The Effect of Water Chemistry on the Physical Properties of Iron Colloids and Aqueous Iron Suspensions

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2000 AWWA Water Quality and Technology Conference; Salt Lake City, Utah; November 5-8, 2000

Iron Corrosion and Release, and Red Water (Source Water Iron)

- Particle formation
- Discolored water (complaints)
- Staining of fixtures, clothing
- Metallic tasting water
- Flow restriction
- Oxidant demand
- Biofilm

Iron Release Pathways from DS

- Physical route
  - abrasion or erosion of pipe scale
  - sediment transport
  - changes in water flow patterns
- Chemical
  - dissolution of scale
  - oxidation/reduction
  - ferrous (soluble)
  - precipitation/particle (ferric iron)

Chemical Iron Release

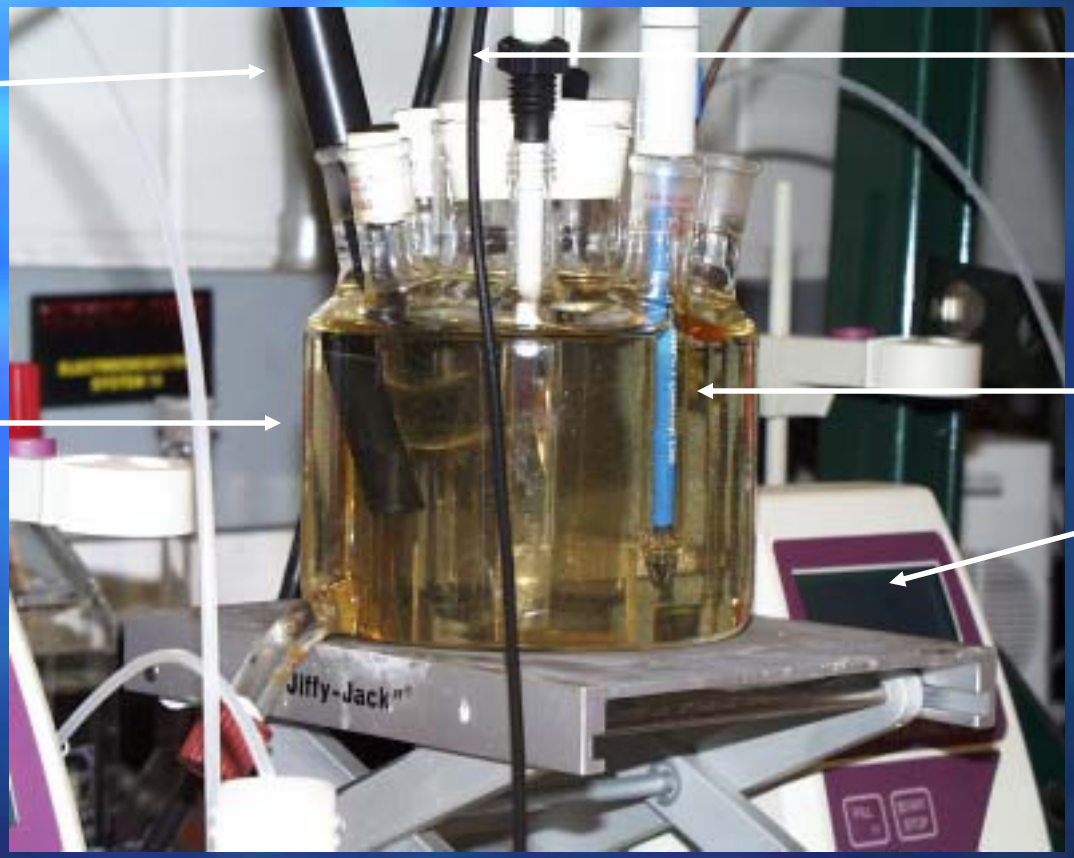
Role of Particles/Colloids

- When oxygen and chlorine are in contact with scale, ferrous ions are oxidized within the scale or close to the surface- *particles incorporated in scale-reflect scale*
- When oxidants are not present at surface, ferrous iron can diffuse into solution and is oxidized further out- *particles form in bulk water*

Research Objectives
Highlights

- **Describe the impact of water chemistry on the properties of iron colloids/particles**
  - pH, DIC, orthophosphate, polyphosphate formulations, silicate
  - Structure, size, shape, surface charge, crystalline nature, density
- **Describe the impact of water chemistry on the properties of iron suspensions**
  - Color, turbidity, particle/colloid stability

Particle Generation Reactor
(1 and 5 mg/L Fe)



