May 01, 2019

# Iron, Manganese, and Sulfide Removal Options and Updates

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# Water Quality Standards

| | |
|---|---|
| Initial | Fe + Mn < 0.3 mg/l |
| 1962 USPHS | Fe < 0.3 mg/l<br>Mn < 0.05 mg/l |
| AWWA ideal | Fe < 0.05 mg/l<br>Mn < 0.01 mg/l |
| Problems with *(White)* | Mn > 0.02 mg/l |
| Treatment goal *(Knocke & Tobiason)* | < 0.015 mg/l |

# Fe & Mn Occurrence

- Fe 5% of the earth's crust
- Mn 0.1% of earth's crust
- Occurrence in water due to reducing bacteria in the aquifer or sediment of lakes & reservoirs
  - Dissolved in anaerobic reducing conditions
  - Dissolved in water with elevated $CO_2$
- Other sources
  - Fe coagulants
  - Water treatment residuals
- Frequently found with $H_2S$, $NH_3$, and As

# Iron and Manganese

Problems

- Dirty water
- Stained fixtures
- Stained laundry
- Metallic tastes
  - Fe > 0.2 mg/l
  - Mn > 0.1 mg/l
- Scavenger – adsorbs metals

# Iron and Manganese

Bacterial growth in water system

- Taste & odor
- Reduced hydraulic capacity
- Clog well screens and pumps
- Increased $Cl_2$ demand

# Distribution System Cleanup

Hydrogen peroxide & flushing

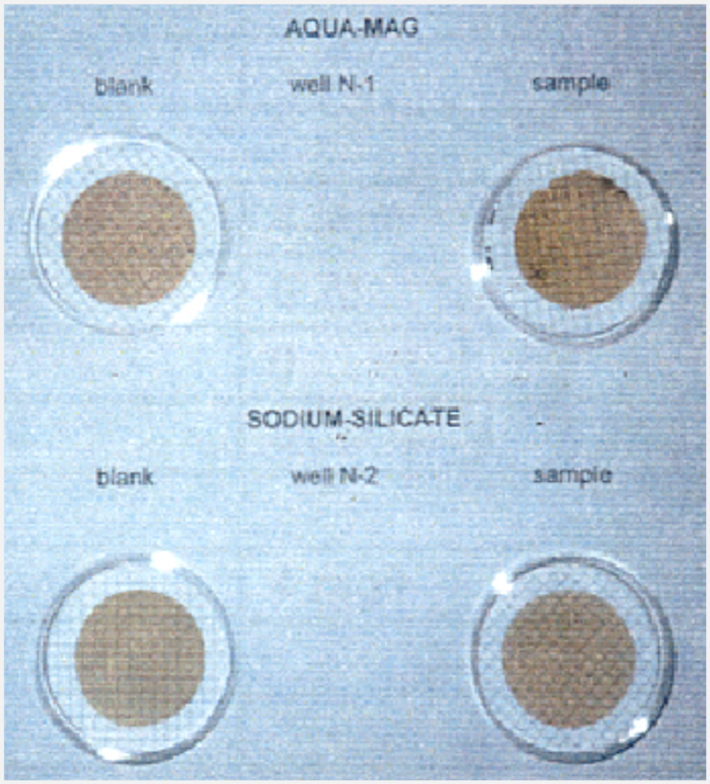
- Seaside, CA (1978) & Alberta
- 50 to 100 mg/l $H_2O_2$
- More effective than chlorine
- Flushed next morning
- Switched to chloramines

# Iron & Manganese Treatment Options

- Sequestering
- Oxidation/Filtration
- Adsorption/Catalytic Oxidation
- Biological

