

AADE Fluid Management

February 23, 2012



Produced Water

- Is it a waste
 - Estimated at 25 Billion Barrels per year
 - By far the largest waste in the industry
- Is it a Resource
 - Halliburton estimates total water used for fracturing in 2008 was 3.5 billion Barrels (2011 very similar)

Water Worries

What is Driving the concern?

- Disposal availability & cost
- Fresh water availability & cost
- Regulations
- Quality of water for reuse in E&P fluids
- Public Relations

Water Uses Drilling and Completion

- Drilling Mud - 4000 to 10,000 BBL
- Rig Wash – 500 to 10,000 BBL
 - Some use up to 500 BBL/day
- Drill in completion Fluid – 1000BBL to 4000BBL
- Stimulation Fluid- 100,000 to 300,000 BBL
 - Some new fracs = 30 to 40 stages
approximately 300,000 bbls some even more

300,000 BBL Frac Job



Oilfield Wastewater Contaminants

- Categories
 - Organics
 - Dissolved Solids
 - Suspended Solids
 - Bio-contaminants
- Measured in parts per million (ppm) or milligrams per liter (mg/L)



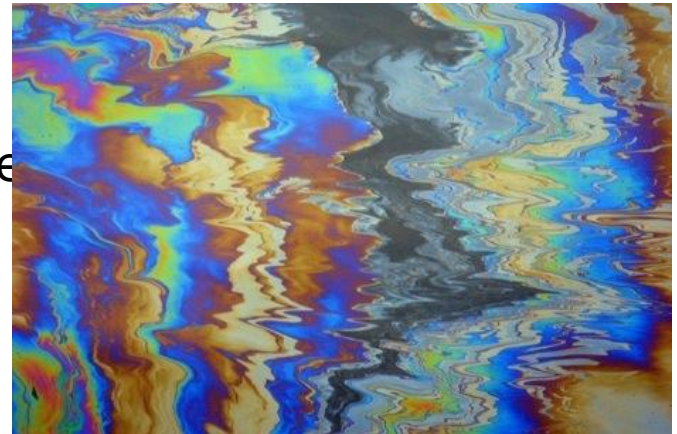
Oilfield Wastewater Contaminants

- **Suspended Solids** – float on the surface, suspended as a colloid, or suspended due to the motion of the water (not in solution)
 - Sand, silt, carbonates, clays, proppant, polymers...
 - Reported as Total Suspended Solids (TSS)
 - Cause sediment buildup, block light penetration, carry pathogens; abrasive on equipment; decrease well productivity



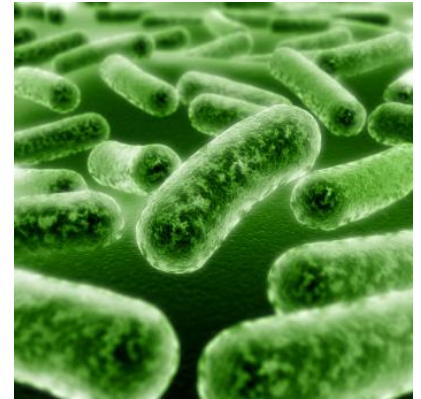
Oilfield Wastewater Contaminants

- **Organics** – carbon-based liquids, insoluble or partially insoluble in water.
 - Oil, grease, VOCs, BTEX, etc.
 - Harmful to humans, plant & animal life



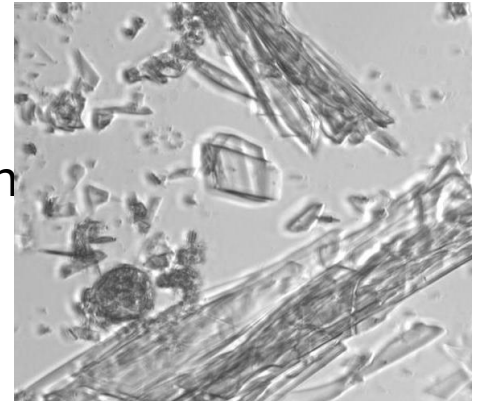
Oilfield Wastewater Contaminants

- **Bio-contaminants** – microorganisms present in water
 - Bacteria, algae, fungi...
 - Cause microbially influenced corrosion (MIC); contribute to creation of toxic substances (H_2S)



