Difficult Well Problems
May Require Well Forensics

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“Well Forensics”

- Forensic Science – application of science to legal investigations for admissible evidence.
- Investigation (Webster) – a careful and detailed search and examination.
- All well assessment activities are investigative lets look at common & more difficult

Parameters for Scale Development

Calcium Carbonate Scale Formation

\[
\begin{align*}
pH & = > 7.0 \\
\text{Alk} & = > 150 \text{ mg/l} \\
\text{Hd} & = > 180 \text{ mg/l} \\
\text{LSI} & = \text{positive} \\
\text{Ca} & = \text{present}
\end{align*}
\]

- Good potential for carbonate deposits to form.
- Typical treatment will neutralize acid and produce carbon dioxide gas.
Calcium Carbonate Scale from a Well

Oxide / Hydroxide Scale

- Iron = > 1.0 mg/l
- Manganese = > 0.1 mg/l
- Positive ORP

- Corrosion of the well structure.
- Any aeration, such as cascading water, fractured rock aquifers
- Presence of any of the iron & manganese oxidizing bacteria will result in oxide accumulation.

Calcium Sulfate Scale Formation

- pH = > 7.0
- Alk = > 150 mg/l
- Hd = > 100 mg/l
- SO₄ = > 100 mg/l
- LSI = positive
- Ca present

- Typically occurs with carbonate scales.
- Very difficult to dissolve and remove from a well.
- Requires careful attention to chemicals used in cleaning.

Calcium Sulfate Scale from a Column Pipe

More often than not, scale or incrustation within the well is a combination (Matrix)
Why Important

- **Correct acid for the problem**
  - Mineral acid for mineral scale
  - Organic acid for organic deposits - biofilm
  - Sulfamic acid not good for sulfate scale
  - Oxalic acid & strong mineral acid good on iron deposits

- **Correct acid concentration for the problem**
  - Stronger the potential of deposits, more acid required.

Common Well Problems

- Scale accumulations
- **biomass build-up**
- Sediment infiltration and development
- Corrosion
- Coliform occurrence

> any change that impacts operation or quality

Biofouling on Pumps & Motors

What Problems are Caused by Biofilm

- Water Quality Decline
- Foul odor and taste
- Production Losses
- Corrosion Damage
- Unsafe Water

80% OF WELL FOULING IS RELATED TO BACTERIA
(per AWWA Research Foundation)

- Directly as the primary blockage
- Presence of problematic organisms
- Indirectly:
  - Providing a sticky base for mineral attachment
  - Corrosion activity resulting in accumulation of by-products and loss of water quality
  - Corrosion activity resulting in structural failure
Heavy biomass providing direct impaction

The sticky exopolymer (slime) of the biofilm accounts for the formation of mineral deposits in the flow space of both gravel pack and formation.

Providing a sticky base for mineral attachment

Corrosion activity resulting in accumulation of by-products and loss of water quality

Anaerobic Bacteria

Shallow Alluvial Well System that sat out of service for 2 years

BACTERIAL ENVIRONMENT
Common Well Problems

- Scale accumulations
- biomass build-up
- sediment infiltration and development
- corrosion
- coliform occurrence

➢ any change that impacts operation or quality

Development/Redevelopment

The combined chemical and mechanical efforts targeting muds and sediment within the borehole and near-well aquifer

New and Older Wells

Formation Particles (sediment)
**Purge Disrupted Material**

- Purge until visual turbidity lessens
- Remove disrupted material
- Remove any fill

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**Common Well Problems**

- Scale accumulations
- Biomass build-up
- Sediment infiltration and development
- Corrosion
- Coliform occurrence

➢ any change that impacts operation or quality

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**Scale & Corrosion Indicators**

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**2016 USGS Study**

Corrosion Potential of US Groundwater

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**Concentration Cell Corrosion (Oxygen Cell)**

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**MIC**

Microbial Influenced Corrosion

- Corrosion influenced by growth process of bacteria
- Under deposit corrosion – absence of $O_2$
- Corrosion from bacterial acids and enzymes (pitting)
- Iron oxidizing bacteria – most common!
Iron Oxidizing Bacteria

Bacteria that deposit iron or manganese oxides
Identified under the light microscope based on morphology

Gallionella ferruginea

Common Well Problems

- Scale accumulations
- biomass build-up
- sediment infiltration and development
- corrosion
- coliform occurrence

➢ any change that impacts operation or quality

Coliforms

Coliforms and Biofilm

- Coliforms are mostly anaerobic or facultative
- Mature Biofilm harbor anaerobic bacteria
- As Biofilm matures increase probability of Coliforms

(Per Characklis WG, Biofilm Development)

Total Coliform Rule

April 1, 2016

- No MCL for Total Coliform
- Various level will trigger treatment changes not public notice or stop service
- E-Coli MCL violations will be in various levels requiring:
  – Corrective action
  – Identify sanitary defects through out system

Difficult Well Problems

and Well Forensics

- Well construction related issues
- Water quality issues
- Deposited materials not responding to standard treatments
- Operational issues within water chemistry
I. Unable to Development Well

- Dual Rotary drilling technology – Barber Rig
- Standard physical and chemical technologies not working for development.
- Sample collected and submitted to lab:

Results: Clays were natural formation clays and not responding to conventional development
Bench Test Studies

Using multiple surfactant and dispersant chemistries eventually found a combination that produced movement within a few hours.