DO electrode

Gas feed line

1.2 L cell

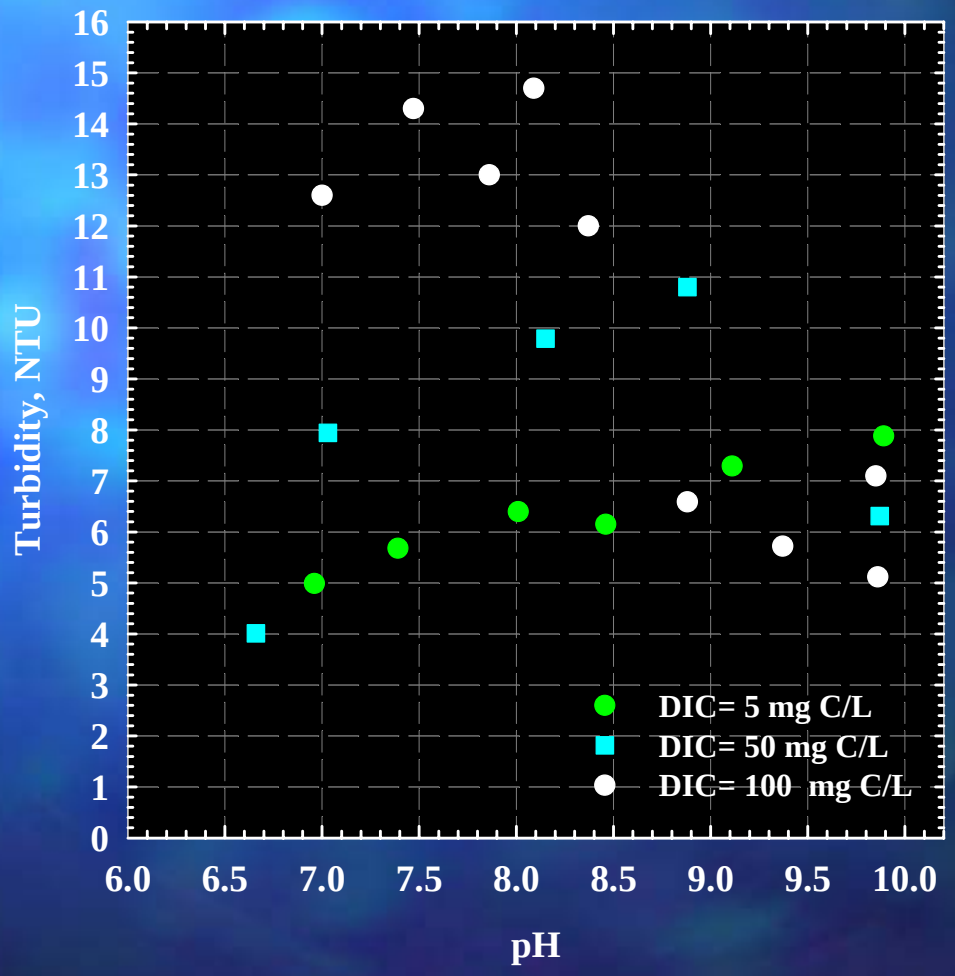
pH electrode

Acid/base titrators

The Effect of pH and DIC on Iron Particles and Iron Suspensions

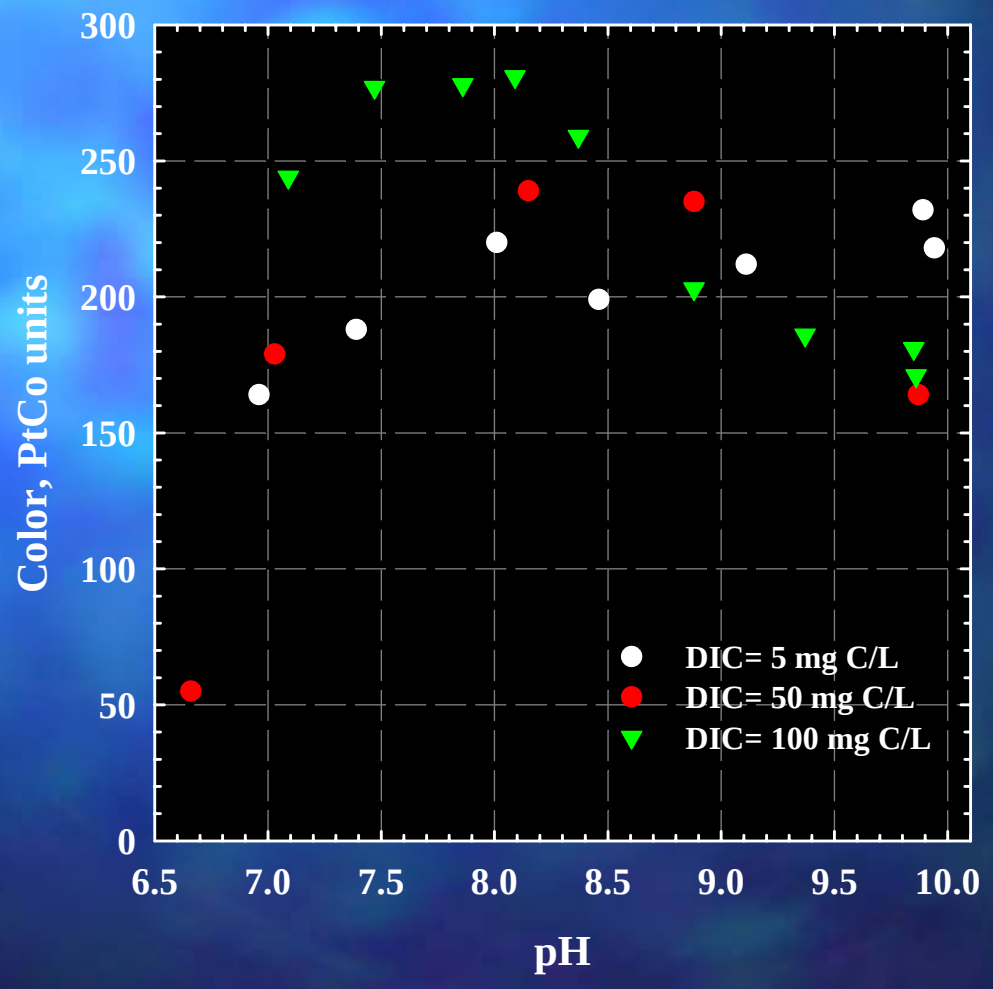
Effect of pH and DIC on Turbidity of Iron Suspensions