Oilfield Wastewater Contaminants

- **Dissolved Solids** – inorganic and organic substances molecularly dispersed in water
 - Salts, metals, minerals, treatment chemicals...
 - Includes toxic substances such as lead and arsenic
 - Includes NORM
 - Reported as Total Dissolved Solids (TDS)
 - Cause scaling, harm plants and wildlife, and interfere with municipal water treatment processes



Process	Organics	Low TDS <10,000 mg/L	Medium TDS <50,000 mg/L	High TDS >50,000 mg/L	Suspended Solids	Bio-Contaminants
Evaporation						
Membrane Filtration						
Advanced Oxidation						
Sorption						
Electrocoagulation						
Crystallization						
Flocculation/ Coagulation						
Gravimetric Separation						

Water Contaminates quantity

Table 3: Produced Water Quality – All Plays

PARAMETER	UNITS	HAYNESVILLE	COTTON VALLEY	EAGLE FORD	PERMIAN*
Total Alkalinity (as CaCO ₃)	mg/L	100 to 1,000	50 to 450	150 to 350	700
pH	SU	5.4 to 6.5	5.6 to 6.0	5.9 to 6.5	7.4
Specific Conductance	umhos/cm	31,000 to 235,000	150,000 to 280,000	700 to 9,500	48,000
Total Dissolved Solids	mg/L	7,300 to 190,000	100,000 to 170,000	500 to 6,000	30,000
Total Suspended Solids	mg/L	20 to 300	100 to 500	20 to 60	80
Total Organic Carbon	mg/L	20 to 1,400	10 to 2,100	15 to 1,800	6
Chloride	mg/L	7,000 to 110,000	50,000 to 100,000	100 to 3,200	1,600
Bromide	mg/L	20 to 300	300 to 600	1 to 20	160
Sulfate	mg/L	ND	ND to 350	ND	70
Barium	mg/L	10 to 500	10 to 250	1 to 3	3
Calcium	mg/L	500 to 13,000	1,000 to 10,000	5 to 35	300
Iron	mg/L	25 to 120	80 to 350	20 to 50	25
Sodium	mg/L	500 to 42,000	20,000 to 35,000	50 to 1,600	8,400
Strontium	mg/L	10 to 3,300	500 to 14,000	1 to 15	150

Water Quality Requirements

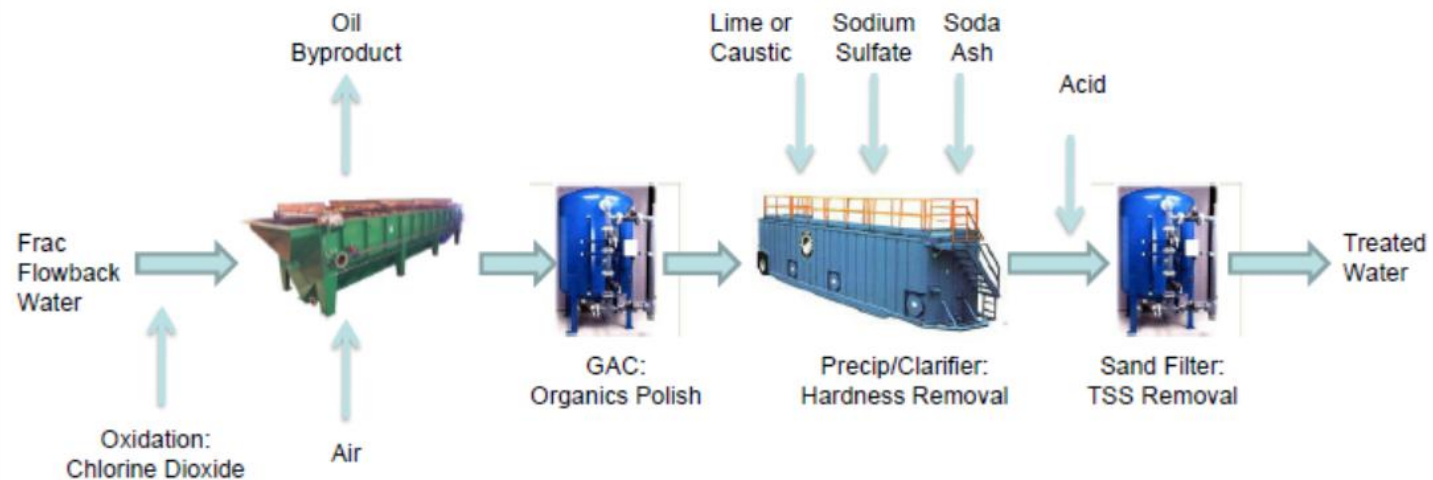
Table 4: Hydraulic Fracturing Fluid Requirements – All Plays

