Improving Salt Water Disposal Well Performance With Chlorine Dioxide

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Energizing Chemistry

SWD's Are A Headache

Typical problems

SWD Tankage

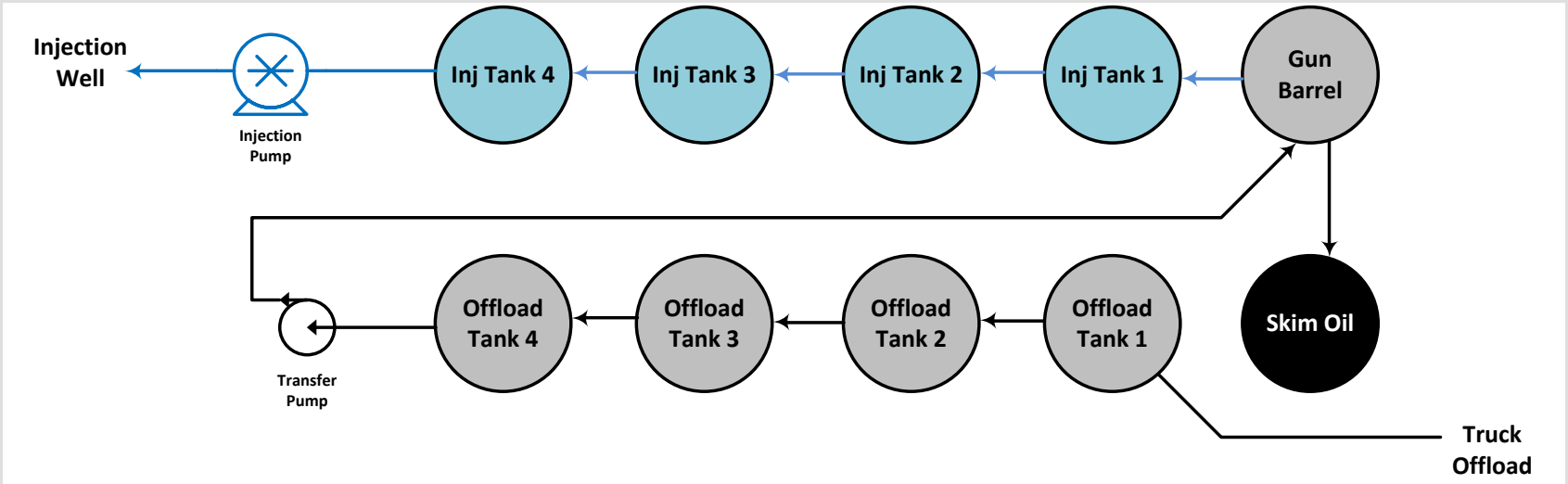
- Provides residence time for bacteria growth
- SRB's proliferate
  - Produce H_2S
  - FeS

Water

- Contains hydrocarbons
- Sour
- Contaminated with bacterial biofilm, oil/water emulsions, FeS, etc.

Disposal underground into a formation with small pores

Typical SWD Design



In Theory

- Offload tanks provide equalization
- Gunbarrel allows oil/water separation
- Oil is skimmed for sale
- Clean water injected downhole

In Reality

- Water becomes increasingly “dirty” passing through system
- Black “septic” water
- H_2S
- Floating emulsion layer (hydrocarbon, FeS, biofilm)
- Septic sludge on bottom of tanks
- Wellbore pluggage

SWD Problem Causes

Combination of water, food and time

- Bacteria proliferate = floating biomass
- Anaerobic bacteria produce H_2S
- H_2S + Fe = FeS (Iron Sulfide)
- FeS + Oil + Water + Biomass = Stable Emulsion

The Result

- Emulsion
  - Plugs well bore and formation
    - High pressures, lower injectivity
  - Requires periodic manual cleaning
- H_2S endangers employees
- Oil tied up in emulsion can't be recovered for sale
- Lower quality skim oil (High BS&W)

SWD Solutions

The Solution Must

- Kill bacteria
- Eliminate H_2S, which
  - Stops corrosion and FeS formation
  - Improves worker safety
- Eliminates FeS to break up oil/water emulsion

ClO_2 and/or s-ClO_2

- Destroys H_2S by converting to soluble SO_4
- Dissolves FeS, destabilizing oil/water emulsion
  - Converts sulfur to SO_4
  - Iron to $Fe(OH)_3$
- Kills bacteria and destroys biofilm

Note that no other chemistry is required to treat the SWD's discussed in this paper.