5 mg Fe/L, 23°C, PO_2=0.122 atm



The Effect of pH and DIC on Apparent Color

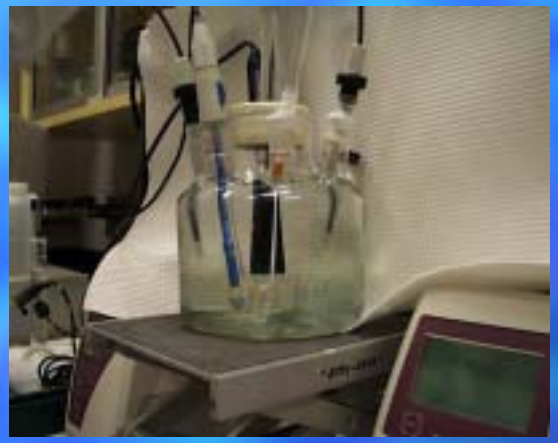
5 mg Fe/L, 23°C, PO_2=0.122 atm



Color Development in High pH (10) and High DIC (100 mg C/L) Water

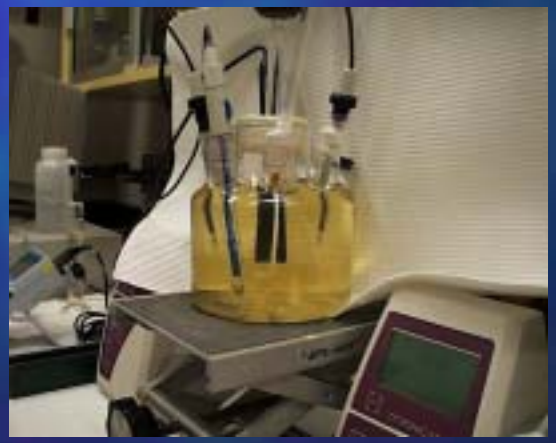
5 mg Fe/L, 23°C, PO_2=0.122 atm

5 seconds



15 seconds

45 seconds

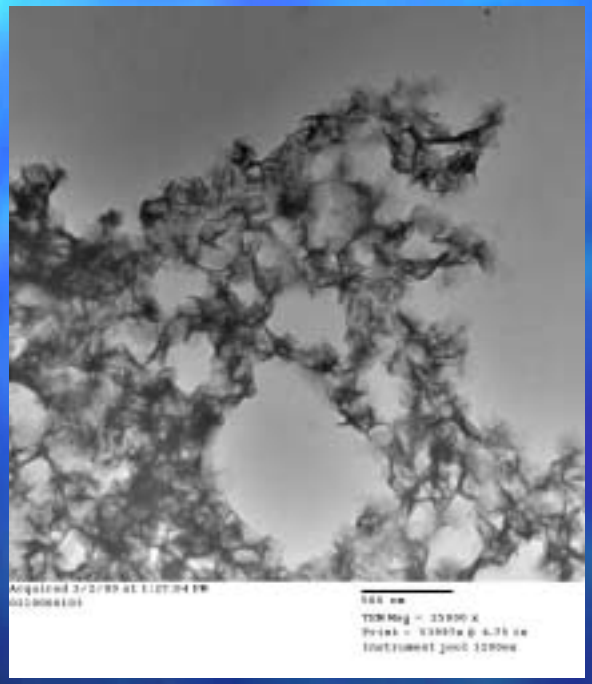


180 seconds

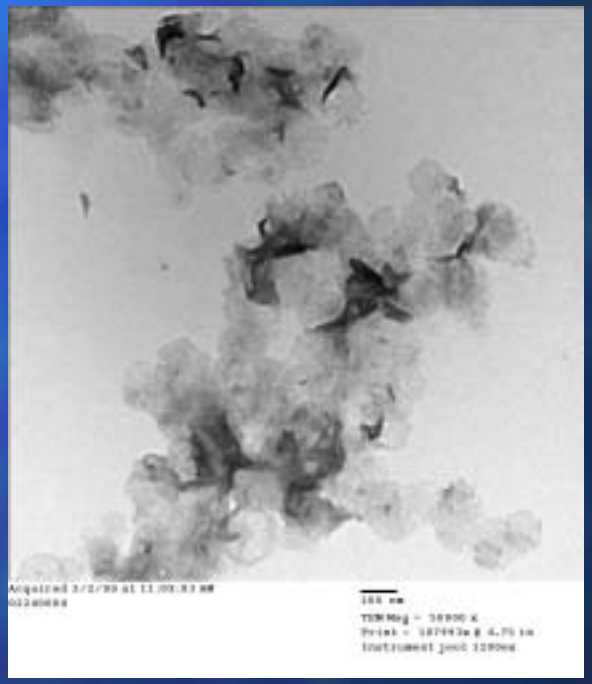
The Effect of pH and DIC on Iron Colloids