PARAMETER	UNIT	SLICKWATER	BLENDED SLICKWATER ¹	GEL
pH	SU	6 to 8	6 to 8	6 to 8
Chloride	mg/L	<30,000 ²	<90,000 ³	<100
Alkalinity (as CaCO ₃)	mg/L	<150	<400	<250
Hardness	mg/L	<180	<425	<300
Barium	mg/L	<100	<400	<150
Calcium	mg/L	<300	<1,000	<100
Iron	mg/L	<50	<150	<10
Phosphate	mg/L	<1	<1	<1
Sulfate	mg/L	<10	<50	<50
Bacteria	#/mL	<100	<100	<100
Total Suspended Solids	mg/L	<50	<150	<25
Total Dissolved Solids	mg/L	<40,000	<100,000 ³	<700
Entrained Oils / Organics	mg/L	<25	<25	<1

Simple Treatment

Example of Reuse Treatment Solution

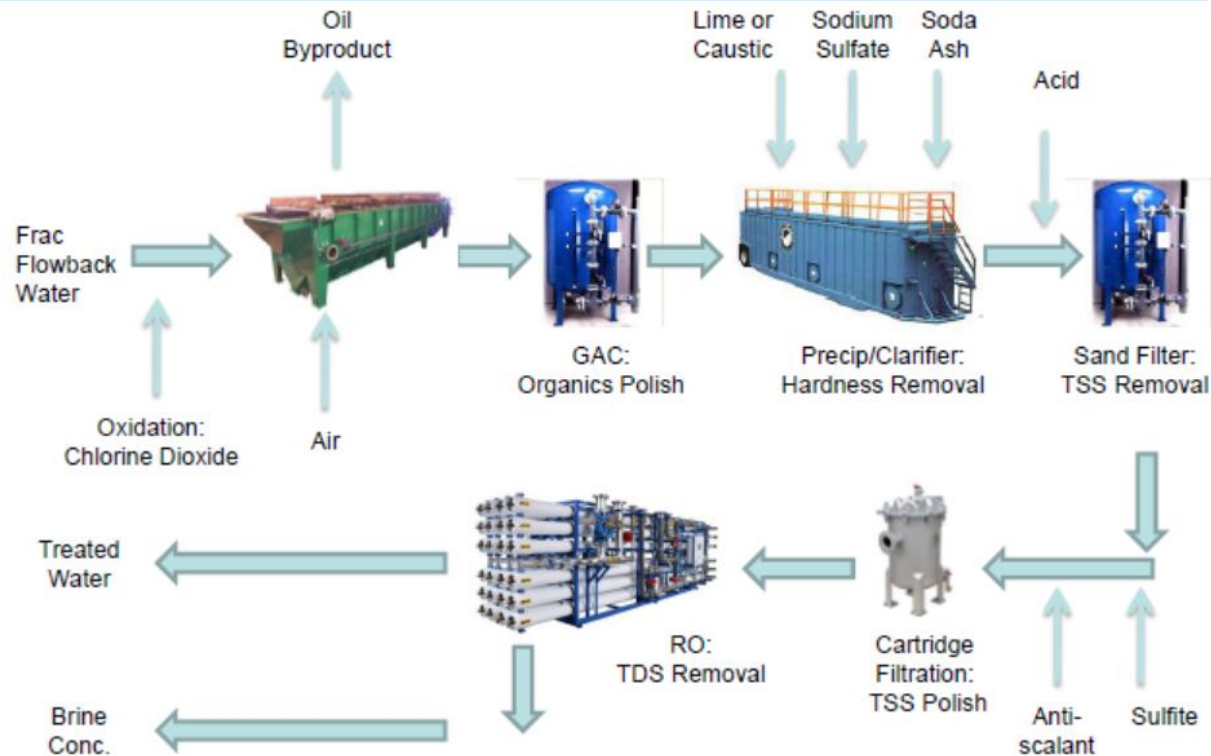
CDM



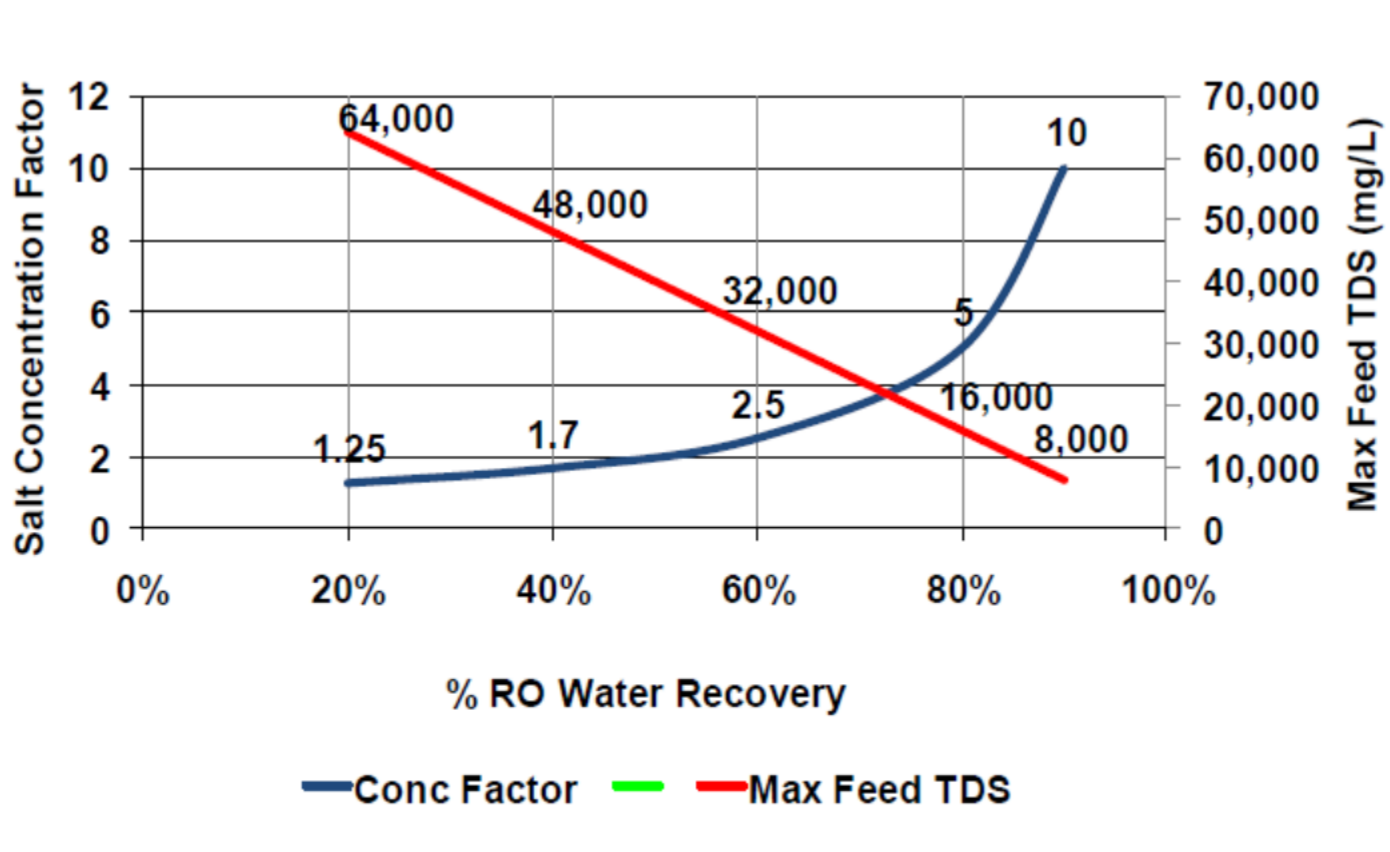
Flow Chart For TDS Removal

Example Treatment Solution for TDS Removal

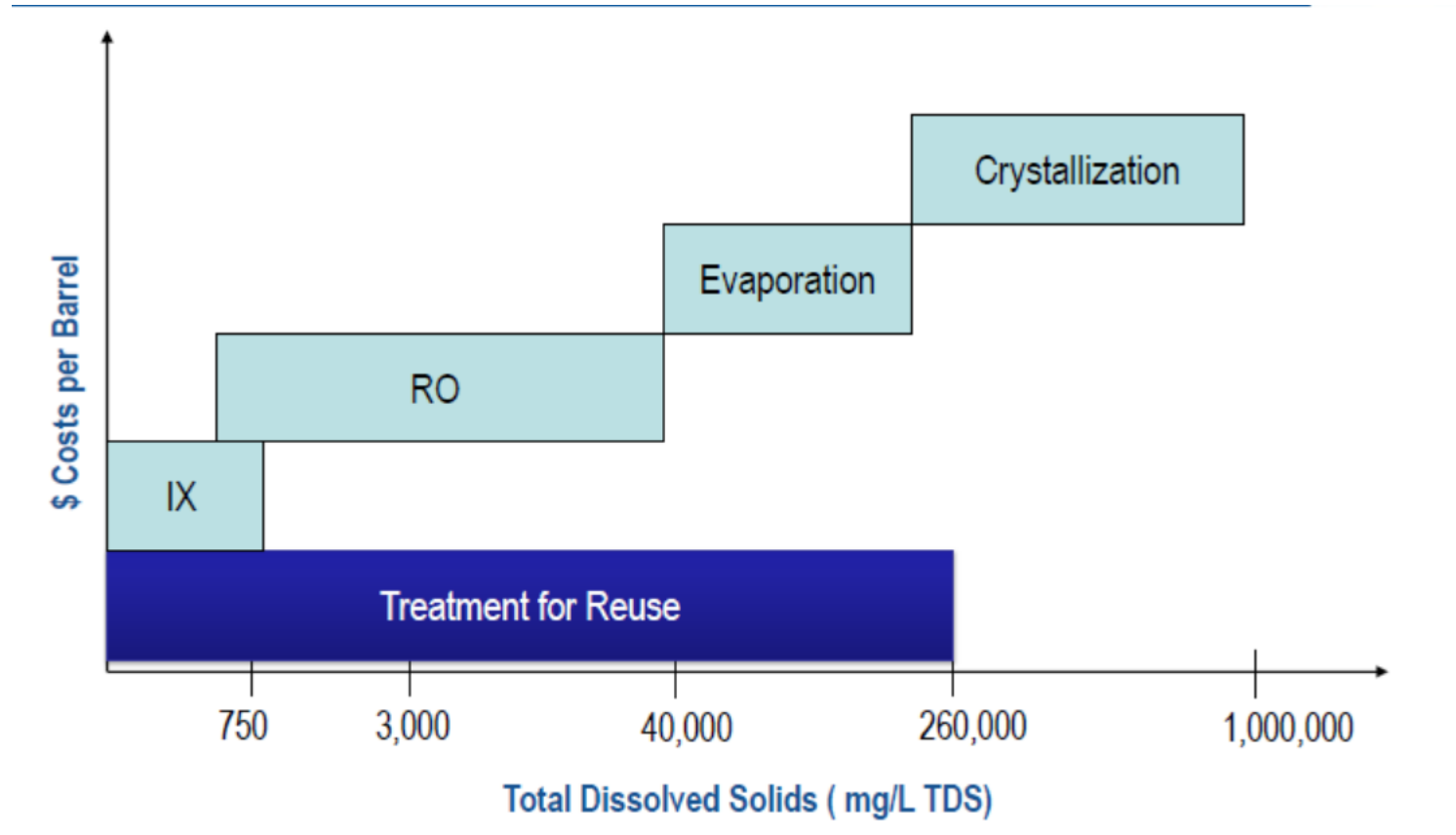
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Salt Concentration vs Recovery