Where to Feed ClO_2 or s-ClO_2 to an SWD

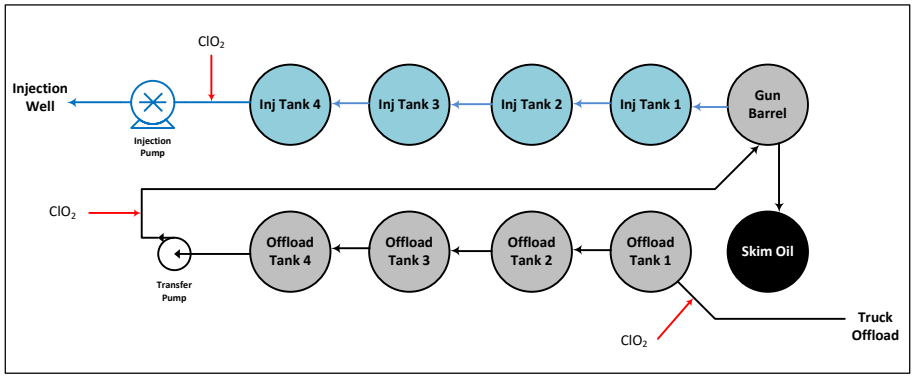
Unloading Lines/Tanks

- Cleans entire system
- Minimizes all tank cleanings
- No H_2S
- Improved skim oil recovery & quality
- Clean injection water
- Maintains well bore cleanliness
- Lower injection pressure
- Higher injection rates

- **Gunbarrel**
- Transfer line to gunbarrel
- Cleans gunbarrel and injection tanks
- No H_2S downstream of injection point
- Improved skim oil recovery & quality
- Clean injection water
- Maintains well bore cleanliness
- Lower injection pressure
- Higher injection rates

Well Only

- Continuous or intermittent
- s-ClO_2 not recommended
  - Slower reaction kinetics
- Continuous treatment more costly than treating entire SWD system
- Intermittent treatment may be economical
  - Treated like a stim job
- Lose the benefits of improved skim oil recovery & quality
- Does not eliminate H_2S in the system



2 Methods For Initial Cleanup of SWD System

Isolate Individual Tanks

- Isolate tank and circulate while dosing with ClO_2
- Fast cleanup (< 1 day per tank)
- Only works with ClO_2

Clean Entire System Together

- Feed ClO_2 or s-ClO_2 to the portion of the system to be treated
- Fed at modest dosages
- Cleans up progressively through the system as contaminants are destroyed
- May take from a few days to several months.

Key Considerations

- Large amounts of contamination in sludge layers and emulsion pads
- Impossible to know how much chemical/time is required for initial cleaning
- After cleaning, maintenance dosage much, much lower.

Dosage Determination

General Comments

- Impossible to know how much contaminant present in sludge & emulsion that ClO_2 will react with
- Do need to know the demand of the bulk water so that sufficient chemical is fed to obtain a residual in the water to gradually react with and eliminate contaminants in sludge and emulsion layers

Offloading Tanks

- Demand is highly variable
- Collect samples from as many trucks as possible for at least a week
- Test a daily composite sample

Gunbarrel

- Less variable water quality
- Offloading tanks provide equalization
- Analyze daily sample from transfer line for one week

Monitoring System Performance

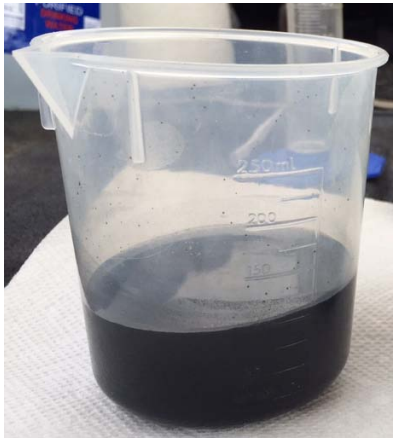
ClO_2 or s-ClO_2 Residual
- Simple titration procedure
- Monitor residual in each tank to insure adequate chemical present

Injection Pressure
- Should decrease after system tanks are clean
- Pressure increase would indicate inadequate chemical feed

Disposal Well Injectivity Rate
- At similar injection pressure, injection rate should increase
- Higher injection rates can increase injection pressure

