HYDROZONIX

Produced Water Treatment for Reuse

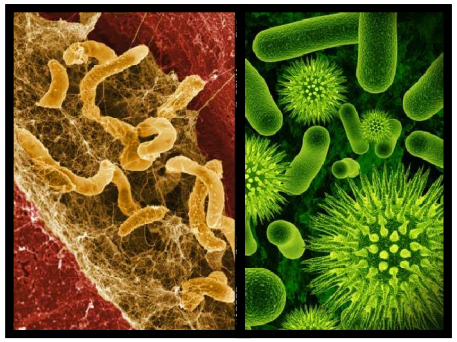
Basic Treatment Requirements

What Are Your Goals

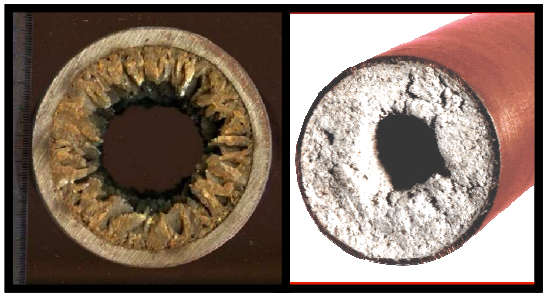
Constituent	Slickwater	Guar (Linear)	Guar (XL)	Hybrids (XL)
Chlorides (ppm)	140K (anionic) No Limit (cationic)	60K	60K	60K
Total Hardness (ppm)	50K	20K	20K	20K
Iron (ppm)	25	10	10	10
Oil (ppm)	100	50	50	50
TSS (ppm)	100	100	100	100
Boron (ppm)	No Limit	10	10	No Limit
Bacteria (cfu/ml)	100	100	100	100

Water Treatment Requirements

Microbial Control



Scale Inhibition



Filtration

Microbial Control

Oxidizing vs. Non-Oxidizing Biocides

Non-Oxidizing Biocides

- No compatibility issues ?
- Potentially lower cost
- No effect on Iron or Sulfides
- No real time monitoring
- Bacterial resistance concerns
- Efficacy concerns in produced water *

Oxidizing Biocides

- Compatibility issues
- Potentially higher cost
- Oxidizes Iron and Sulfides
- Real time monitoring
- No bacterial resistance concerns
- No efficacy concerns in produced water

* ”Produced Water Exposure Alters Bacterial Response to Biocides”, Vikram, A.; Lupus, D.; Bibby, K.; Univ. of Pittsburgh

Microbial Control

Non-Oxidizing Biocides

SPE 14138 "Critical Evaluation of Biocide-Friction Reducer Interactions Used in Slickwater Fracs"

- THPS reduces FR viscosity
- Glut interacts with Oxygen Scavengers, causes crosslinks in certain cases and negative FR interaction in high ORP
- DBNPA, Thione negative FR interaction at higher concentrations

SPE 119569 "Are You Buying Too Much Friction Reducer Because of Your Biocide"

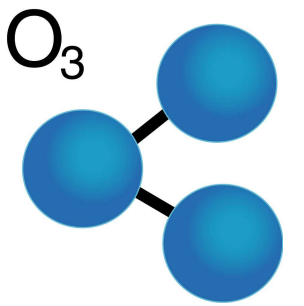
- Quat forms agglomerates in FR
- Quat degrades FR performance
- Quat performance is degraded by FR

Microbial Control

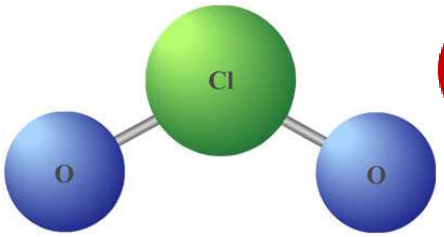
Oxidizing Biocides

Oxidizers:

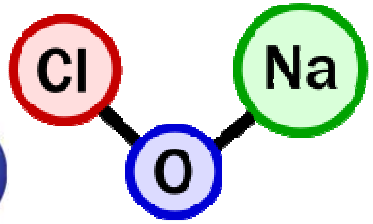
- Preferential for Microbial Control
- Verifiable treatment, real time methods
- Oxidizes Iron, Sulfides for improved water quality
- Increases ORP, reduces breaker dose, improves breaker performance
- Must control compatibility !!!!!