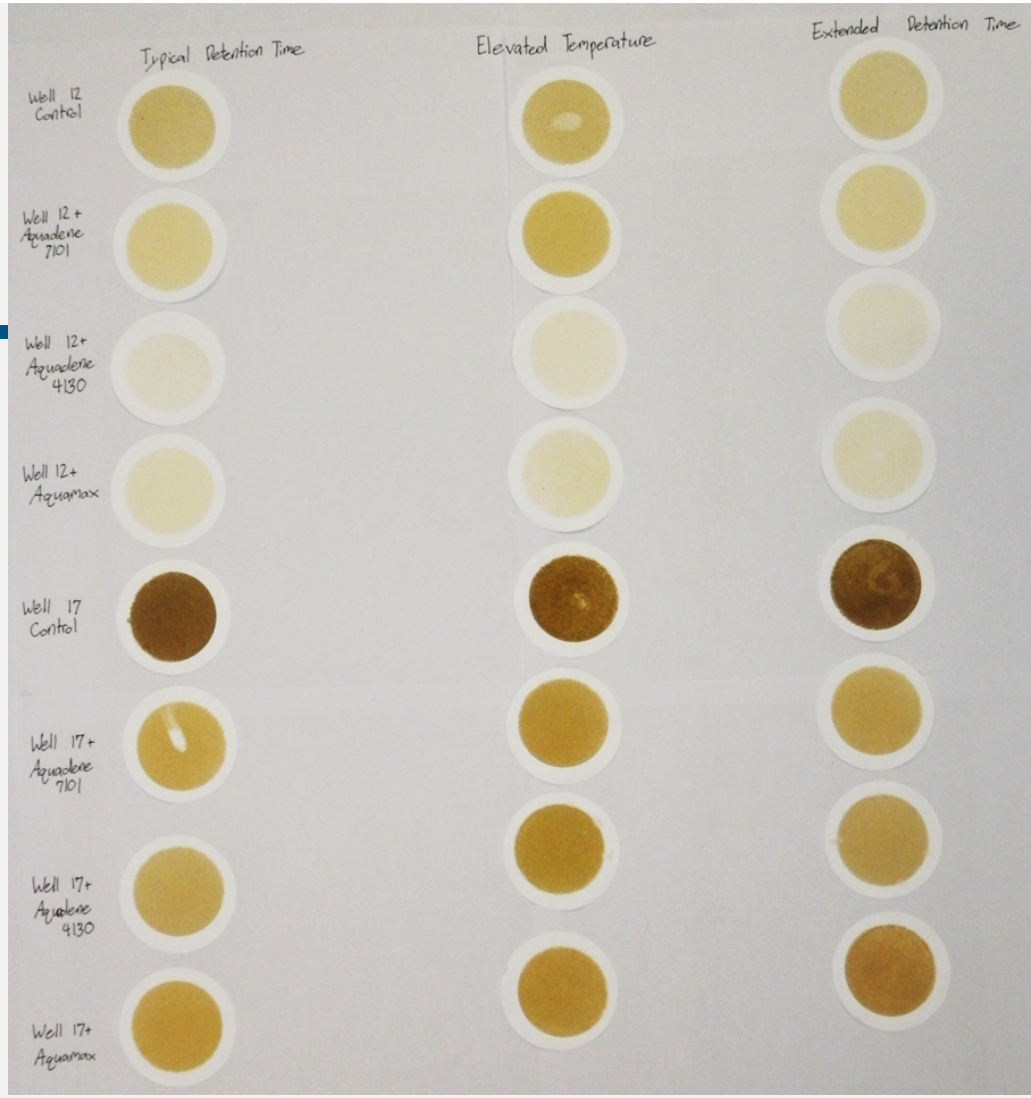
# Iron & Manganese Sequestering

- Sequestering agent
  - Polyphosphates
  - Silicates
- Temporarily tie up Fe & Mn
- Break down with
  - Time
  - Elevated Temperature



# Sequestering Evaluation

- Wholesale purveyor
- 65 CFS Wellfield
- Well 12
  - Fe <0.05 mg/l
  - Mn 0.09 mg/l
- Well 17
  - Fe <0.05 mg/l
  - Mn 0.18 mg/l
- 1 L samples
- Chloraminated supply