5 mg Fe/L, 23°C, PO_2=0.122 atm, DIC= 100 mg C/L

pH=7



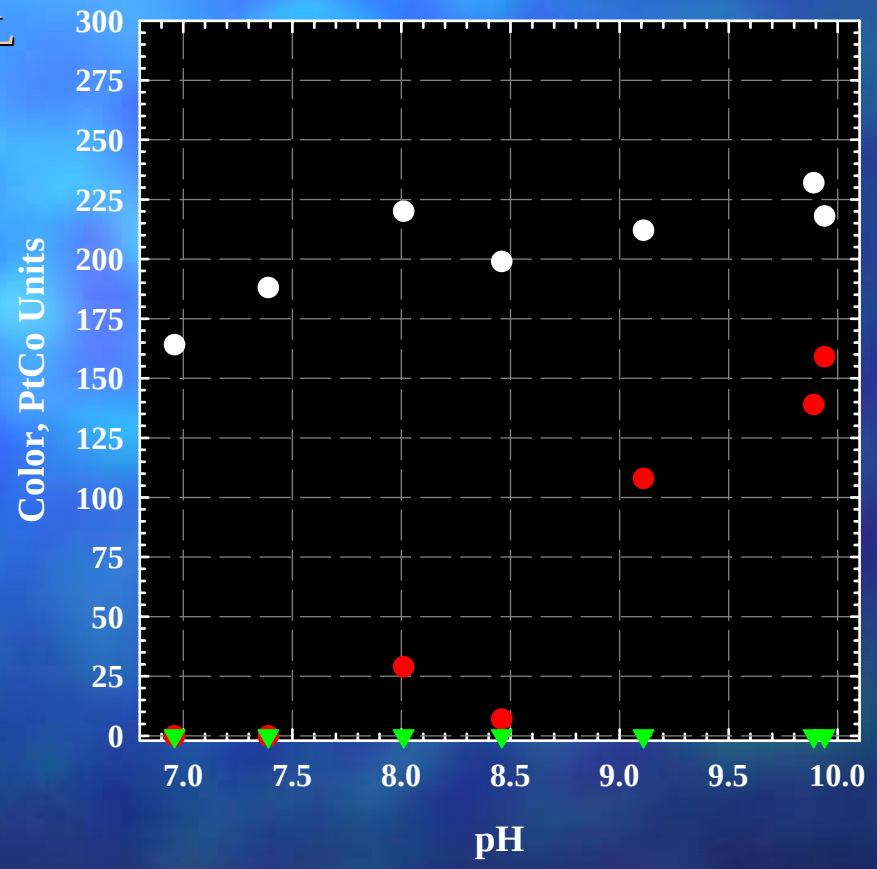
pH=10



The Effect of pH on Filtered Color

5 mg Fe/L, 23°C, PO_2=0.122 atm

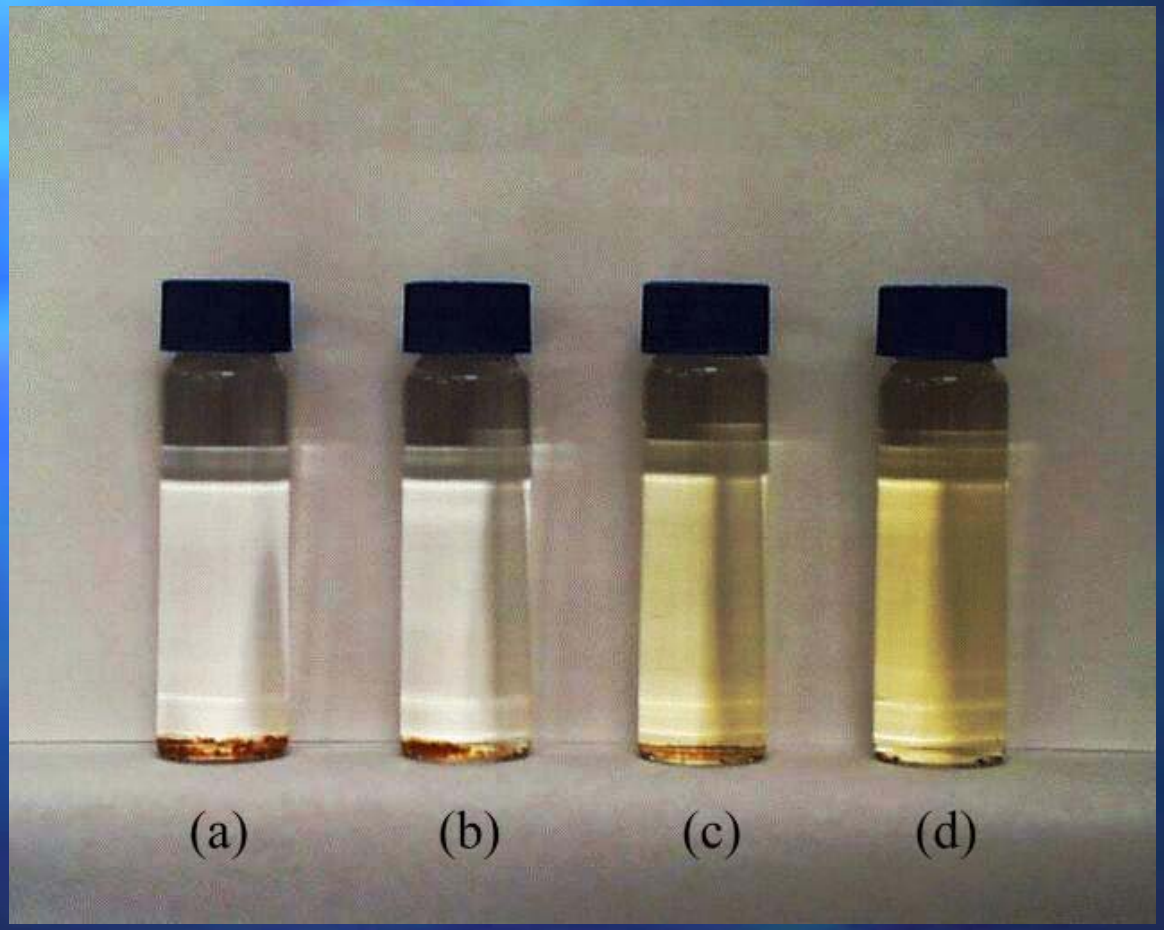
DIC=5 mg C/L



The Effect of pH on the Stability of Iron Suspensions

5 mg Fe/L, DIC= 5 mg C/L, 22°C, P_{O_2}=0.122 atm

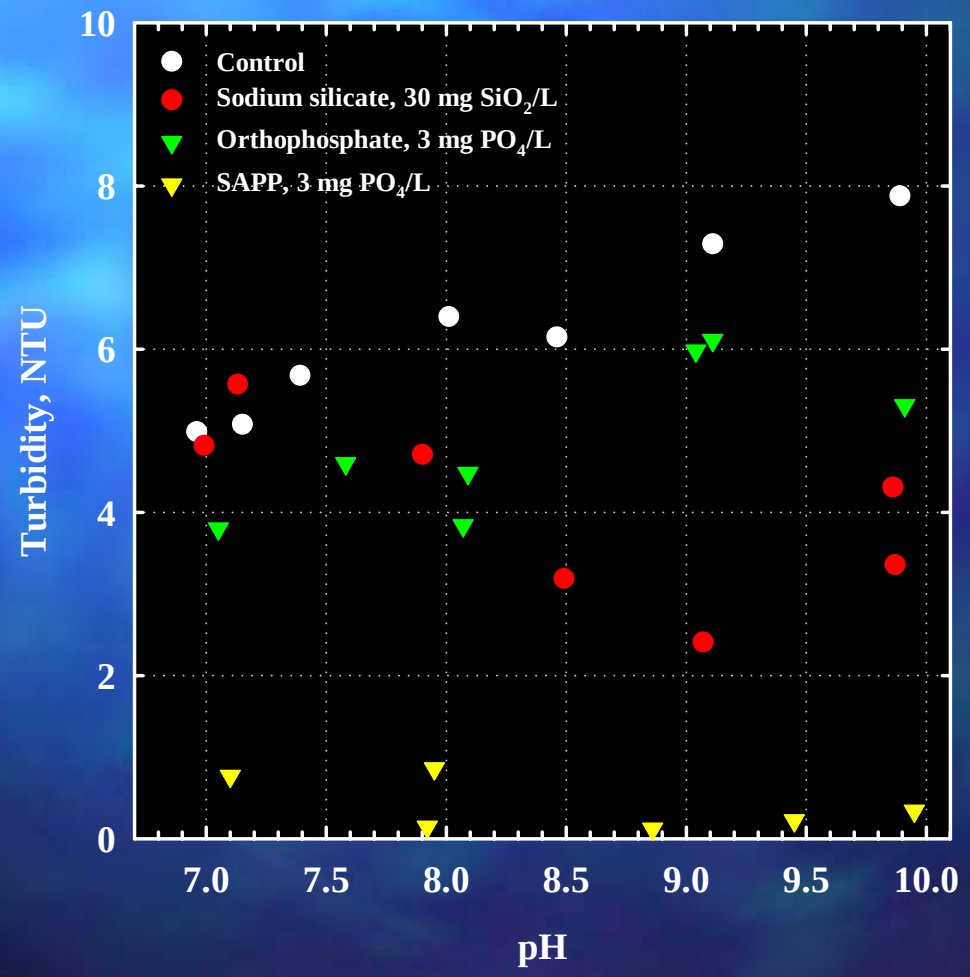
pH= (a) 6, (b) 7, (c) 8, and (d) 9



The Effect of “Corrosion Inhibitors” on Iron Particles and Iron Suspensions

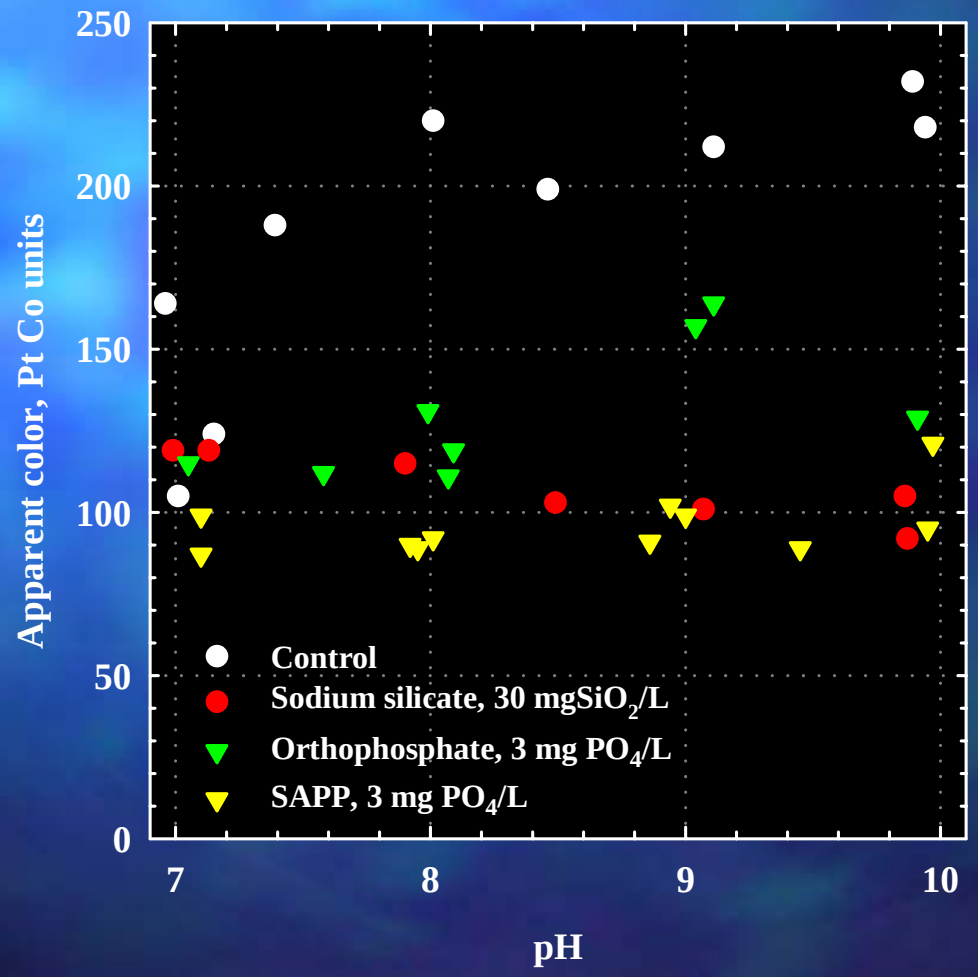
The Effect of Corrosion Inhibitors on Turbidity