Skim Oil Quality & Quantity
- Recovery rates highly variable with the source of disposal water
- Quality will increase dramatically
  - Typical BS&W <0.3%
  - Skim oil more valuable

Visual Observation of Injection Water
- Clear
- No suspended solids



Case History #1

Treatment Program: ClO_2
Length of Time: 1-1/2 years
Water Injection Rate: 5,200 bpd
Chemical Injection Location: Transfer Line to Gunbarrel
Chemical Dosage: 24 ppm
Injection Well Pressure Before: 780 psig
Injection Well Pressure After: 680 psig
BS&W Before: 4+%
BS&W After: <0.2%
Comments: First system to be treated. The injection well pressure decreased within 3 days of beginning treatment. Injection rate has increased from 3,300 bpd to 5,200 bpd at the lower injection pressure.

Case History #2

Treatment Program: ClO_2
Length of Time: 8 months
Water Injection Rate: 1,800 bpd
Chemical Injection Location: Transfer Line to Gunbarrel
Chemical Dosage: 37 ppm
Injection Well Pressure Before: 1,600 psig
Injection Well Pressure After: 1,250 psig
BS&W Before: 4+%
BS&W After: <0.2%
Comments: An initial well stimulation was done with ClO_2 to lower the injection pressure, which was exceeding permitted limits. The system from the Gunbarrel downstream is now treated with ClO_2 to maintain system cleanliness and low well pressure.

Note orange color due to iron (converted FeS to $Fe(OH)_3$ and precipitated, allow removal before injection. Note how clean water is after system is cleaned up and on maintenance treatment in the 2nd photograph.

Case History #3

Treatment Program: ClO_2 and s-ClO_2
Length of Time: 1 year
Water Injection Rate: 833 bpd
Chemical Injection Location: Transfer Line to Gunbarrel
Chemical Dosage: 37 ppm
Injection Well Pressure Before: 1,500 psig
Injection Well Pressure After: 1,000 psig
BS&W Before: 4+%
BS&W After: <0.2%
Comments: An initial well stimulation was done with ClO_2 to lower the injection pressure, which was exceeding permitted limits. The system from the Gunbarrel downstream is now treated with s-ClO_2 to maintain system cleanliness and low well pressure.

Case History #4

Treatment Program: **s-**ClO_2
Length of Time: **5** months
Water Injection Rate: 1,500 bpd
Chemical Injection Location: Transfer Line to Gunbarrel
Chemical Dosage: 300 ppm
Injection Well Pressure Before: 1,400 psig
Injection Well Pressure After: 900 psig
BS&W Before: 4+%
BS&W After: <0.2%
Comments: An initial well stimulation was done with ClO_2 to lower the injection pressure, which was exceeding permitted limits. The system from the Gunbarrel downstream is now treated with s-ClO_2 to maintain system cleanliness and low well pressure.

Case History #5

Treatment Program: **s-**ClO_2
Length of Time: 1 year
Water Injection Rate: **3**,800 bpd
Chemical Injection Location: Transfer Line to Gunbarrel
Chemical Dosage: 45 ppm
Injection Well Pressure Before: 750 psig
Injection Well Pressure After: 660 psig
BS&W Before: 4+%
BS&W After: <0.2%
Comments: System was cleaned up and is maintained with s-ClO_2

Summary

Both ClO_2 and s-ClO_2 have demonstrated the following benefits in SWD's

- Clean tanks, including the gunbarrel
- Eliminate sulfides (primarily H_2S)
  - Convert to soluble SO_4
- Eliminate FeS
  - Sulfide converted to soluble SO_4
  - Iron solubilized as Fe^{2+} or Fe^{3+}, which precipitates as $Fe(OH)_3$
    - Topside removal before injection
- Resolves oil/water emulsions
- Cleaner, more valuable skim oil
  - Typically about 0.2% BS&W
- Eliminates other treatment chemicals
  - Possible exception of scale inhibitor

Summary (cont.)

ClO_2

- Stronger oxidizer
  - More effective on bacteria and biomass
    - Use on systems with heavy biological contamination
  - Use for wellbore cleanup
- More economical
- Does require generation equipment onsite

S-ClO_2

- Small systems (low pumping rates)
- Low chemical use rates
- No injection pressure issues
- Simple, one drum treatment

Thank You!

QUESTIONS?