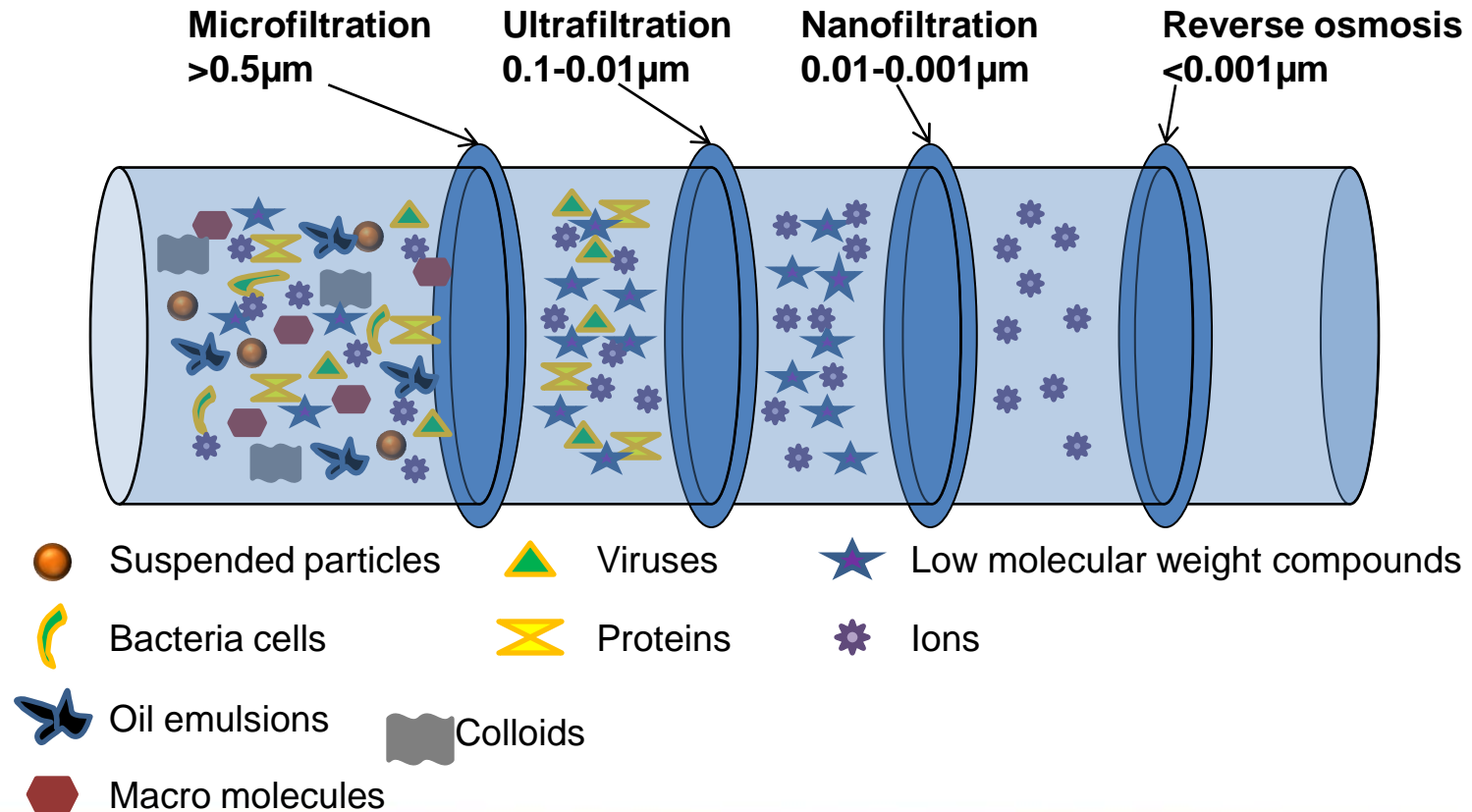


Cost and Applicability vs TDS



Technologies for Wastewater Treatment

Membrane Filtration



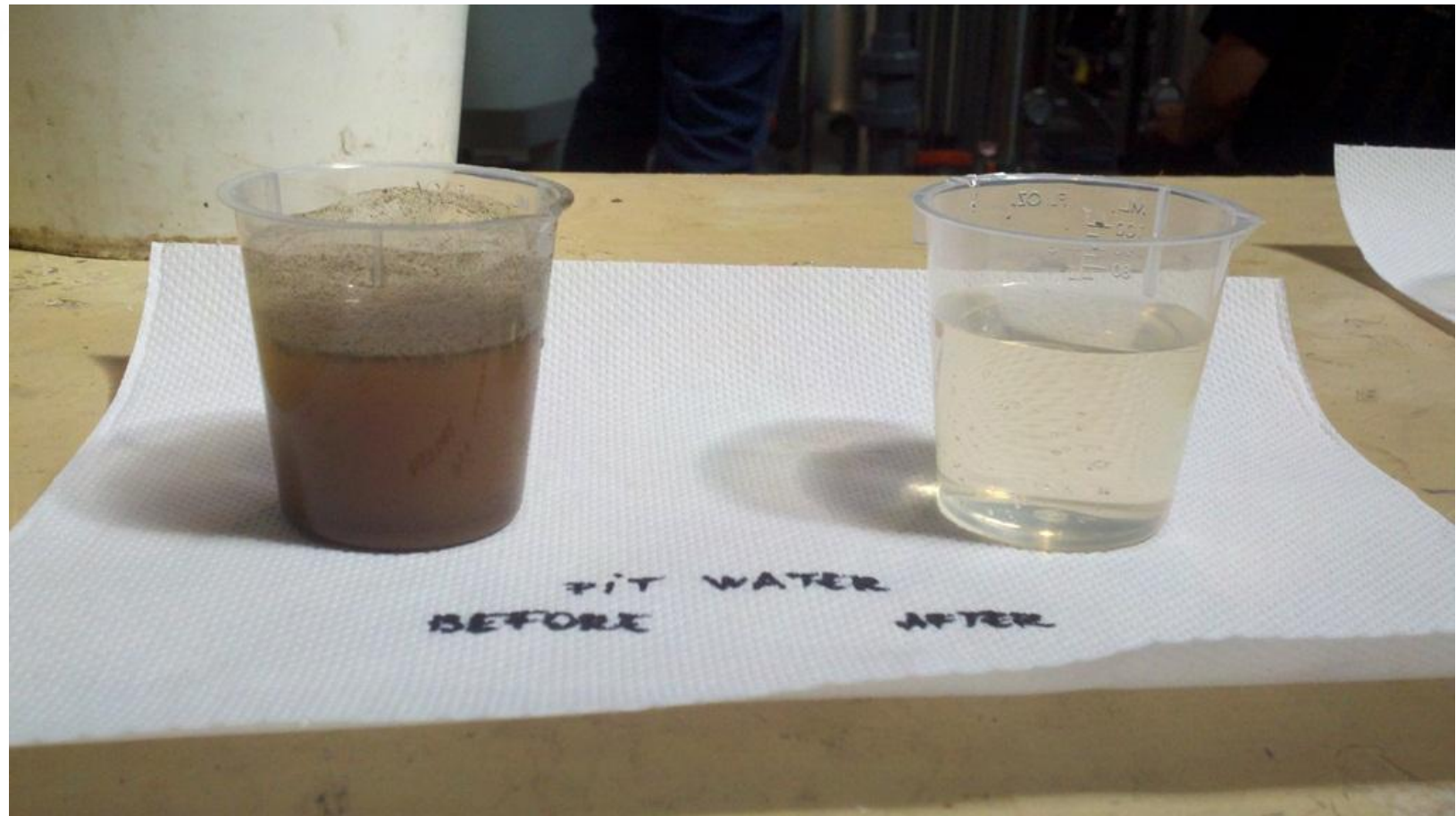
Fluid Source	Permian PW			Permian PW			Permian PW		
Sample code	CCHF1	CCHP		DNcmF1	DVNcmP		DNmnF1	DVNmnp	
Observations	With Pre-treatment			With Pre-treatment			With Pre-treatment		
Type of sample	Feed	Permeate	Δ%	Feed	Permeate	Δ%	Feed	Permeate	Δ%
pH	6.6	8.6		7.4	6.5		7.4	7.1	
TOC	99.0	60.0	39.4%	360.0		-100.0%			
COD	6,600.0	6,400.0	3.0%	6,000.0	370.0	-93.8%	12,000.0	650.0	-94.6%
Turbidity	550.0	14.0	97.5%	550.0	12.0	-97.8%	27.0	16.0	-40.7%
Alk. as CaCO3	480.0	450.0	6.3%	950.0	100.0	-89.5%	530.0	57.0	-89.2%
TDS	96,000.0	120,000.0	-25.0%	90,000.0	10,000.0	-88.9%	120,000.0	22,000.0	-81.7%