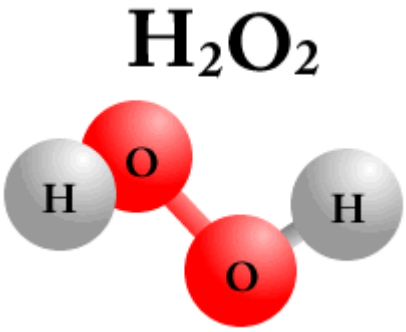
Ozone



Chlorine Dioxide



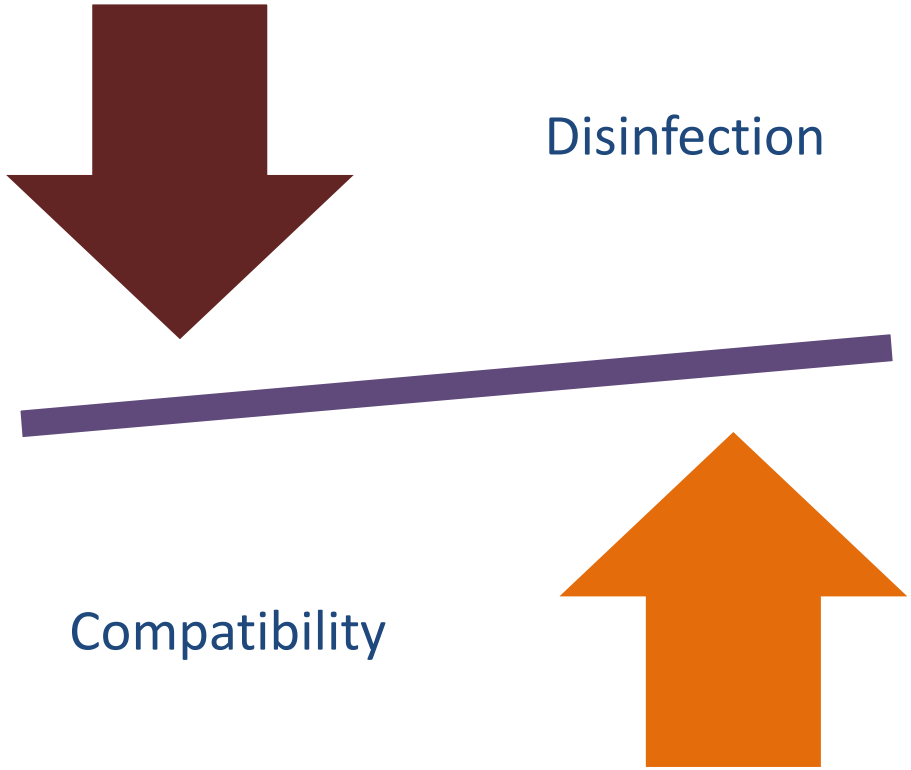
Sodium Hypochlorite



Hydrogen Peroxide

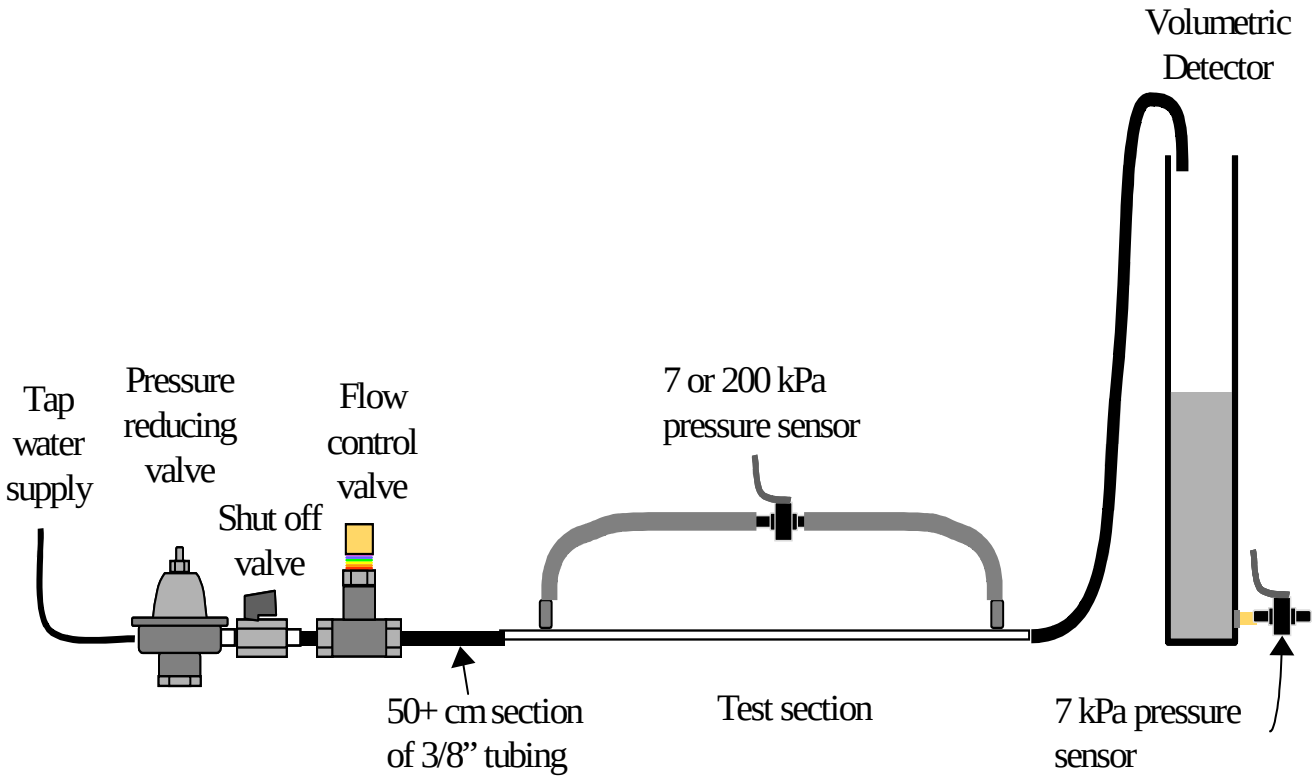
Disinfection vs. Compatibility

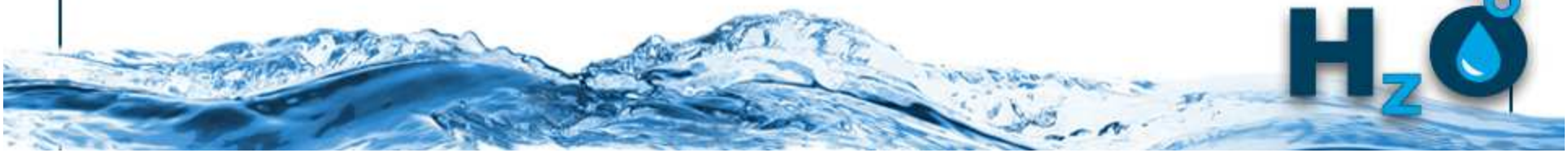
Oxidant	Oxidation Potential, V	Half-Life @ 20°C
Hydroxyl Radicals	2.8	< 1 sec
Ozone	2.3	20 min.
Hydrogen Peroxide	1.8	Hours
Chlorine Dioxide	1.5	93 min.
Chlorine	1.4	140 min.

