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

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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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Parameters for Scale Development

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Calcium Carbonate Scale Formation

pH = > 7.0
Alk = > 150 mg/l
Hd = > 180 mg/l
LSI = positive
Ca present

- Good potential for carbonate deposits to form.
- Typical treatment will neutralize acid and produce carbon dioxide gas.

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Calcium Carbonate Scale from a Well

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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.

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Iron Oxide Scale from a Well

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Calcium Sulfate Scale Formation

pH = > 7.0
Alk = > 150 mg/l
Hd = > 100 mg/l
SO_4 = > 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.

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Calcium Sulfate Scale from a Column Pipe

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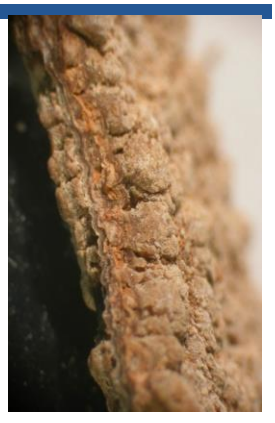
More often than not, scale or incrustation within the well is a combination (Matrix)



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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.

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Biofouling on Pumps & Motors

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What Problems are Caused by Biofilm

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

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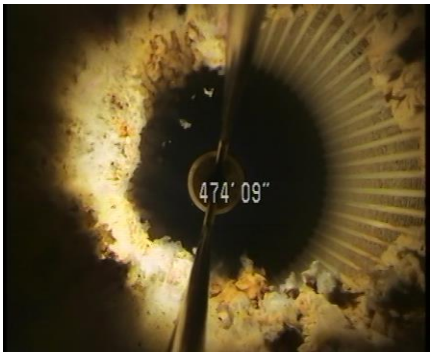

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80% OF WELL FOULING IS RELATED TO BACTERIA

(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**

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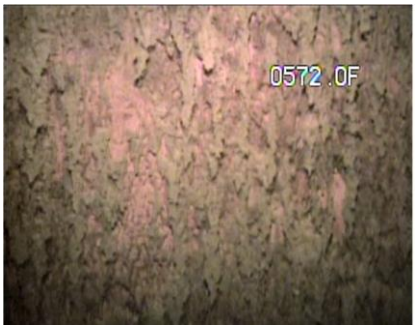
Heavy biomass providing direct impaction



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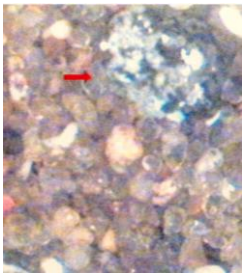

Microscopic image of the matrix blockage material

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

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Providing a sticky base for mineral attachment

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

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Anaerobic Bacteria

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

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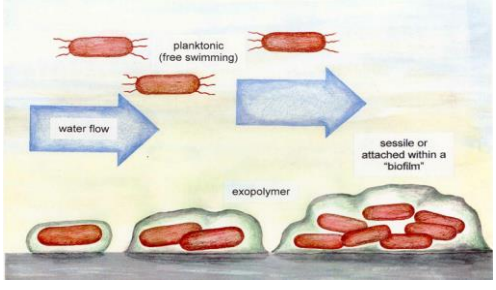
BACTERIAL ENVIRONMENT



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Heavy Biofilm Deposits

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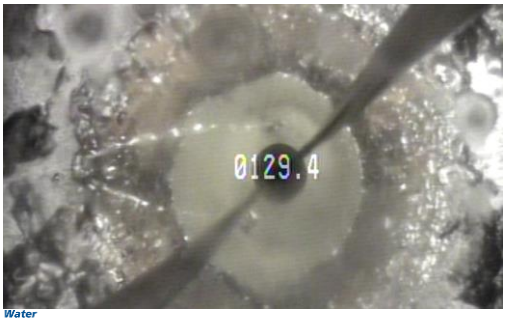
Cascading Water



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Common Well Problems

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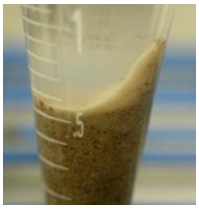
Development/Redevelopment

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

New and Older Wells



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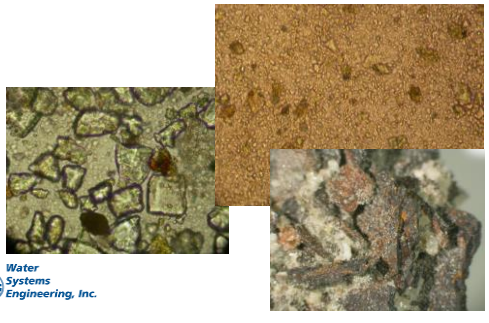
Formation Particles
(sediment)



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Purge Disrupted Material

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

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Photo courtesy of Johnson Screens

Common Well Problems

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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!