Fe_{tot} = 5 mg/L, DIC= 5 mg C/L, 0.122 atm O_2,, 23°C



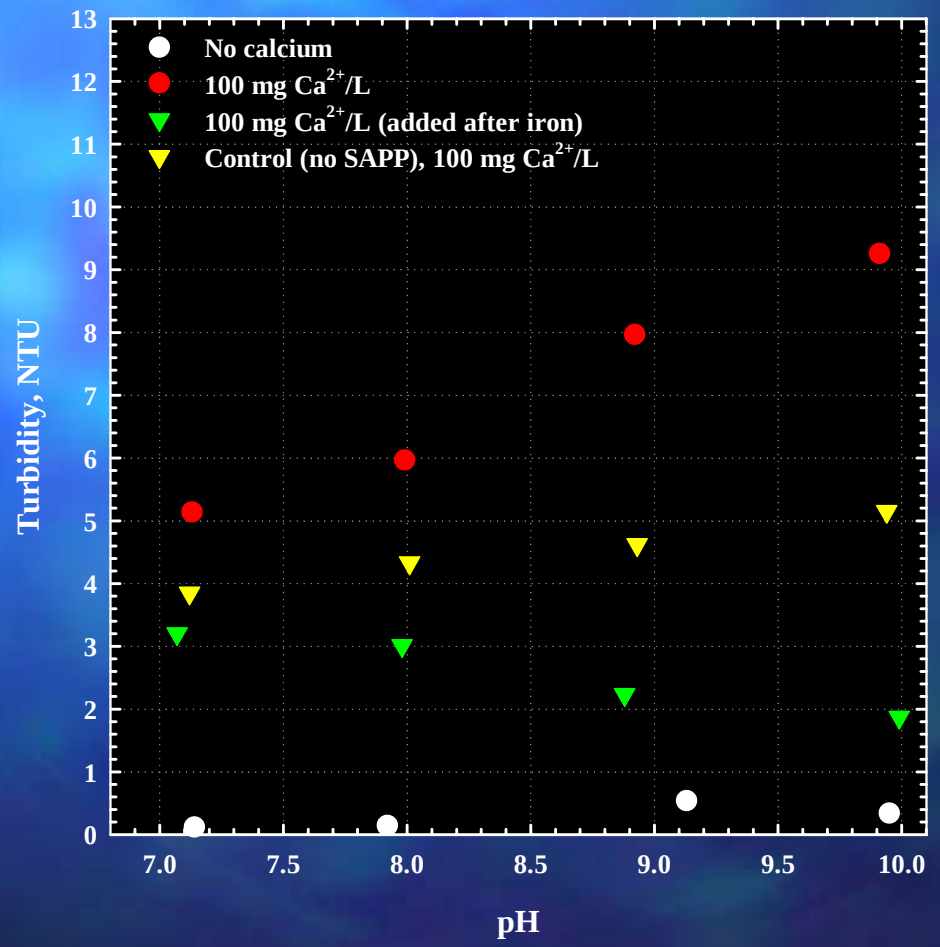
The Effect of Corrosion Inhibitors on Color

Fe_{tot} = 5 mg/L, DIC= 5 mg C/L, 0.122 atm O_2,, 23°C



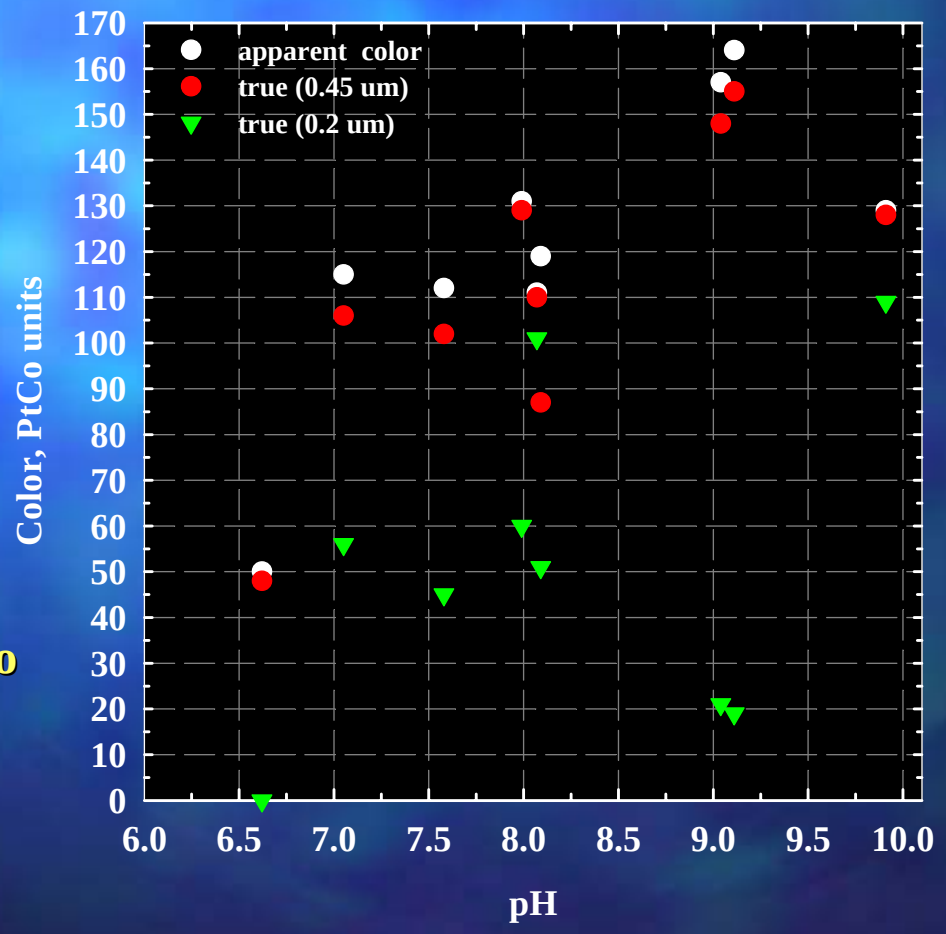
The Effect of SAPP on Turbidity when 100 mg/L Calcium is Present