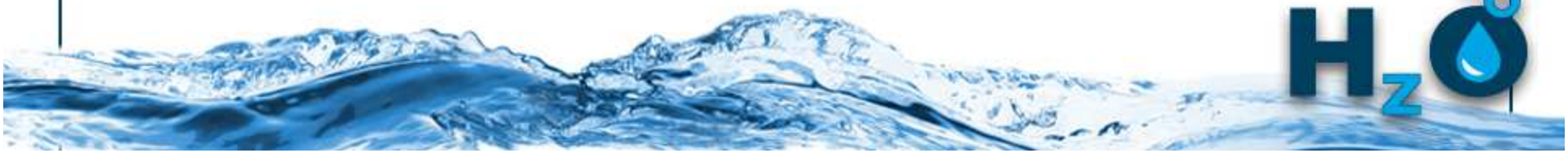


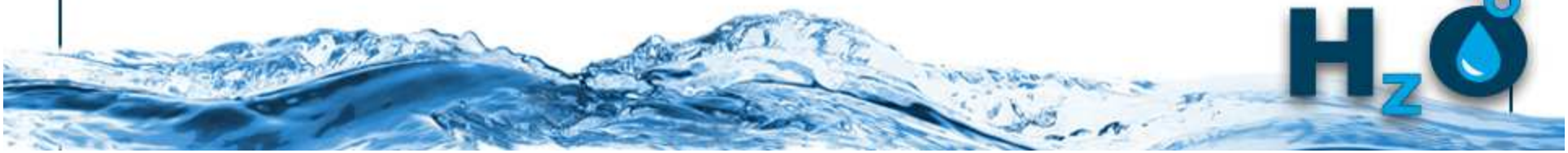
Disinfection vs. Compatibility

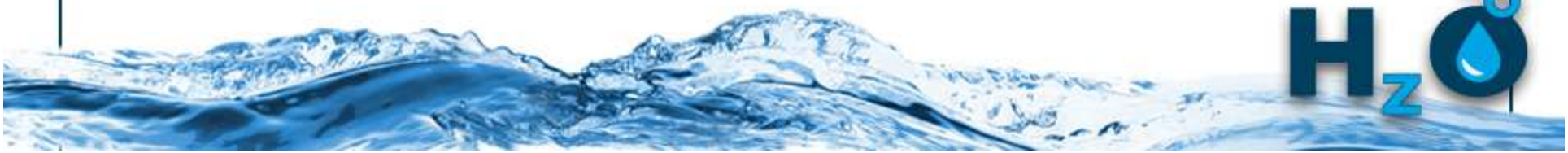
Friction Testing Device





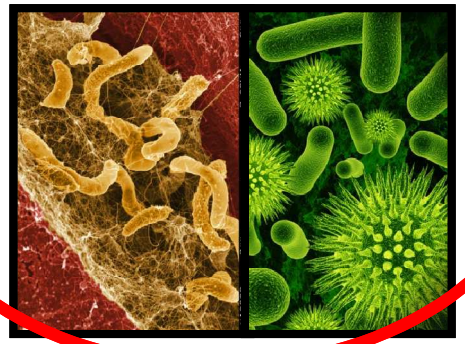






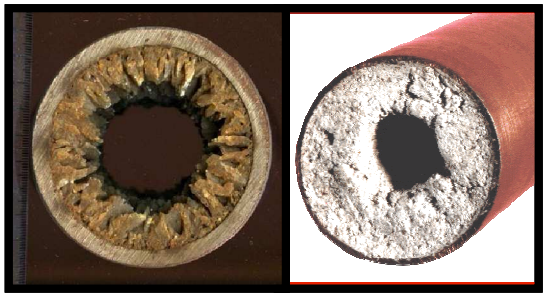
Water Treatment Requirements

Microbial Control



Oxidizers !!!!!

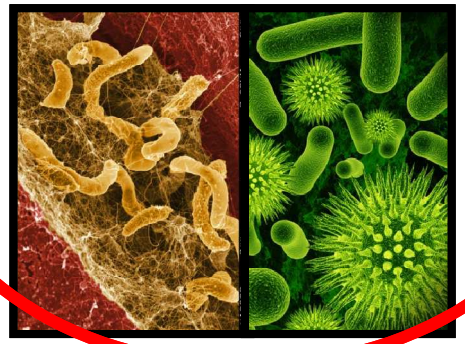
Scale Inhibition



Filtration

Water Treatment Requirements

Microbial Control



Oxidizers !!!!!

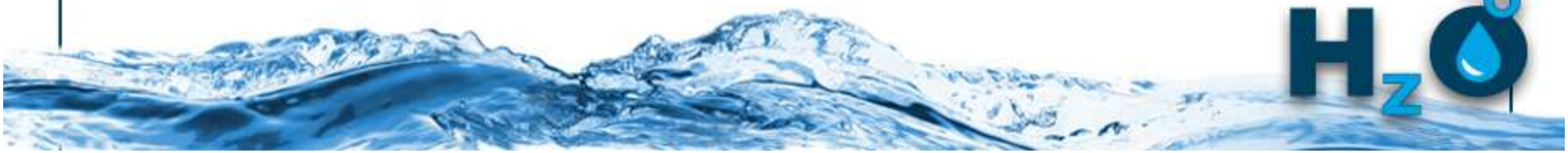
Scale Inhibition

Filtration

Bag Filtration

What are the Basics ?

- Bag Filtration
  - Bag Fit
  - Filter Pod Quality
  - TSS Goals
  - TSS Size Distribution
  - Micron Size
  - TSS loading



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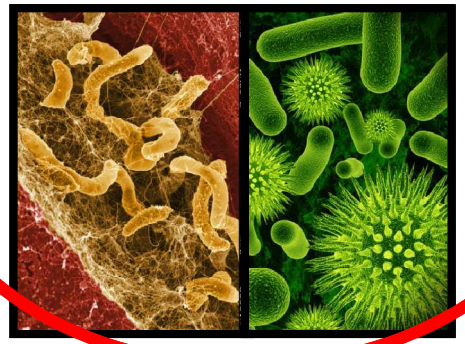


Oxidizers !!!!!