BOD	550.0	370.0	32.7%	5,500.0	39.0	-99.3%	1,900.0	51.0	-97.3%
TSS	660.0	63.0	90.5%	1,200.0	22.0	-98.2%	4,800.0	11.0	-99.8%
Ba	14.0	3.1	77.9%	35.0	29.0	-17.1%	2.4	1.4	-41.7%
Ca	3,600.0	1,300.0	63.9%	2,600.0	990.0	-61.9%	4,600.0	1,300.0	-71.7%
Fe	29.0	0.4	98.6%	7.6	1.0	-86.8%	160.0	0.0	-100.0%
Mg	520.0	2.7	99.5%	1,200.0	42.0	-96.5%	1,200.0	0.7	-99.9%
Sr	370.0	270.0	27.0%	440.0	160.0	-63.6%	92.0	24.0	-73.9%
Cl	58,000.0	63,000.0	-8.6%	49,000.0	5,500.0	-88.8%	62,000.0	12,000.0	-80.6%
SO4	700.0	620.0	11.4%	240.0	15.0	-93.8%	2,900.0	480.0	-83.4%
O&G	300.0	9.1	97.0%	29.0	nd		13,000.0	6.6	-99.9%
Heterotrophic Pt. Ct.	400.0	5.0	98.8%	ND	16.0		150.0	nd	
APB	nd	nd		ND	nd		nd	nd	
SRB	21.0	nd							