Used in the field with success!

II. Oily Film

Investigated Treatment Options

- Worked with D’Limonene chemistry in the past. (citrus based degreaser)
- Currently several formulas of D’Limonene are NSF certified.
- Identified a product best for the water chemistry of this aquifer.

III. Changes in Water Chemistry

(A Water Treatment Example)
Problem Investigation

- Scale buildup within the piping and storage near to the plant
- Sight visit, system and operational review
- Sample sent to the lab:

![Sample Image 1](image1)

![Sample Image 2](image2)

Lab Results

99.7% Calcium Carbonate

![Lab Results Image](image3)

Operational Change

- Due to intermittent finished water color, corrosion potential was hypothesized within the past year.
- Consultant recommended pH adjustment of finished water up to max. of 9.0

However – only a few system components were of metal construction – mostly PVC.

Operational Change Correction

- 30% raw water by-pass the treatment system – Raw water iron settling in distribution system
- Calculated the LSI for the finished water balance

- Recommended pH maintained at 8.0 – 8.2 to reduce potential of calcium carbonate deposits

IV. Black Particulate

Food processing rinse water.

![Black Particulate Image](image4)

Samples Collected & Analysed

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent by Weight of Dissolvable Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon compounds</td>
<td>71.24</td>
</tr>
<tr>
<td>Iron oxide</td>
<td>3.37</td>
</tr>
<tr>
<td>Aluminum compounds</td>
<td>0.02</td>
</tr>
<tr>
<td>Insoluble particulate</td>
<td>3.13</td>
</tr>
<tr>
<td>Organic biomass, moisture</td>
<td>22.24</td>
</tr>
<tr>
<td>Water</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

![Samples Collected & Analysed Image](image5)
**Water Analysis**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH Value</td>
<td>8.32</td>
</tr>
<tr>
<td>Phenolphthalein Alkalinity</td>
<td>104</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>1,428</td>
</tr>
<tr>
<td>Hydroxide Alkalinity</td>
<td>ND</td>
</tr>
<tr>
<td>Carbonate Alkalinity</td>
<td>208</td>
</tr>
<tr>
<td>Bicarbonate Alkalinity</td>
<td>1220</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>2,218</td>
</tr>
<tr>
<td>Conductivity (µm or µS/cm)</td>
<td>3,080</td>
</tr>
<tr>
<td>ORP (mV)</td>
<td>199.2</td>
</tr>
<tr>
<td>Langelier Saturation Index (at 16°C)</td>
<td>-0.86</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>4</td>
</tr>
<tr>
<td>Carbonate Hardness</td>
<td>4</td>
</tr>
<tr>
<td>Non Carbonate Hardness</td>
<td>ND</td>
</tr>
<tr>
<td>Calcium</td>
<td>ND</td>
</tr>
<tr>
<td>Magnesium</td>
<td>4</td>
</tr>
<tr>
<td>Sodium (as Na)</td>
<td>782.00</td>
</tr>
<tr>
<td>Potassium (as K)</td>
<td>3.30</td>
</tr>
<tr>
<td>Phosphate (as PO₄)</td>
<td>0.68</td>
</tr>
<tr>
<td>Chlorides (as Cl)</td>
<td>165.6</td>
</tr>
<tr>
<td>Nitrate (Nitrogen)</td>
<td>0.3</td>
</tr>
<tr>
<td>Chlorine (as Cl)</td>
<td>ND</td>
</tr>
<tr>
<td>Dissolved Iron (as Fe²⁺)</td>
<td>ND</td>
</tr>
<tr>
<td>Suspended Iron (as Fe³⁺)</td>
<td>0.05</td>
</tr>
<tr>
<td>Iron Total (as Fe)</td>
<td>0.05</td>
</tr>
<tr>
<td>Iron (resuspended)</td>
<td>0.30</td>
</tr>
<tr>
<td>Copper (as Cu)</td>
<td>ND</td>
</tr>
<tr>
<td>Manganese (as Mn)</td>
<td>ND</td>
</tr>
<tr>
<td>Sulfate (as SO₄)</td>
<td>ND</td>
</tr>
<tr>
<td>Silica (as SiO₂)</td>
<td>24.1</td>
</tr>
<tr>
<td>Tannin/Lignin</td>
<td>0.6</td>
</tr>
<tr>
<td>Total Organic Carbon (C)</td>
<td>9.6</td>
</tr>
</tbody>
</table>

**Evaluation**

- Lignite exhibits ion exchange with calcium
- Chloride solutions facilitate exchange
  - Results: low calcium – high sodium & chlorides
- High TOC (total organic carbon)
  - Weaker coals like lignite exhibit high TOC levels
- Lignite is not uncommon to this formation

**Screened Interval**

*Screened 72 feet into Lignite*

**Resolution**

- Cleaned/disinfected well due to heavy biofilm
- Redeveloped well to remove residual Lignite
- Sealed subject screened interval with packer
- Operated well for past 2 years with no issues

**Conclusion**

- All well assessment activities are investigative
- Not all problems are easily identified
- Difficult ones require a detailed search & examination. **WELL FORENSICS**

**QUESTIONS & ANSWERS (HOPEFULLY)**