Scale Inhibition

- Blending
- Scale Inhibitors
- TDS Removal

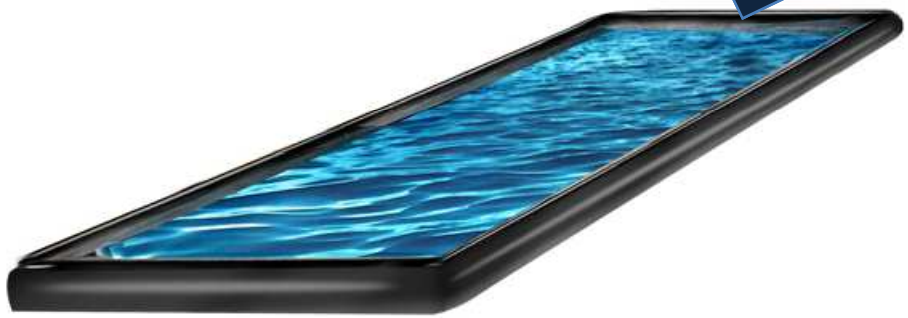
Filtration

Water Treatment Requirements

Conventional Treatment Program

Blend

Disinfection



Fresh/Brackish Water

Produced Water

Pre-treatment TDS Removal

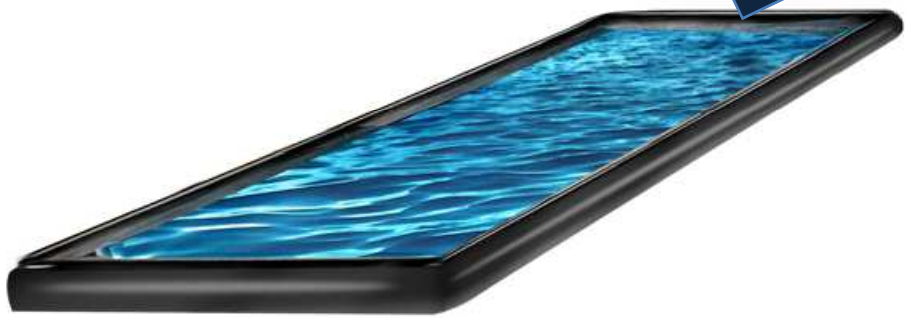
- Floc and drop
- EC
- Resins

Water Treatment Requirements

Conventional Treatment Program

Blend for Scale Inhibition

Disinfection



Fresh/Brackish Water

Pre-treatment

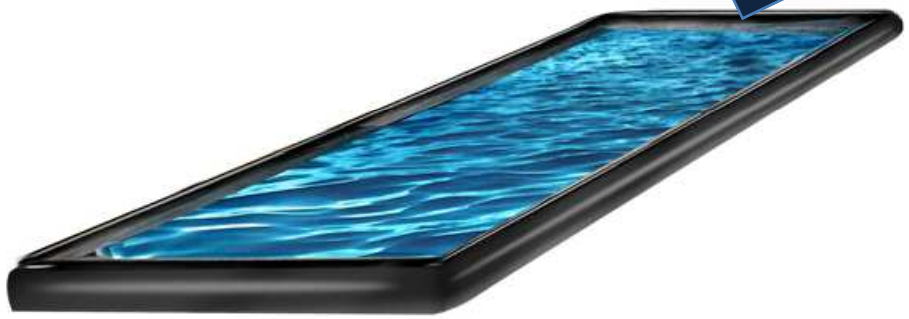
Produced Water

Water Treatment Requirements

Conventional Treatment Program

Blend for Scale Inhibition

Disinfection



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Pre-treatment

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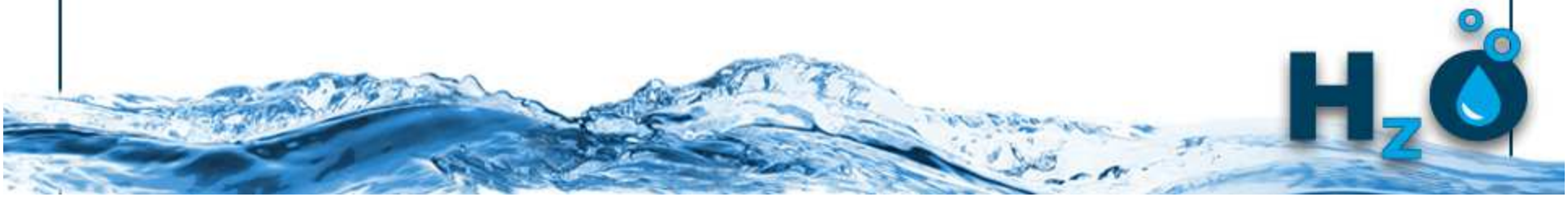
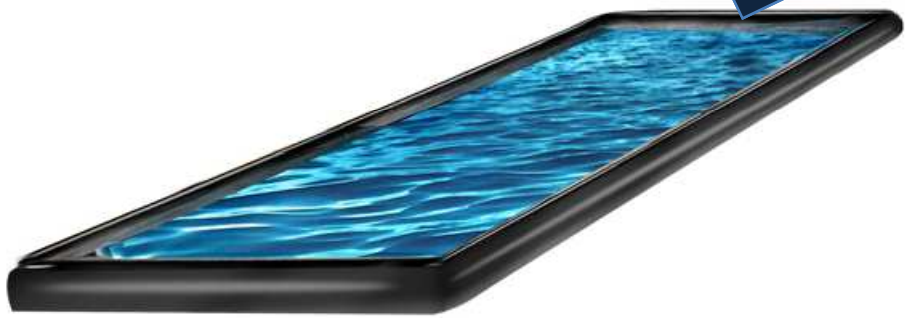


Water Treatment Requirements

Conventional Treatment Program

Blend for Gel Compatibility

Disinfection



Fresh/Brackish Water

Produced Water

Pre-treatment

Cross-linked gel fluids

- Gel Compatibility can be maintained over narrow range.
- TSS, TDS, Chlorides and Boron are all issues.
- Once Gel recipe is developed water quality must remain in a narrow range to maintain gel compatibility
- Control of water quality is paramount