Fe_{tot}= 5 mg/L, DIC= 5 mg C/L, 0.122 atm O_2, 22°C, 3 mg PO_4/L



The Effect of Orthophosphate on Color

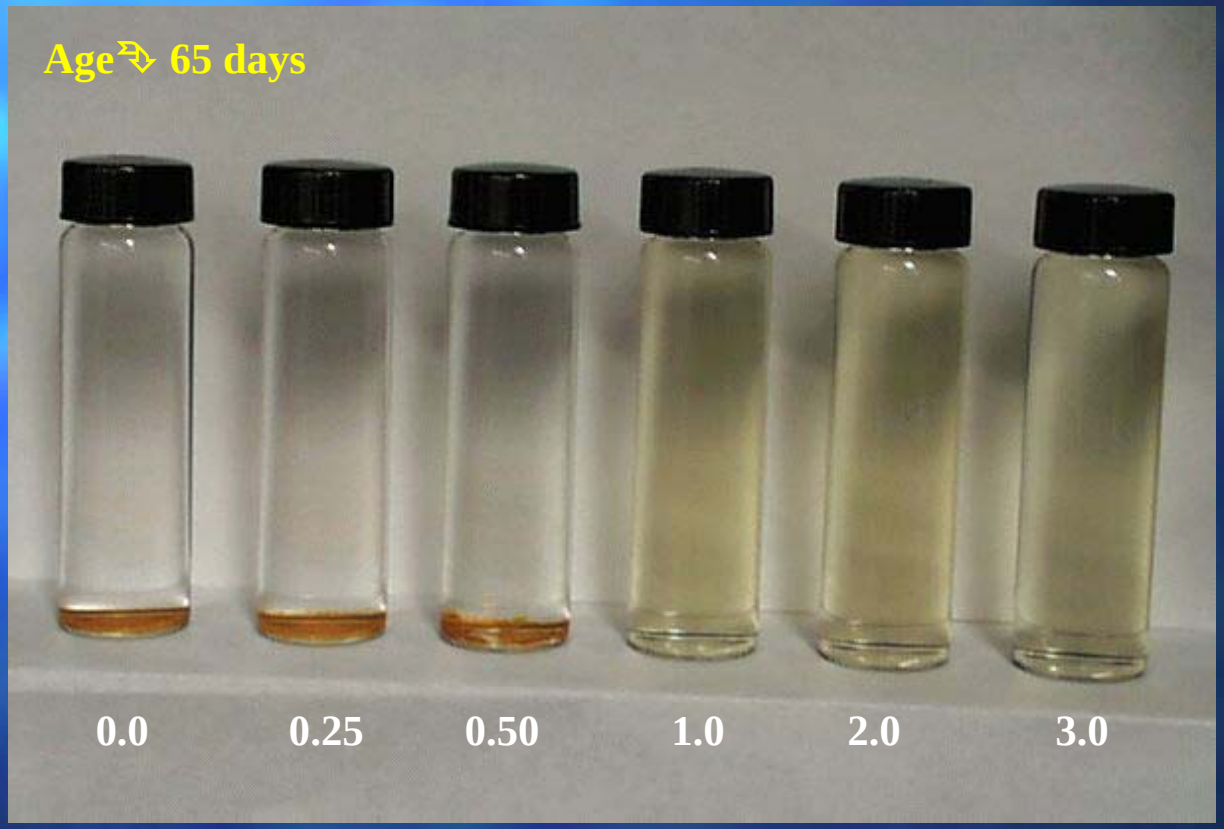
Fe_{tot}= 5 mg/L, DIC= 5 mg C/L, 0.122 atm O_2, 22°C, 3 mg PO_4/L



Light scattering particle size=200 to 225 nm

Effect of Orthophosphate on Iron Suspension Stability

5 mg Fe/l, PO_2= 0.122 atm, pH=8, DIC= 5 mg C/L, 22 ^{O}C

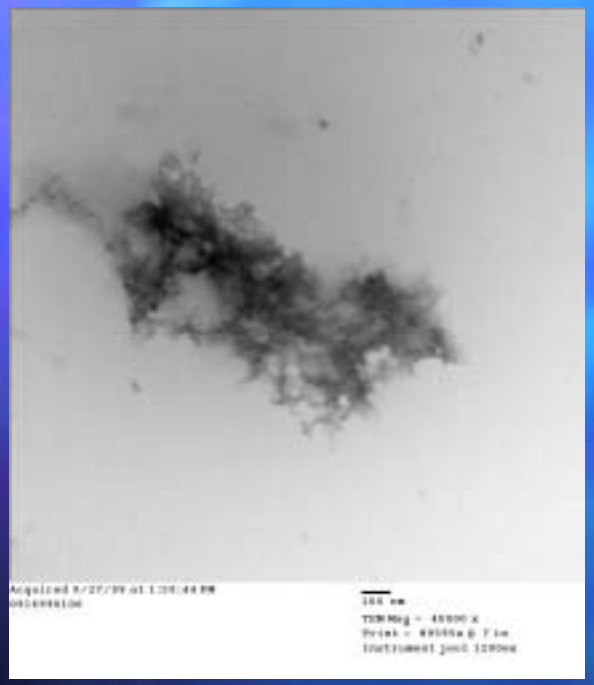


Phosphate, mg PO_4/L

The Effect of Orthophosphate on Iron Colloids

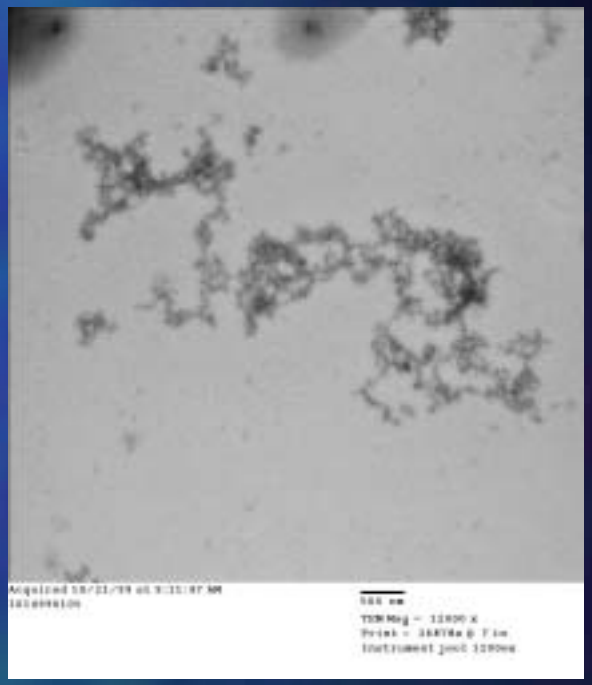
TEM micrograph of iron particles

1 mg Fe/L, pH=7.85 to 7.89, 22.5 to 23°C, DIC= 5 mg C/L, PO_2=0.122 atm



0 mg PO_4/L (crystal)

