The Proper Care and Feeding of Salt Water Disposal Wells

Robert Perry

Wesley Teasdale

NALCO Champion
An Ecolab Company

Taking Energy Further™

Introduction

Water treatment for disposal:

- Protect assets (e.g., electrochemical corrosion, bacterial induced corrosion, and scale),
- Protect the near bore-hole formation from plugging and damage (scale, TSS, oil, bacteria), and
- Minimize oil loss

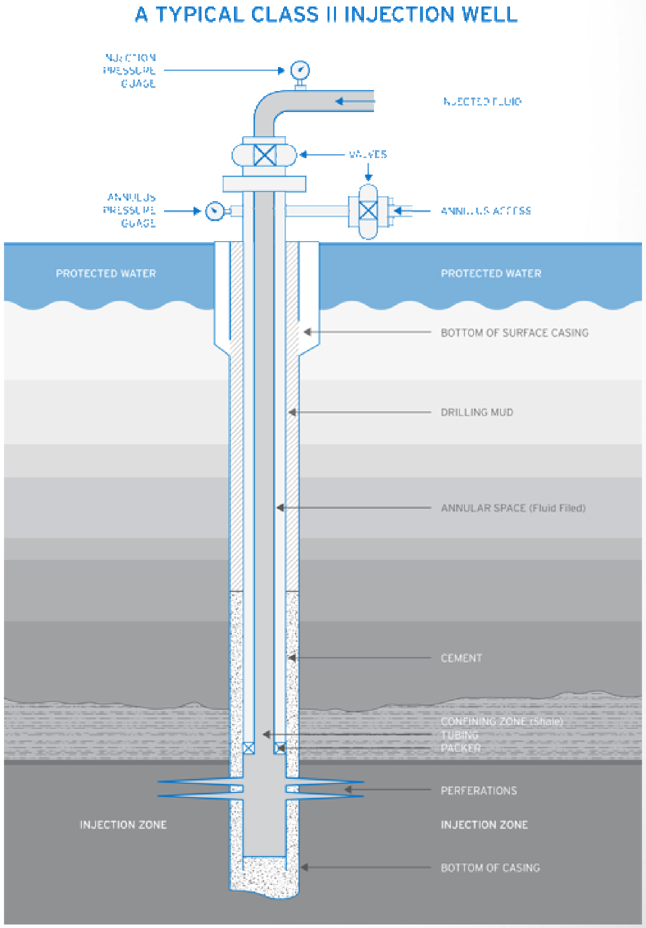
Poor water quality can degrade even high quality porous formations and lead to increased maintenance costs for the injection well

– its easier to inject cleaner water

Design of a Class II Well

The design and operation of a Salt Water Disposal Well (SWD) is dependent on:

- The planned operating conditions
- The general reservoir characteristics of the injection zone, and
- The quantity and quality of the water to be injected



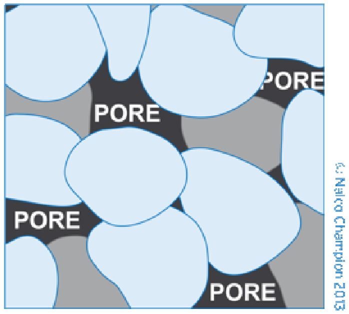
Operational Consideration – what level of treatment is necessary

- Open hole or cased and perforated completion
- Geology and Hydrogeology of the injection zone
- Compatibility of injection fluids with each other and the injection zone and formation fluids
- Permitted volume and pressure of injection

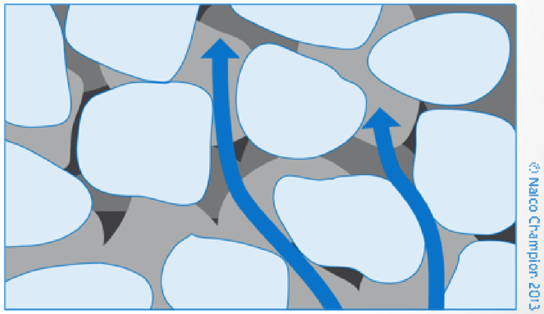
Injection Zone Characteristics - Porosity & Permeability

Measure of how easily water will flow through the rock and the size of particle the formation will accept without plugging.