Gel Compatibility Testing

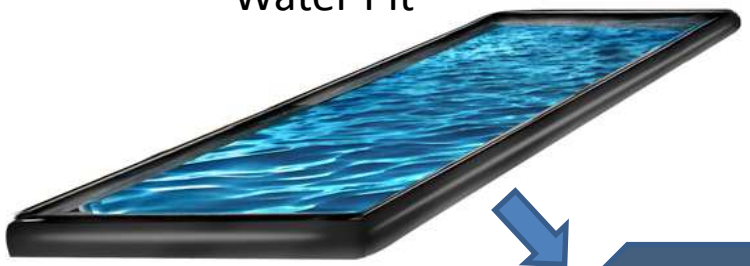
Rheology Testing

- Viscosity
- Gel Stability
- Break Time

Recycling for Crosslink Gel Fracs

Quality Assurance / Quality Control Program

Fresh
Water Pit

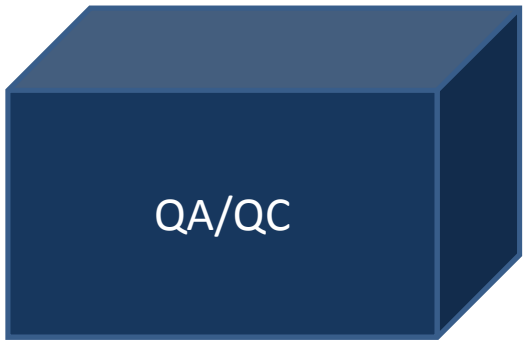


Produced Water Storage

QA/QC

Recycling for Crosslink Gel Fracs

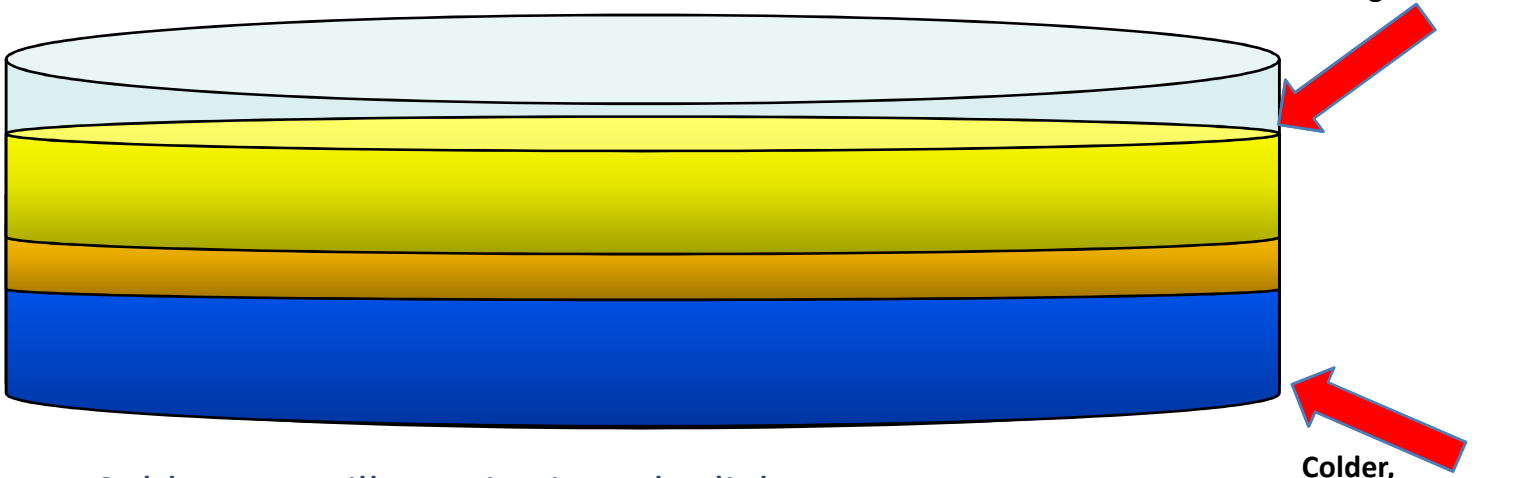
Quality Assurance Quality Control Program



- Mix/Recirculate Produced Water Source
- Calibrate Pumps for Consistent Blend
- Real Time Monitoring of TDS
- Real Time Monitoring of Chlorides
- Real Time Monitoring of Boron
- Real Time Monitoring of Other Parameters

Temperature Stratification

- Even a 0.1 C (0.18 F) or greater temperature difference can inhibit mixing
- Without mixing thermal stratification occurs
- Without mixing only slight diffusion takes place as the only mechanism to transfer biocide
- Water age becomes an issue, newer colder water sinks to bottom, warmer water stays in tank longer
- Bacterial growth is supported