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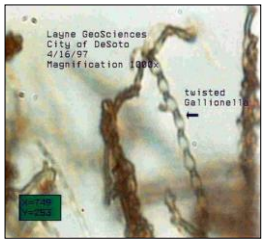
Iron Oxidizing Bacteria

Bacteria that deposit iron or manganese oxides

Identified under the light microscope based on morphology



Gallionella ferruginea

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Common Well Problems

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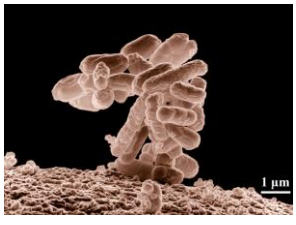
Coliforms



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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)

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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

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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

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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:

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Mudded up Screen

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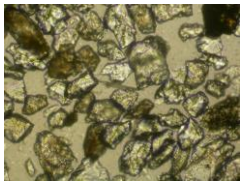
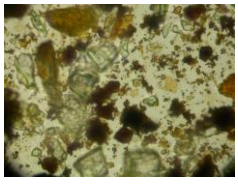
Analysis of sample

Microscopic & Chemical



More uniformity of clay particles indicate processed clays or drilling mud



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Settled Mud to Analyse

Lighter fluffy clays that settle slower indicate that they are processed not natural formation materials

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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

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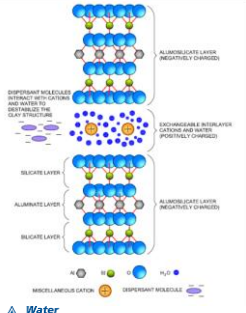
Mud & Clay Dispersion



Returns from a developed well

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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!

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II. Oily Film

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Laboratory Analysis

- **Oily material identified as a form of <u>Coal Tar</u>**
- **Knew we had a difficult hydrocarbon**
- **Needed an effective degreaser**

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Investigated Treatment Options

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

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Rehabilitated the well with the D'Limonene chemistry removing the oily film.

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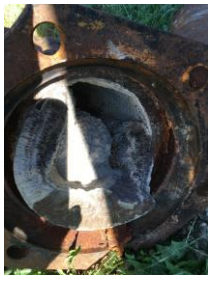
III. Changes in Water Chemistry

(A Water Treatment Example)



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Problem Investigation

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


Lab Results

99.7% Calcium Carbonate


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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.

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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**

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IV. Black Particulate

Food processing rinse water.

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Samples Collected & Analysed


Component	Percent by Weight of Dissolvable Mass
Carbon compounds	71.24
Iron oxide	3.37
Aluminum compounds	0.02
Insoluble particulate	3.13
Organic biomass, moisture	22.24
Total	100.0%

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Water Analysis

ND - Not Detected
NA - Not Applicable
* as $CaCO_3$

	Well No. 2 14 Minutes mg/l
pH Value	8.32
Phenolphthalein Alkalinity *	104
Total Alkalinity *	1,428
Hydroxide Alkalinity	ND
Carbonate Alkalinity	208
Bicarbonate Alkalinity	1220
Total Dissolved Solids	2,218
Conductivity (µm or µS/cm)	3,080
ORP (mV)	199.2
Langelier Saturation Index (at 16° C)	- 0.86
Total Hardness *	4
Carbonate Hardness	4
Non Carbonate Hardness	ND
Calcium *	ND
Magnesium *	4
Sodium (as Na)	782.00
Potassium (as K)	3.30
Phosphate (as PO_4)	0.68
Chlorides (as Cl)	165.6
Nitrate (Nitrogen)	0.3
Chlorine (as Cl)	ND
Dissolved Iron (as Fe^{2+})	ND
Suspended Iron (as Fe^{2+})	0.05
Iron Total (as Fe)	0.05
Iron (resuspended)	0.30
Copper (as Cu)	ND
Manganese (as Mn)	ND
Sulfate (as SO_4)	ND
Silica (as SiO_2)	24.1
Tannin/Lignin	0.6
Total Organic Carbon (C)	9.6

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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

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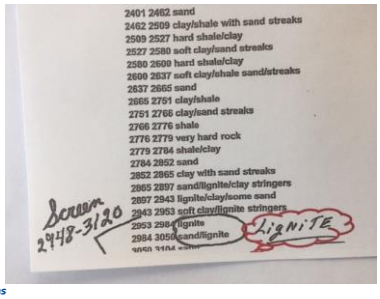
Screened Interval



Screened 72 feet Into **Lignite**

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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

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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)

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