Rule of Thumb: particle sizes need to be less than 1/3 the size of the pore opening so that if stacking occurs the formation will not become plugged



Porosity



Permeability

Injection Zone Characteristics – Compatibility of the Injected Fluids with the Formation

Formation Stability: Upon contact with non-equilibrium injection fluids, clays and other fine grained materials present in the injection zone formation are susceptible to:

- Migration (Clay deflocculation)
- Structural alteration (swelling)

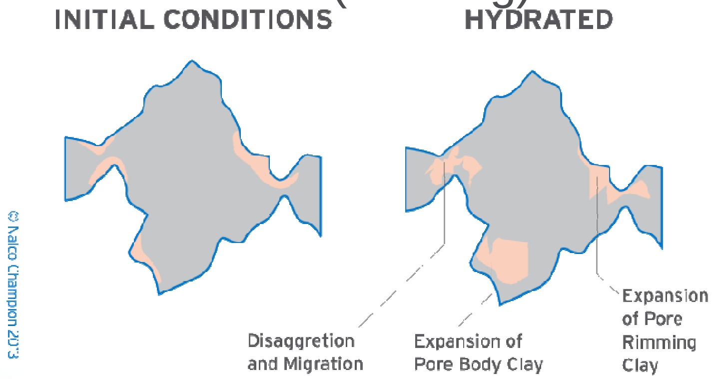


Illustration of Formation Damage Due to Clay Swelling

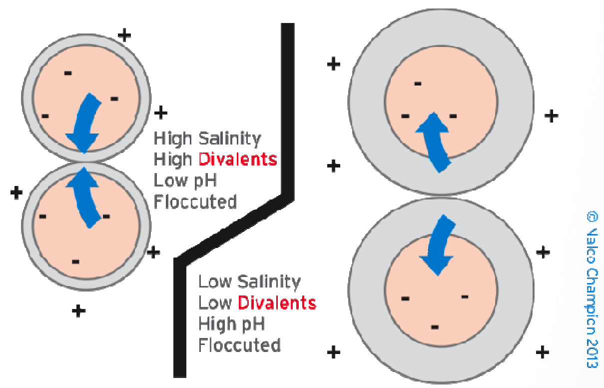


Illustration of Mechanisms of Clay Deflocculation

Water Chemistry and Fluid Compatibility

Water chemistry is perhaps the most important aspect to understand regarding sub-surface disposal and injection operations. Water chemistry consists of:

- cationic and anionic properties (dissolved solids),
- pH,
- suspended solids,
- temperature,
- pressure,
- specific gravity,
- dissolved gasses, and
- bacteria

Water Compatibility – Scale Formation

Dissolved Solids	
Common Cantions (+)	Common Annions (-)
Sodium (Na^+)	Chloride (Cl^-)
Calcium (Ca^{2+})	Bicarbonate (HCO_3)
Magnesium (Mg^{2+})	Carbonate (CO_3)
Iron (Fe^{2+})	Sulfate (SO_4)
Barium (Ba^{2+})	
Potassium (K^+)	

Water Chemistry – Scale Formation

- The biggest potentials for scale formation in SWD applications are related to changes in temperature and pressure, and the mixing of waters.
- Common scale inhibitors are nucleation or crystal growth modifiers, with phosphonate and phosphate esters being better nucleation inhibitors with polymers being better crystal growth modifiers.
- When selecting scale inhibitors, product compatibility is a main concern.
- The application of scale inhibitors for water systems should be continuous and upstream of the onset of scaling.