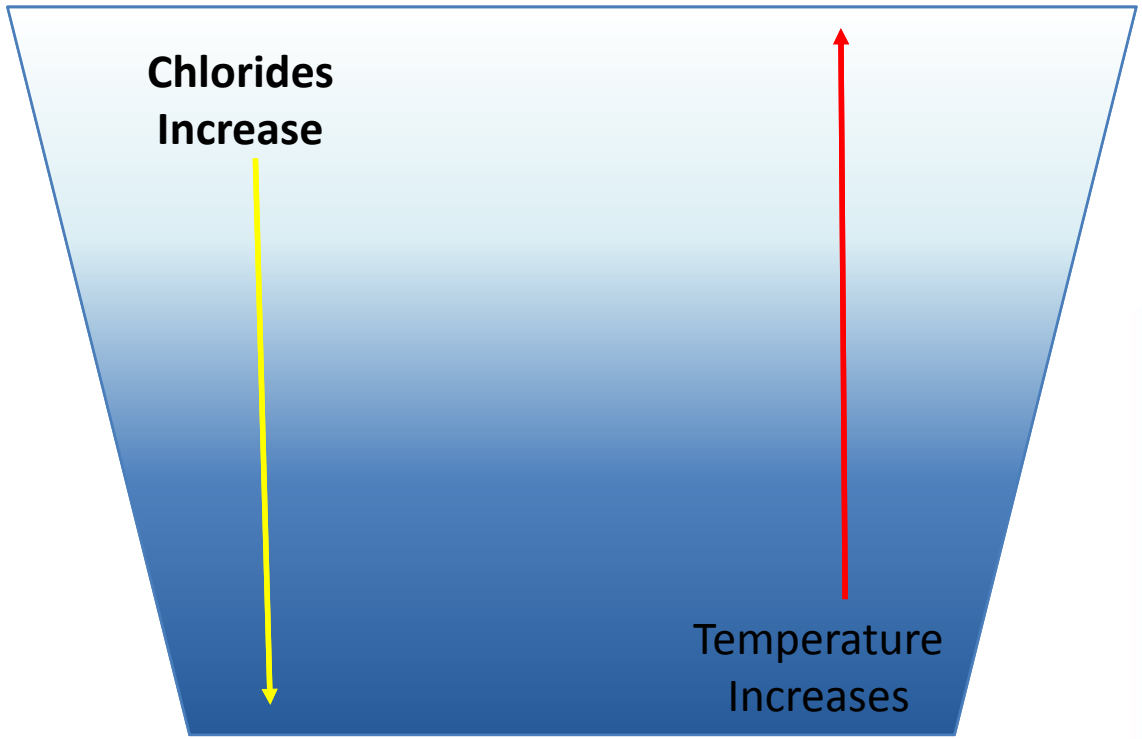


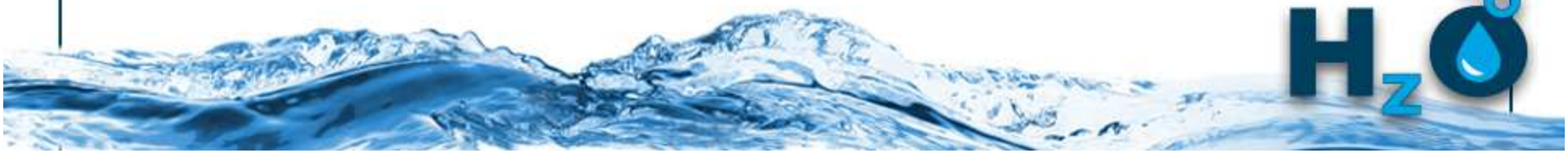
Cold water will not rise into the lighter, warmer water

Produced Water Mixing

Stratification

- A static, unmixed pit will stratify
- Chlorides will increase with depth
- Temperature will decrease with depth
- Zones are created at different depths with changing water quality

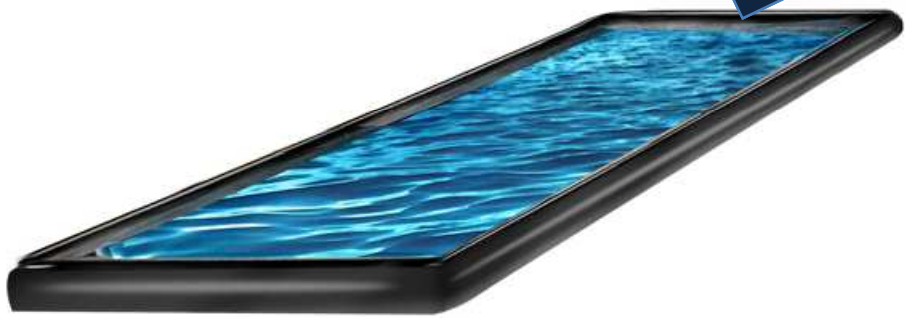




Water Treatment Requirements

Produced Water Requiring Accumulation

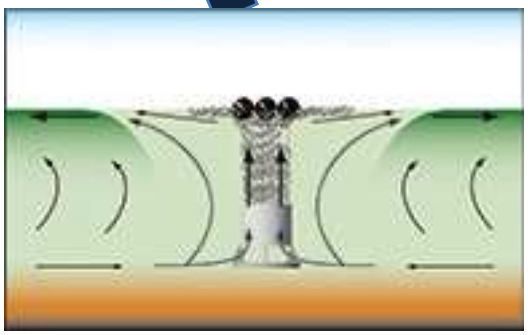
Conventional Treatment Program



Fresh/Brackish Water

Blend

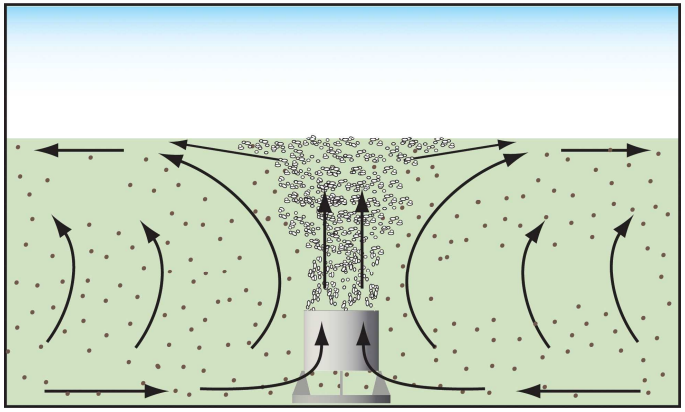
Disinfection



Produced Water w/ Aeration

Water Treatment Requirements

Produced Water with Accumulation Time



Aeration

- Bacterial Control
- Iron Oxidation
- Sulfide Oxidation
- $0.01-$0.02/bbl

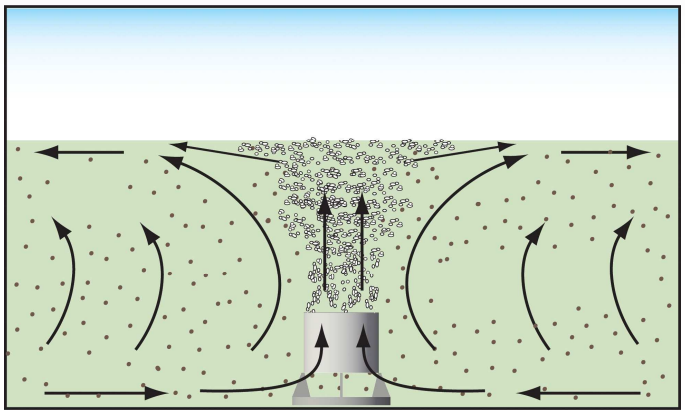
Filtration

- Solids Control
- $0.01-$0.02/bb

Oxidation

- Bacterial Control via Oxidation
- Iron Oxidation
- Sulfide Oxidation
- $0.20-$0.22/bbl

