver stainless steel membrane	Pall ceramic filter
pH	5.1	5.2	5.6	5.5	5.3
Turbidity (NTU)	125	120	0.5	2.1	0.12
Total Iron (mg/L)	180	180	130	140	140
TSS (mg/L)	680	660	500	640	670
Particle counts (/cc)	330,500	327,000	133,200	133,200	131,800

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Haynesville Produced Water Permeate

Filtration Results for Aerated and pH Adjusted water

Field (Warehouse)data	pH-adjusted continuously mixed water after aeration	10 micron bag filter	hollow fiber membrane	stainless steel membrane	ceramic filter
pH	7.3	7.3	7.3	7.4	7.3
Turbidity (NTU)	1440	980	3.0	1.9	2.3
Total Iron (mg/L)	144	140	1.4	<0.001	<0.001
TSS (mg/L)	930	430	130	430	210
Particle counts (/cc)	653,000	651,000	12,780	11,640	12,810

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Conclusions

- Membrane filtration alone is not sufficient for waters that contain dissolved iron, because subsequent iron oxidation results in reintroduction of TSS and turbidity.
- Aeration and pH adjustment converts the dissolved iron to a filterable size, eliminating the problem of post membrane reoccurrence.
- In combination with aeration and pH adjustment the ceramic, stainless steel and plastic UF membranes all produced a stable permeate, reduced the iron to its detection limit and resulted in TSS levels near drinking water quality.

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Thank you for your attention!

Questions

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