# Oxidation Filtration

- Historically most commonly used
- Less frequent today
- Oxidants
  - $O_2$ and $Cl_2$ for Fe
  - $KMnO_4$ or $NaMnO_4$ for Mn
    - Handling issues
  - Ozone
  - Chlorine dioxide

# Potassium or Sodium Permanganate

- Strong oxidizer
- Fast reaction
- More expensive than chlorine
- Potential colloidal Mn formation
- Beneficial with elevated silicate concentration
- Pink water if overfed
- Color monitors to minimize overfeeding

# Oxidation/Filtration

- Goal is to produce filterable precipitates
- Filter media
  - Greensand with anthracite cap
  - Low loading rates
  - 3 to 5 gpm/SF

# Adsorption/Catalytic Oxidation

- Two-step process
  - Mn adsorbed then oxidized
  - Fe oxidized & filtered
- Oxidant - $Cl_2$ or NaOCl
- $KMnO_4$ with high $SiO_2$
- Iron preoxidized and filtered
- High loading rates
  - 8 to 12+ gpm/SF
  - Smaller footprint

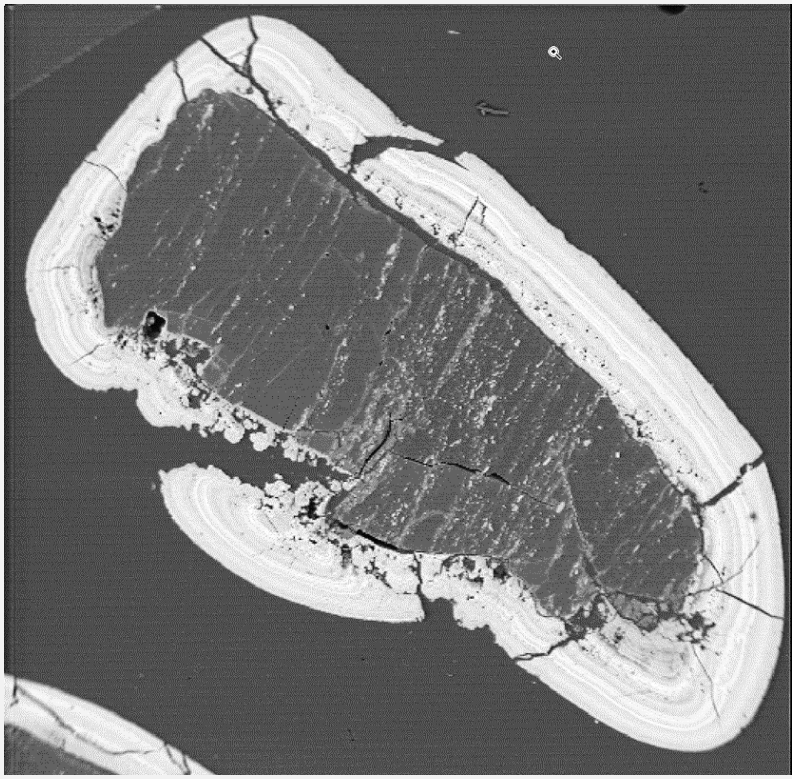
# Adsorption/Catalytic Oxidation

- Filter effluent free $Cl_2$
  - 0.5 mg/l min
  - 1.0 mg/l typical
- With low Fe, most Mn removal occurs in the upper 12 inches