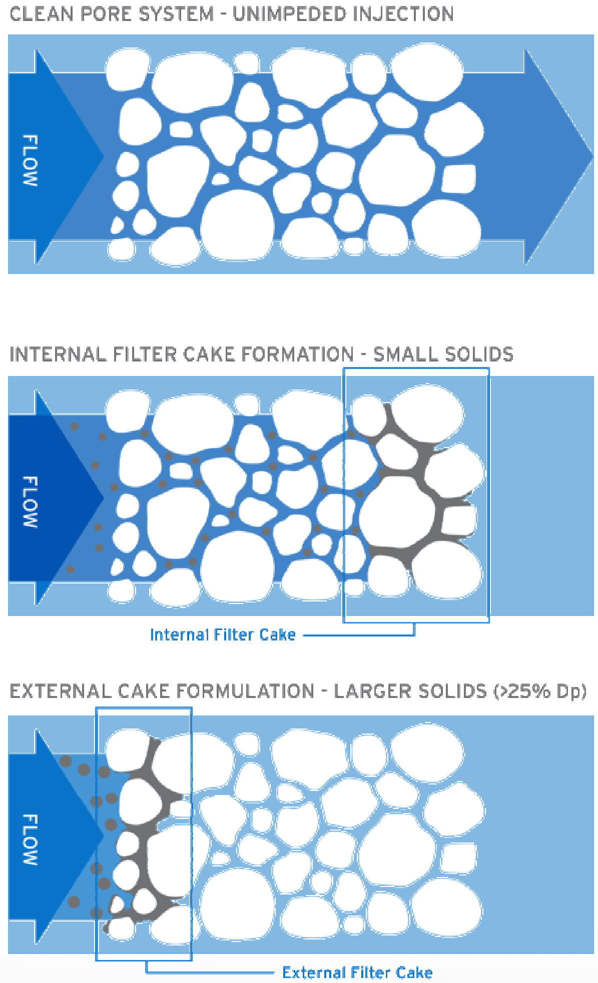
Water Quality – Suspended Solids

Total Suspended Solids (TSS) refers to any particulate matter that is suspended in the water phase.

- Scales,
- Corrosion products,
- Bacteria and algae
- Formation materials such as sand, silt, and clays.
- Foreign materials such as frac sand, drilling mud, and chemicals associated with these operations

Suspended solids can have a negative impact on fluid treating equipment, reduce run time of filter systems, and can plug formations.

Water Quality – Suspended Solids



Water Quality – Corrosion

Corrosion is a process that can be reduced but not eliminated. Factors influencing electrochemical corrosion:

1. Higher the chloride concentration, faster the reaction (greater concern when >50,000 ppm in water)
2. pH: has the most influence, lower pH faster the reaction
   - pH between 6.5 and 7.0 = mild corrosion
   - pH between 6.0 and 7.0 = moderate
   - pH less than 6.0 = aggressive
3. Dissolved Acid Gases: CO2, H2S, O2
4. High velocity, history of corrosion, and changes in field characteristics also are issues of concern

Water Quality – Corrosion

SWDs and the associated equipment are a water wet system that will need a robust corrosion prevention program. Corrosion inhibitors are a commonly used to address corrosion protection.

When selecting a corrosion inhibitor, the source of corrosion must be determined (e.g., presence of CO_2 and or H_2S as well as oxygen or bacteria). General types of corrosion inhibitor chemistry include:

- Amines
- Fatty Acids
- Quaternary Amines
- Sulfur Compounds
- Phosphate Esters

These products are applied continuously upstream of the injection system at rates in the range of 10-20 ppm.

Water Chemistry - Bacteria

- Bacteria can be single or multi cell microorganisms that exist everywhere.
- Bacteria can grow rapidly where conditions are suitable and they can utilize a wide range of nutrients, both organic and inorganic.
- Bacteria can be classified by their respiration, cell structure, growth parameters and eating habits.
- Bacteria exist as planktonic (free floating) or sessile (attached). Sessile bacteria can form environments that promote microbial induced corrosion (MIC).

Water Chemistry - Bacteria

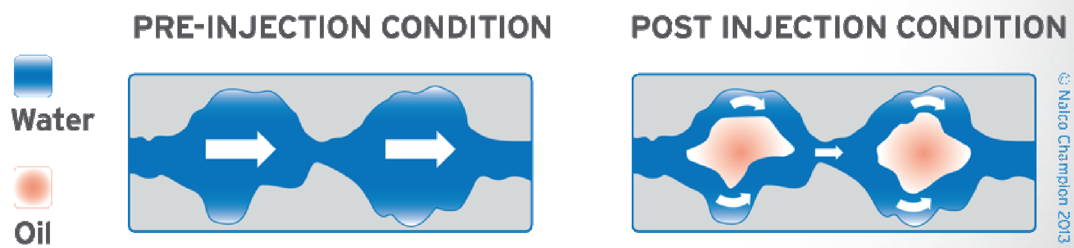
Bacteria can cause several issues in a water treating system, including but not limited to:

1. Biomass accumulation in dead areas of flow lines and equipment, or in the formation
2. Formation of iron sulphide deposits
3. Decline in water injectivity, increasing line pressure or plugging
4. Increased levels of H2S.
5. Microbial Influenced Corrosion (MIC).