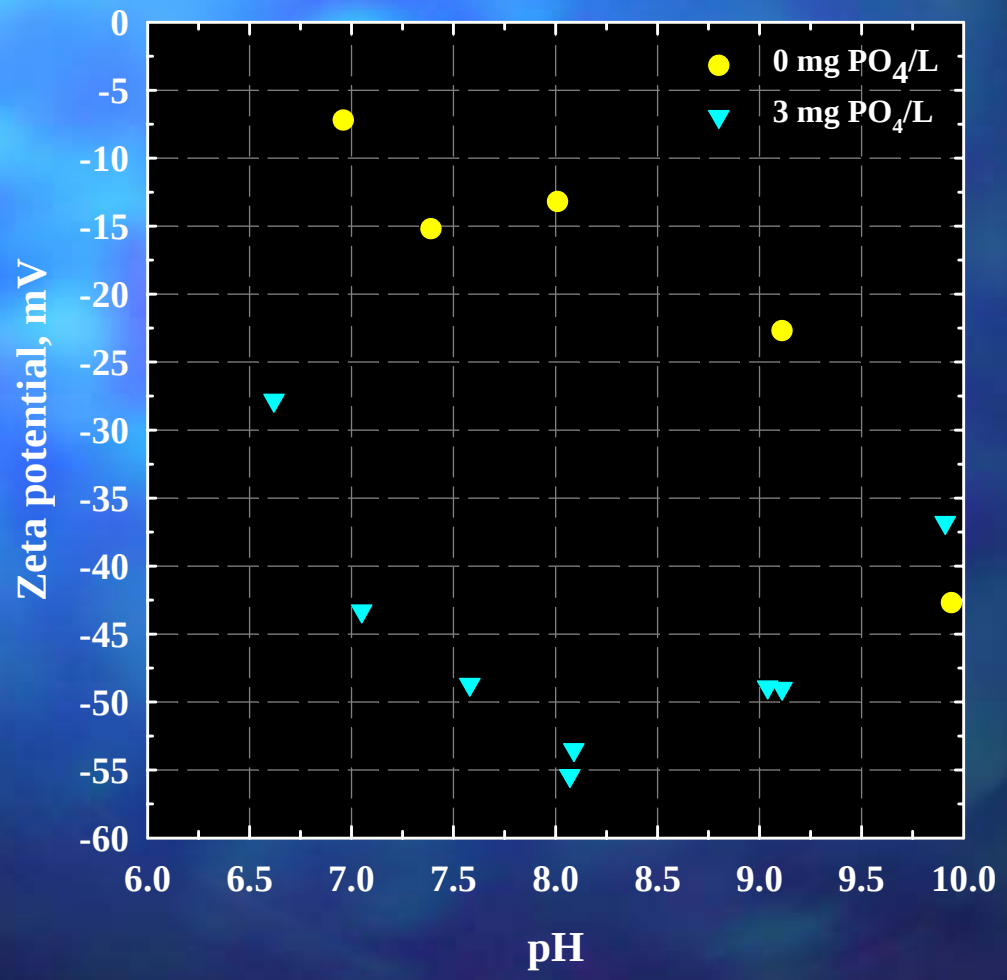
0.5 mg PO_4/L



3 mg PO_4/L (am)

The Effect of Orthophosphate and pH on ZP

Fe_{tot} = 5 mg/L, DIC= 5 mg C/L, 0.122 atm O_2, 22°C



The Effect of pH and DIC on Iron Particles and Suspension

Summary

1. Color and turbidity increased slightly with increase in pH below pH 8.5
2. Apparent color and turbidity increased linearly with increasing iron
3. Intermediate, short-lived solid formed in higher pH and DIC waters
4. Particle charge and suspension stability increased with increasing pH

The Effect of Orthophosphate on Iron Particles and Suspension

Summary

Orthophosphate (inhibitors)…

1. Reduced suspension color and turbidity
2. Adsorbed to iron colloid (EDXA)
3. Increased the charge of iron colloids
4. Stabilized iron colloids
5. Inhibited colloid growth and flocculation

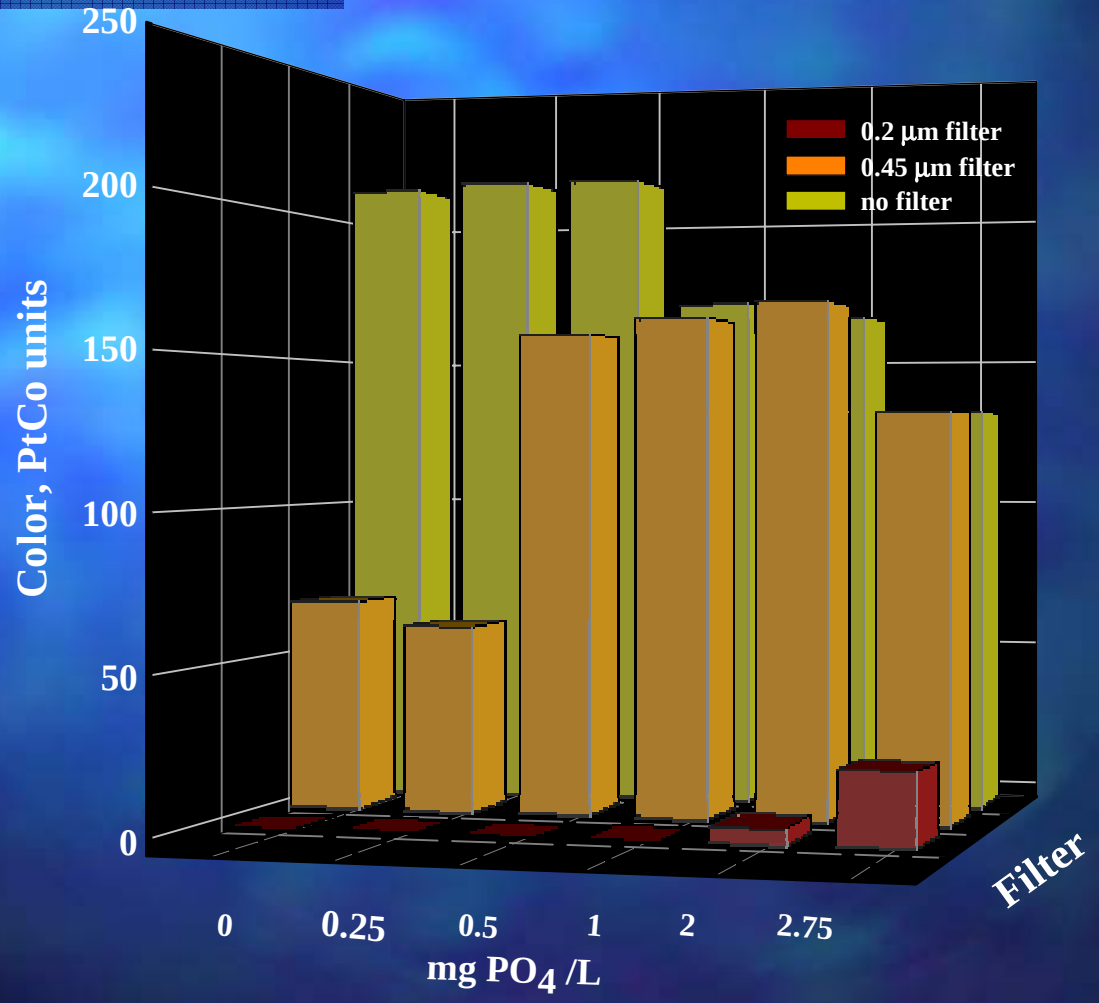
Acknowledgements

- Christy Frietch, Christina Feld, Leslie Wilsong, Amanda Grandin- U.S.EPA, Cincinnati, Ohio
- Michael Schock- U.S.EPA, Cincinnati, Ohio
- University of Illinois Iron Release research team
  - Michael Beckett
  - Pankaj Sarin
  - Jack Beebe
  - Kevin Jim