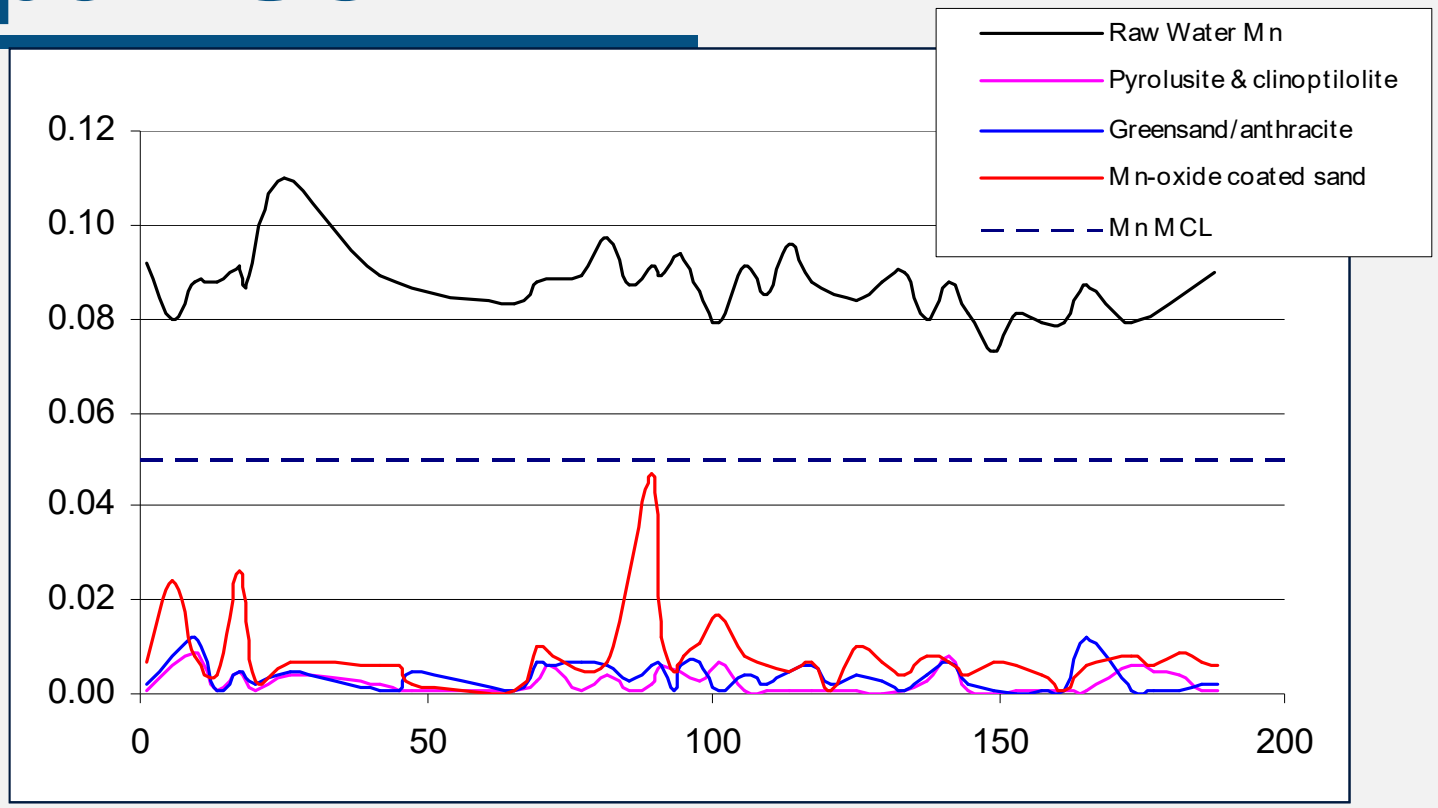
# Alternative Filter Media

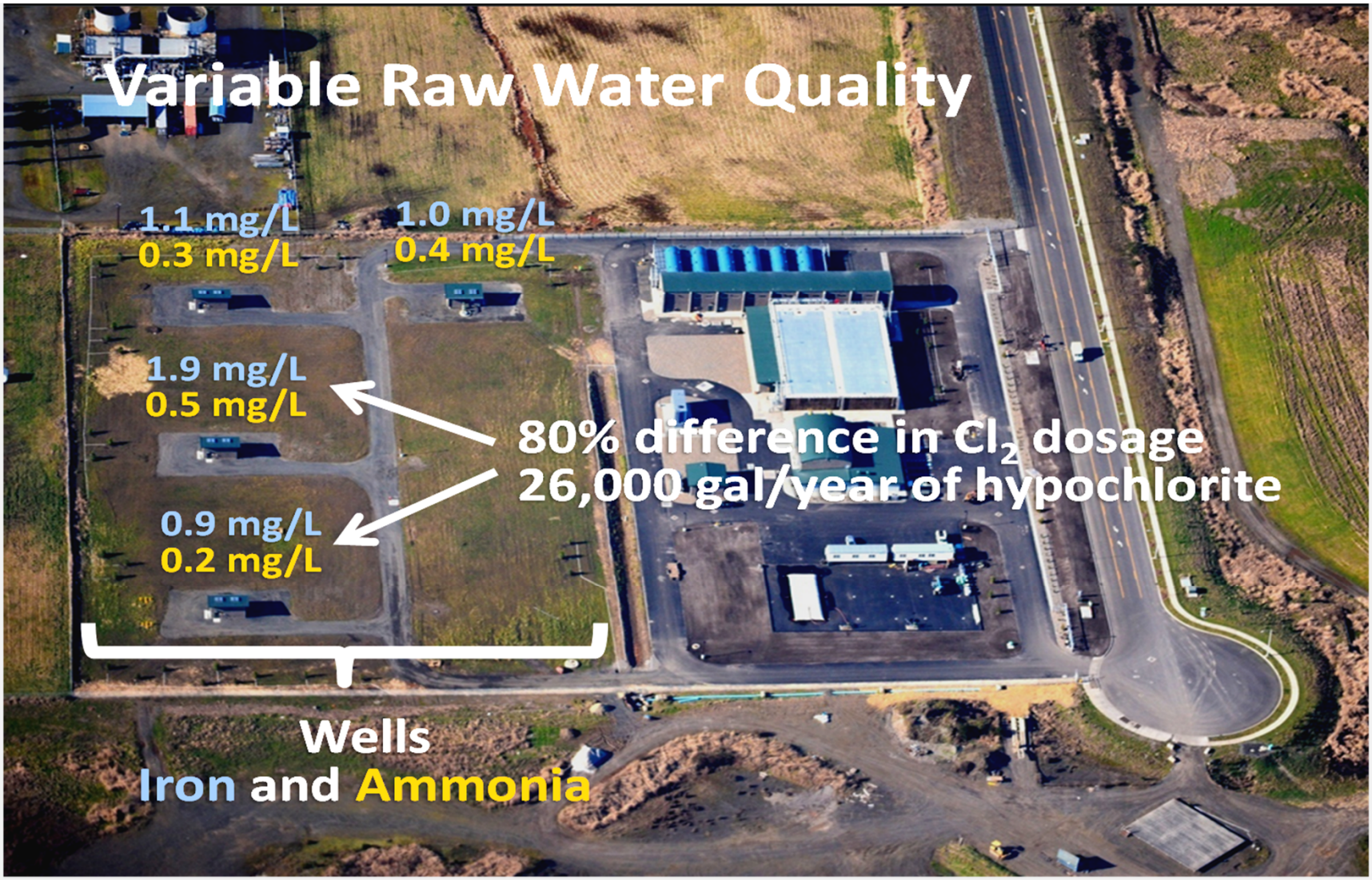
- Pyrolusite
- Manganese Greensand
- GreensandPlus with Anthracite Cap
- Manganese Oxide Coated Silica Sand with Anthracite Cap
- Proprietary (Filtronics Electromedia, Pureflow)

*Source: Tobiason et al, 2007*



# Renton Media Comparison




Variable Raw Water Quality
1.1 mg/L
0.3 mg/L
1.0 mg/L
0.4 mg/L
1.9 mg/L
0.5 mg/L
80% difference in $Cl_2$ dosage
26,000 gal/year of hypochlorite
0.9 mg/L
0.2 mg/L
Wells
Iron and Ammonia