Water Quality – Oil Content

Oil in water streams causes five main problems

1. Loss of revenue for the operator,
2. Serves as a food source for bacteria,
3. Strongly absorbs on to iron sulfide and other scale deposits, reducing the ability to remove these deposits with acid treatments,
4. Reduced filter run times, and
5. Reduces the relative permeability to water in the injection well.



Effect of Skim Oil Injection Into a Water-Saturated Zone

Water Chemistry and Water Quality Criteria

The following guidelines have been established by industry professionals and adopted by Nalco Champion as general water quality requirements for injection water.

- pH: 6.5 – 7.5
- TDS: matched to formation (scaling saturation index <1)
- TSS: < 50 mg/L, 5 micron or less
- Non Corrosive: < 2 mpy
- Oxygen Free: < 50 ppb
- Oil Carryover: < 100 ppm

These specifications serve as a good starting point for acceptable water quality for injection. However, the nature of the formation is the ultimate deciding factor, and in some locations, stricter requirements may be necessary, especially for TSS.

Common Water Treatment Technologies

Increasing Cost

Technology	Application	Technology	Use	CAPEX	OPEX	Maturity	Performance
Filtration	TSS (Build, buy system, $/barrel)	Bag, cartidge, and self cleaning filters, Multimedia filters, sand filters, active media filters, solids hydrocylcones					
Separation	Dispered Oil Separation (Build, buy system, lease service)	Flotation, Active Filtration, selective mebrane, hydrocyclone					
Chemicals	Oxidation	ClO2, MIOX, PAA, Bleach, Ozone					
	THPS/DBNPA/Glut/Quat	Biocides					
	Scale Inhibitors	SI, SORB, Encapsulated SI					
	Production Enhancement Surfactants	Wetting agent, microemulsion agents					
Membrane Separation	TSS/Nano Filtration	Filter and ceramic, Doped ceramic					
	TSS/Reverse Osmosis	Deoil, filter, and RO					
	TSS/Electrocoagulation	Deoil, filter, coagulation					
Thermal Desalination	Deoil/TSS/TDS	Vapor Recompression, Falling Film					
	Deoil/TDS	Membrane Pervap					

Common, Inexpensive, Proven ⟷ **Uncommon, Expensive, Unproven**

Water Treatment Technologies

Chemistry key to optimizing equipment

Low Cost → High Cost

PW Spec	Associated Chemical Treatment	Equipment: Primary	Low Polish	Traditional Ion/colloidal Removal	Select Ion Removal, Adsorption	High Polish	Evaporation / ZLD
	Chemistry	Simple Filtration/ Separation	Advanced filtration, Flotation	Coagulation/ Softening Air Strip, Chemical	IX/NF, UF	NF+RO, UF, Biological	Evaporation/ Crystallization
TSS (mg/L)	Coagulants, Water Clarifiers, Filter Aid Polymers	50	5	10	<2	<2	<2
Min Particle Size (um)	Filter Aid Assistance with Chemistry (DMA, PAC)	10	25	0.5	0.002	Soluble	Soluble
Gas (H_2S, O_2), %	Scavengers	<10%	<10%	95%+	N/A	99%+	99%+
Oil & Grease (mg/L)	Reverse Breakers, Coagulants, Flocculants	100	<50	<50	<2	<2	<2
COD/BOD, %	Oxidizers (i.e. PAA)	0.1	0.2	0.2	N/A	>95%	0.99
Divalent Ion (Ca, Mg, Sr, Ba, SO_4) %	Chemical pretreatment required (see above)	<20%	<20%	0.5	0.9	90%+	0.99
NORM, %	Chemical pretreatment required (see above)	0.1	0.5	>75%	0.9	0.99	0.99
Fe Removal, %	Chemical treatment and/or oxidizers	<20%	20-90%	20-90%	90%+	0.95	0.99
TDS Removal %	Significant chemical pretreatment required (see above)	0	0	20-90%	50-99%	0.99	0.99
Hardness %	Chemical pretreatment required (see above)	0	0	>75%	>75%	30-99%	0.99