Water Treatment Requirements



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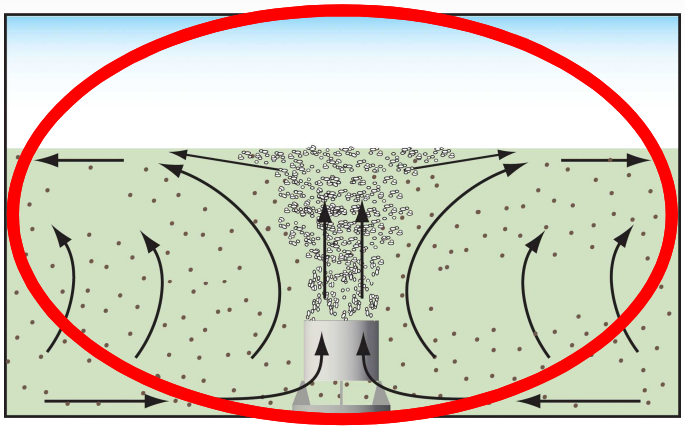

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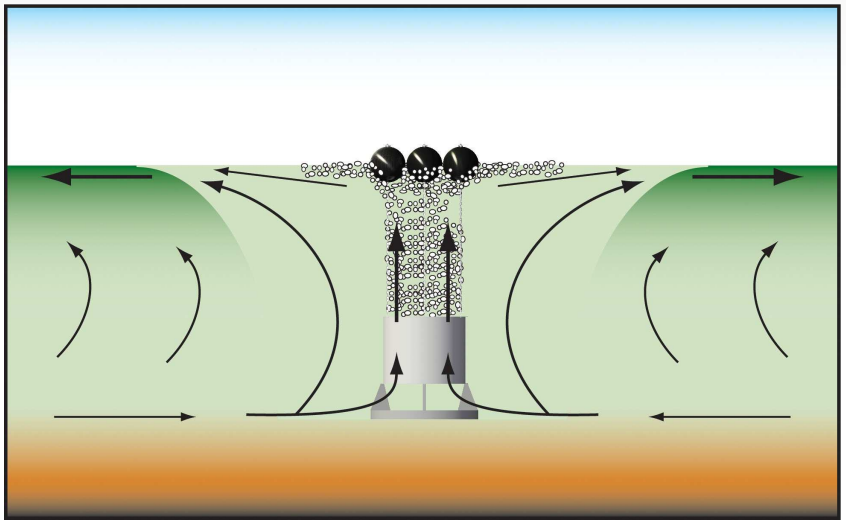
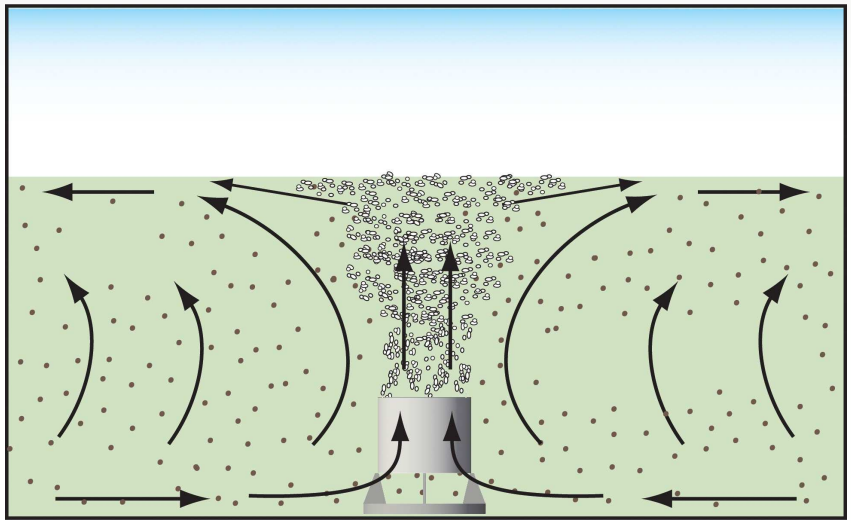
Aeration:

Aerator Type	Lbs O_2 / HP
Surface Aerator: Odor Control, odor cap	1-2 (top 2 feet)
Aire-O2: High Energy, poor O_2 transfer	2
Submersible: Most Energy Efficient for Mixing, Good O2 transfer, flexible for surface, depth or mixing and aeration	4
Bubble Diffusing Line – Submersible: Lowest capital cost, but high capital for compressors, Poor mixing, good O2 transfer, requires high pressure, more energy	5-10

Aeration: Surface vs Submersible





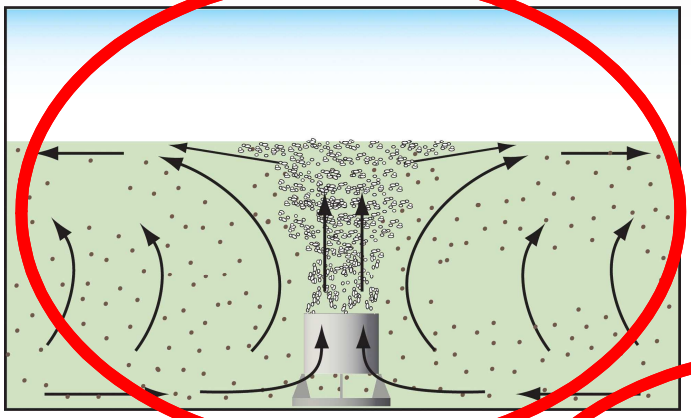
Surface Aeration

- Reduces total hp required
- Provides odor control
- Some improvement in water quality for shallow water (< 6 feet)
- Poor mixing, except in shallow water (< 6 feet)
- Provides some icing inhibition

Submersible Aeration

- More hp required
- Provides odor control
- Improves water quality
- Provides good mixing
- Agitates accumulated solids for easy removal
- Provides icing inhibition

Water Treatment Requirements



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Testing Program

- **Unique Hydrozonix Feature**
- **Real Time Water Quality Testing**
- **Creates certainty for treatment verification**
- **Includes testing Hydrocarbons, Iron, TSS and Bacteria**
- **Test all key parameters once per shift, more frequently when water quality changes**
- **Inline probes for ORP and pH**
- **Hydrozonix has developed proprietary sample prep procedures**