# Backwash Handling & Disposal

- Backwash Water
  - Decant & Recycle
  - Infiltrate
  - Sewer
- Backwash Solids
  - Sewer
  - Filter Bottom Dumpster
  - Geotextile Bag
  - Mechanical Dewatering

# Backwash Solids

Fe & Mn scavenge metal from the groundwater

Lakewood Water District

| | |
|---|---|
| As | 0.22 mg/L |
| Zn | 7.4 mg/L |

Woodburn, OR

| | |
|---|---|
| As | 0.006-0.012 mg/L |

UWCD

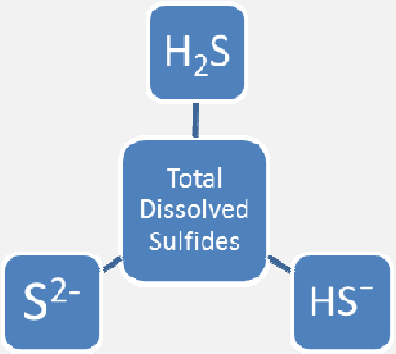
| | |
|---|---|
| As | 0.95 mg/kg |
| Boron | 8.25 mg/kg |
| Copper | 11.4 mg/kg |
| Zinc | 17 mg/kg |

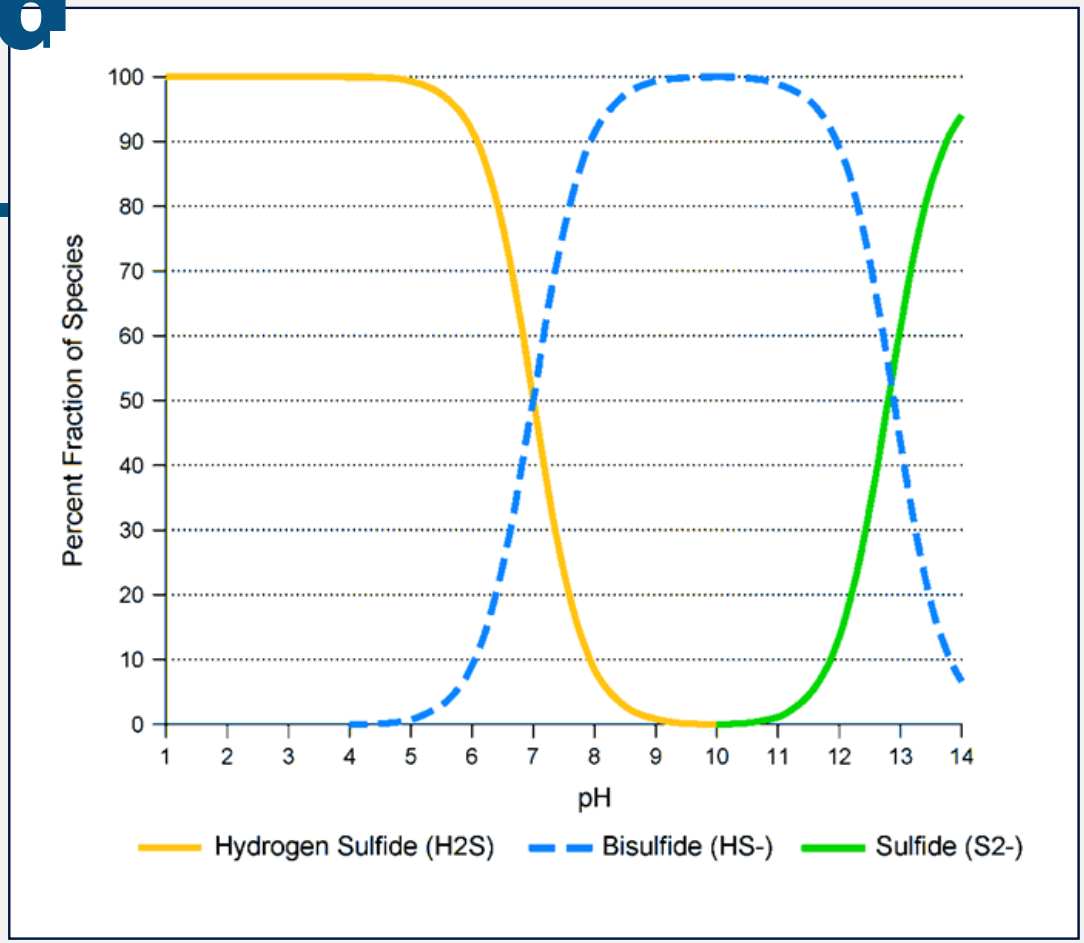
# Sulfides

- Result of bacterial activity in aquifer
- Commonly found in water containing Fe and Mn
- Problems
  - Taste and odor
    - 0.5 ppbv threshold odor (50% of population)
    - 0.5 to 1 ppmv musty/swampy
    - > 1 ppmv  rotten egg
    - Sulfur - metallic
    - Polysulfide ($HS_n^-$) – burnt rubber
  - High chlorine demand
  - Biomediated corrosion of iron pipe

# Total Dissolved Sulfides

- pH dependent
- All forms contribute to undesirable taste
- $H_2S$ can be stripped by aeration
- $HS^-$ cannot be stripped by aeration



# Sulfide Treatment Options

- Aeration
- Catalytic GAC
- Oxidation
  - yields sulfur, polysulfides, sulfites, thiosulfates, sulfate end products
- Oxidation/Filtration
- Chlorination, sulfite addition to form thiosulfate, rechlorination

# Air Stripping Hydrogen Sulfide

- $H_2S$ stripped at acidic pH
  - Acid feed may be req'd