Peracetic Acid Application for Injection Wells/SWDs

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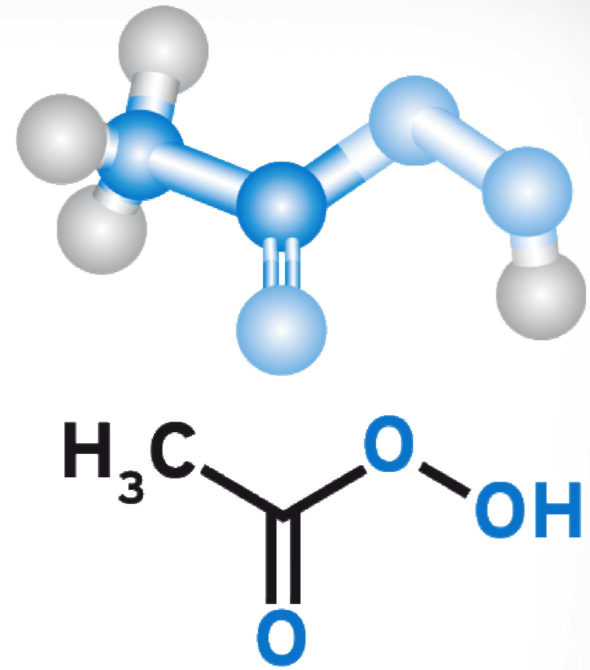
Peracetic Acid



Oxidizing biocide

- Broad Spectrum / Rapid microbial kill

Widely used in the food/beverage industry

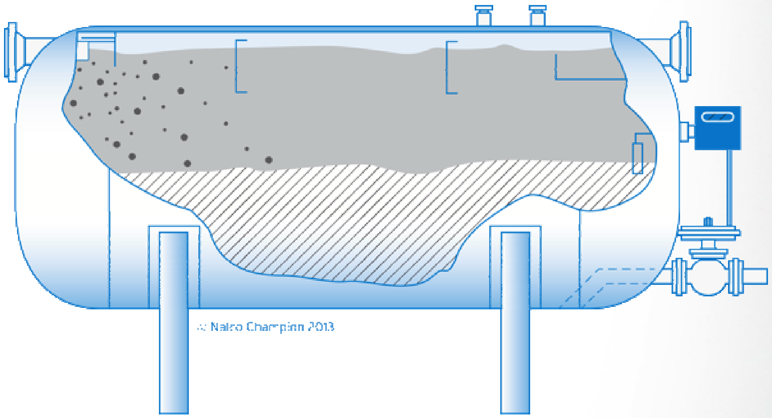
- Equipment and direct food sanitizing
- Used/produced globally for decades

Registered for use in oilfield's

Peroxyacetic Acid (PAA) is a reaction product of **Acetic Acid** (HOAc) and **Hydrogen peroxide** (H_2O_2)

PAA is produced via an **equilibrium reaction** (always has HOAc and H2O2 present) Breakdown into innocuous compounds: **water and vinegar**

Recent trials have qualified new applications for SWDs

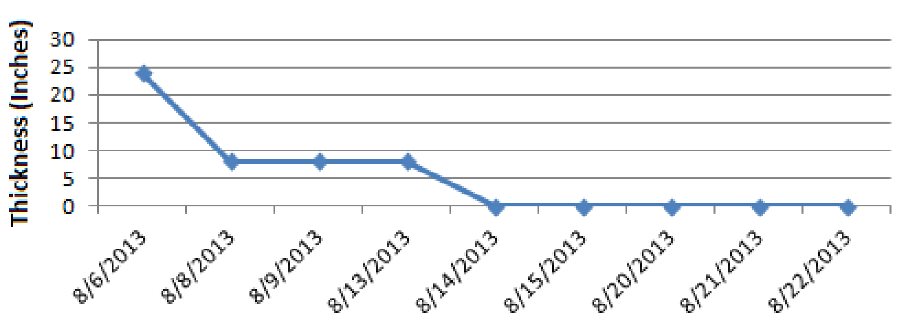
Salt Water Disposal Wells	Freewater Knockout Vessel Pretreatment
	
Needs: FeS removal, microbial control, H_2S removal for pre-filter changes, reduced well pressure	FeS emulsion interface reduction, improved water quality, less slop oil, microbial control

PAA Rehabilitation of FWKO

- Customer challenges:
  - Microbial growth
  - Emulsion pad/bad water and oil quality
  - H_2S produced by microbes
- Implemented treatment in FWKO
  - Reduced FeS emulsion pad to 0” from 25”
  - Reduced H_2S 4-5X
  - Improved oil separation and improved water quality
  - Significant microbial reduction (94%)