Fluid Source	Slop water			Pit Water			9 Pound Spent Mud		
Sample code	SLWF	SLWP		PTWF	PTWP		SMWF	SMWP	
Observations	UF only			UF only			UF only		
Type of sample	Feed	Permeate	Δ%	Feed	Permeate	Δ%	Feed	Permeate	Δ%
pH	7.7	8.0		7.5	7.5		8.8	8.6	
TOC	170.0	110.0	-35.3%	130.0	77.0	-40.8%	42.0	22.0	-47.6%
COD	660.0	470.0	-28.8%	18,000.0	4,500.0	-75.0%	2,700.0	140.0	-94.8%
Turbidity	70.0	12.0	-82.9%	2,600.0	4.1	-99.8%	5,000.0	0.6	-100.0%
Alk. as CaCO3	150.0	120.0	-20.0%	280.0	180.0	-35.7%	290.0	140.0	-51.7%
TDS	1,900.0	1,800.0	-5.3%	130,000.0	110,000.0	-15.4%	99.0	45.0	-54.5%
BOD	35.0	46.0		2,900.0	140.0	-95.2%	12,000.0	4.0	-100.0%
TSS	250.0	21.0	-91.6%	16,000.0	35.0	-99.8%	260.0	0.0	-100.0%
Ba	0.4	0.2	-48.8%	56.0	9.2	-83.6%	430.0	0.4	-99.9%
Ca	270.0	230.0	-14.8%	19,000.0	18,000.0	-5.3%			
Fe							48.0	0.1	-99.8%
Mg	2.4	2.3	-4.2%	270.0	200.0	-25.9%	18.0	0.0	-100.0%
Sr	3.2	2.8	-12.5%	1,200.0	1,100.0	-8.3%			
Cl	380.0	810.0		55,000.0	52,000.0	-5.5%			
SO4	20.0	18.0	-10.0%	220.0	240.0				
O&G	8.4	nd		33.0	nd		8.6	nd	
Heterotrophic Pt. Ct.	22,000.0	28.0	-99.9%	11,000.0	15.0	-99.9%	22,000.0	49.0	-99.8%
APB	460.0	nd		2,400.0	nd		1,100.0	nd	
SRB	2,400.0	nd		nd	nd		460.0	nd	

Membrane Separation



Pit Water



Mobile Membrane Separation



Questions