InfraCal 2 ATR-SP
EPA Method 1664

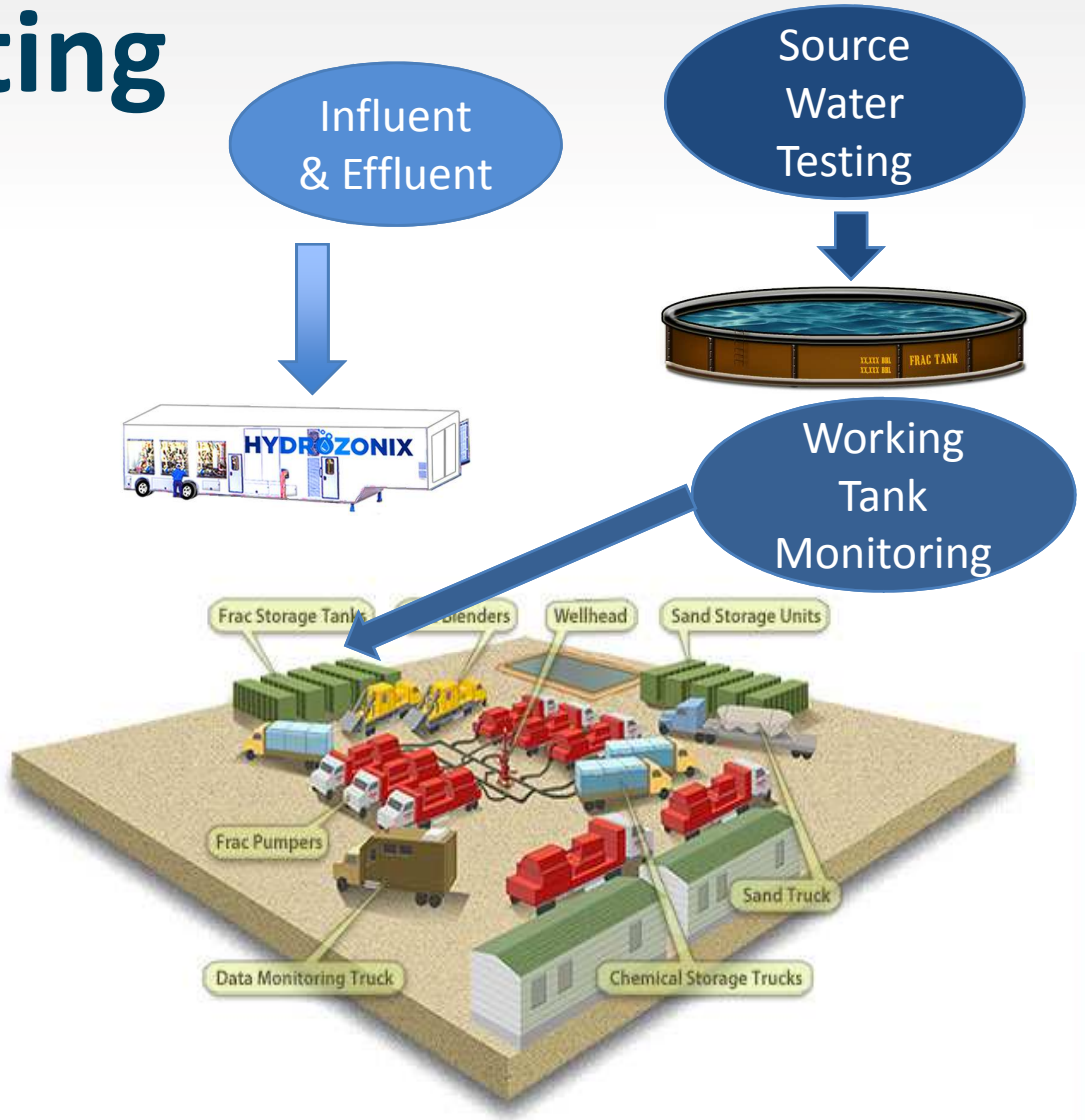
HACH DR 900 for TSS and iron

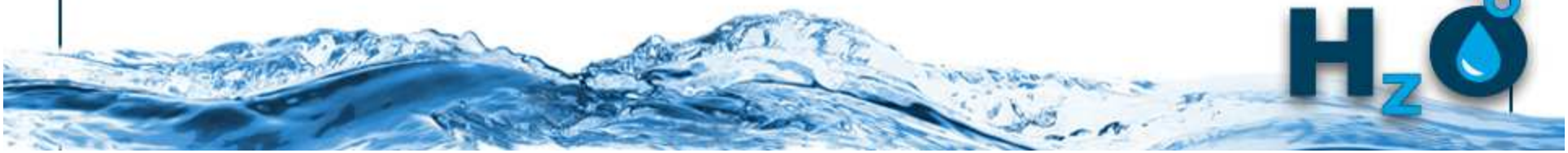
ATP Kit for Real Time Bacteria

Bacteria Testing

Where do I Sample ?

- Influent/Effluent of Treatment System
  - MPN
  - ATP
  - Continuous Testing
- Residual Disinfection / Working Tanks
  - ATP
  - Continuous Testing
- Source Water
  - ATP
  - MPN
  - Baseline Testing





Summary

- **Recycling/Reuse Can be Low Cost** – Less than $0.26/bbl for a complete program of aeration, filtration, oxidation and real time monitoring.
- **Oxidizers are Best** – Effective over wide range of water quality, including 100% produced water as a biocide replacement. Also provides Iron and Hydrogen Sulfide control. Real time testing helps optimize
- **Aeration** – Low Cost Pre-Treatment when needed or for longer storage requirements. Overall improved water quality. Submersible aerators work best and provide the most benefit.
- **Filtration** – An often overlooked, but critical component to a recycle/reuse program. Do a field grain size test and pick the best micron bag.
- **Compatibility** – While other techniques can cause incompatibility we actually improve it by choosing the right oxidizer and using real time monitoring.
- **Real Time Testing** – Most water treatment approaches provide no real time testing, they rely on a “hope for the best” approach. Real time testing is critical for a successful produced water recycling/reuse program. Testing should include working tank monitoring and Flowback testing.


Questions ?
www.hydrozonix.com