  - NaOH to readjust pH
  - Offgas $H_2S$ odor
- Scotts Valley
  - Treating offgas with biotrickling filter/GAC

# Sulfide Oxidation

Chlorine oxidation

- 2.1 mg $Cl_2$/mg sulfide to oxidize to $S^0$
- 8.3 mg $Cl_2$ /mg sulfide to oxidize to $SO_4^{2-}$
- Polysulfide formation
  - Colloidal sulfur and polysulfides initially formed
  - $SO_2$ or sodium bisulfite to form thiosulfate
  - Rechlorinate to convert to $SO_4^{2-}$

# Catalytic Oxidation to Sulfate with GAC

- Adsorbs $H_2S$
- Catalyzes oxidation of $H_2S$ to $SO_4^{2-}$
- Requires dissolved $O_2$
- 5 to 10 minute EBCT
- Excess dissolved $O_2$ to maintain aerobic conditions
- Backwash 8 to 10 gpm/SF for ½ hr
- Bacterial growth
- Operating since 2006

# Prior Water Treatment Work

- Sulfides 0.12 to 0.20 mg/L
  - Elevated pH 8.1 to 8.4
- Manganese 0.07 to 0.12 mg/L
- Ammonia 0.4 to 0.5 mg/L
- High chlorine demand
- High $H_2SO_4$ & NaOH doses
- Water quality & odor complaints
- H2S corrosion

# Taste & Flavor Evaluation

- Panel of City personnel and Maplewood customers
- Taste ranking:

1 – Awful
2 – Poor
3 – Mediocre
4 – Good
5 – Very Good

# Testing Average Taste Scores

| Water | Same Day | Next Day |
|---|---|---|
| Bottled Water | 3.9 | |
| City Hall | 4.1 | |
| Maplewood (shops) | 3.3 | |
| Pyrolusite | 2.1 | 2.9 |
| Greensand | 2.7 | 2.9 |
| Silica sand | 2.6 | 3.1 |
| GAC + greensand | 3.5 | 3.9 |
| Clino+pyro+bisulfite+$Cl_2$ | 1.9 | 3.8 |

# Q & A

## Questions and Discussion

Kennedy Jenks