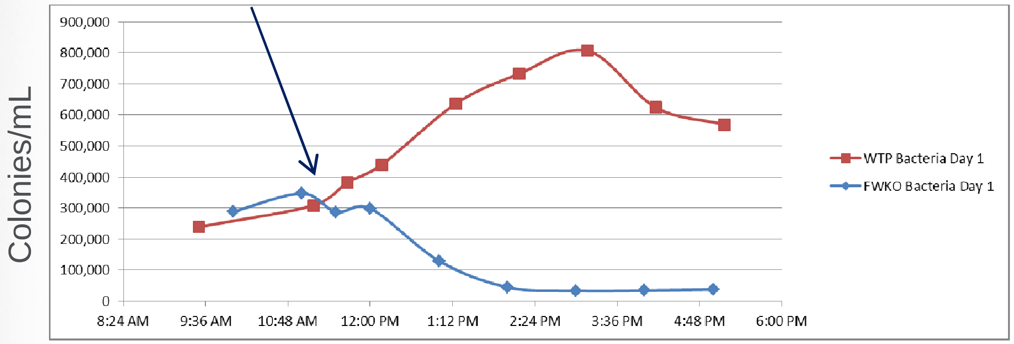
Before

After



PAA Rehabilitation of FWKO

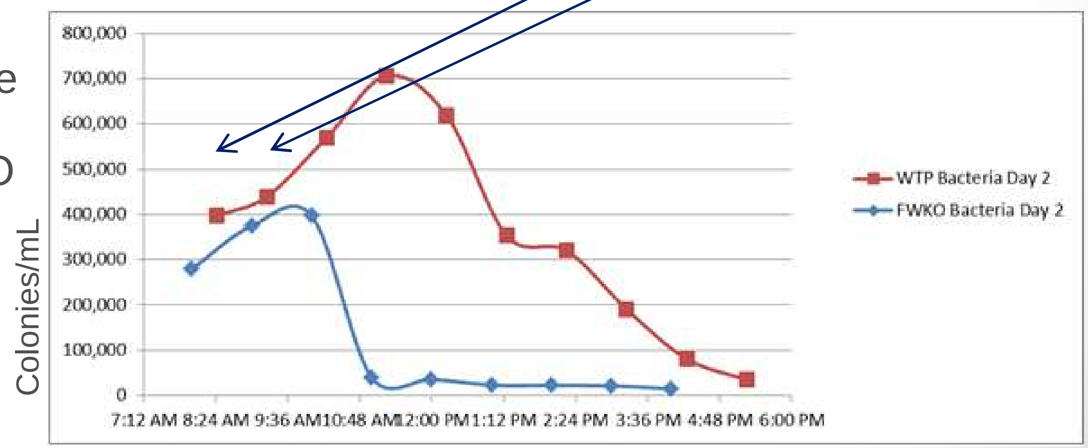
1000 PPM PAA @ 10:45 AM



- Day 1 Significantly decreased bacteria levels in FWKO
- Cleaning released sessile biomass from facility

1000 PPM PAA @ 8:30 AM
1500 PPM PAA @ 9:30 AM

- Day 2 Concentration increase removed new level of biofilm/FeS residual in FWKO
- Trend follows more rapidly down stream in large volume water transfer tanks

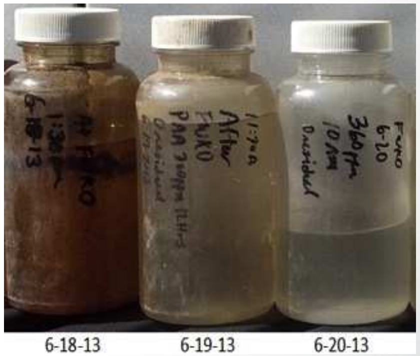


PAA Oil Well 3-Phase Treatment

- Pre-separation water, oil & gas (4000 bbl water/day, 2000 bbl oil/day)
- Results:
  - Significant injection well pressure and H2S reduction

		After 5 Days	%
	Pre trial	PAA Treatment	Reduction
Gas H_2S	20,000 ppm	2,000 ppm	90
Oil Production H_2S	10,000 ppm	2,000 ppm	80
Water H_2S	10,000 ppm	22 ppm	99.8
Inj Well Pressure	1,700 psi	1,375 psi	19

  - Significant micro reduction (using ATP) and water clarification



  - FeS Build up in injection filter significantly reduced

Questions?