The End- THANK-YOU

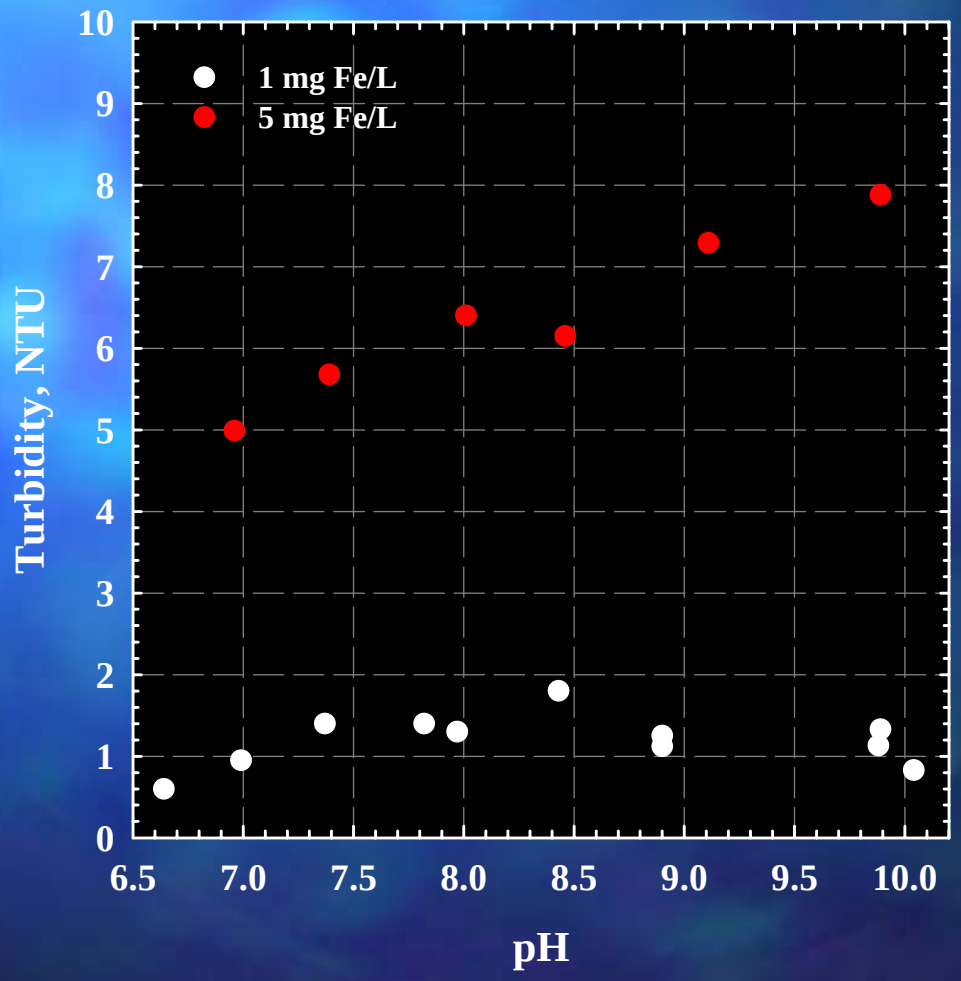
The Effect of Filtration on Color and Total Iron in the Presence of Orthophosphate

Fe_{tot}= 5 mg/L, DIC= 5 mg C/L, 0.122 atm O_2, 22°C, 3 mg PO_4/L, pH 8, 22°C



The Effect of Iron and pH on Turbidity

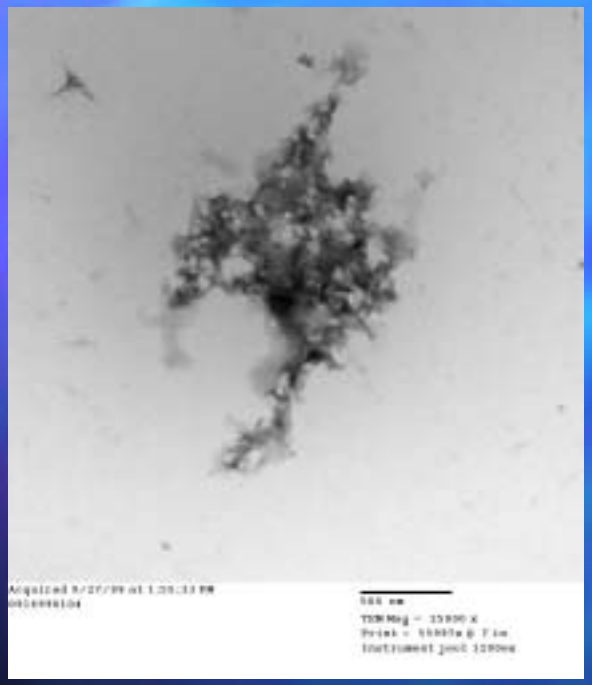
23°C, PO_2=0.122 atm, DIC= 5 mg C/L



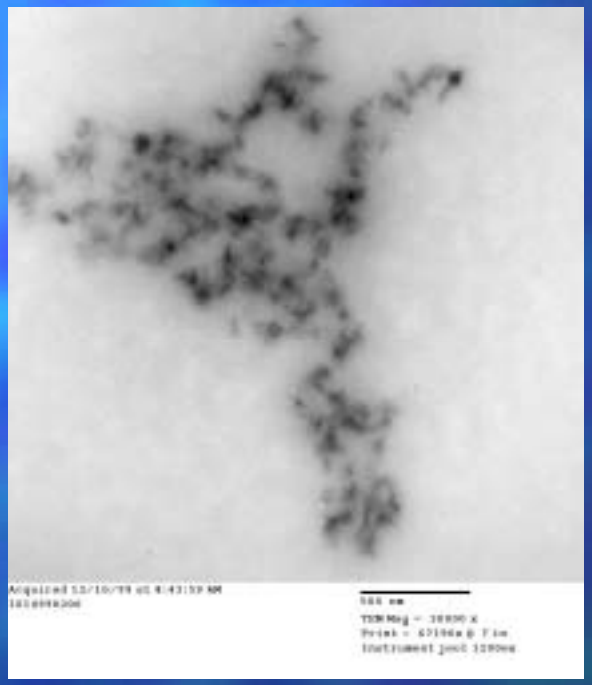
The Effect of DIC on Iron Colloids

TEM micrograph of iron particles

1 mg/L Fe, pH=7.85 to 8.05,22.5 to 23.3°C, PO_2=0.122 atm



5 mg C/L

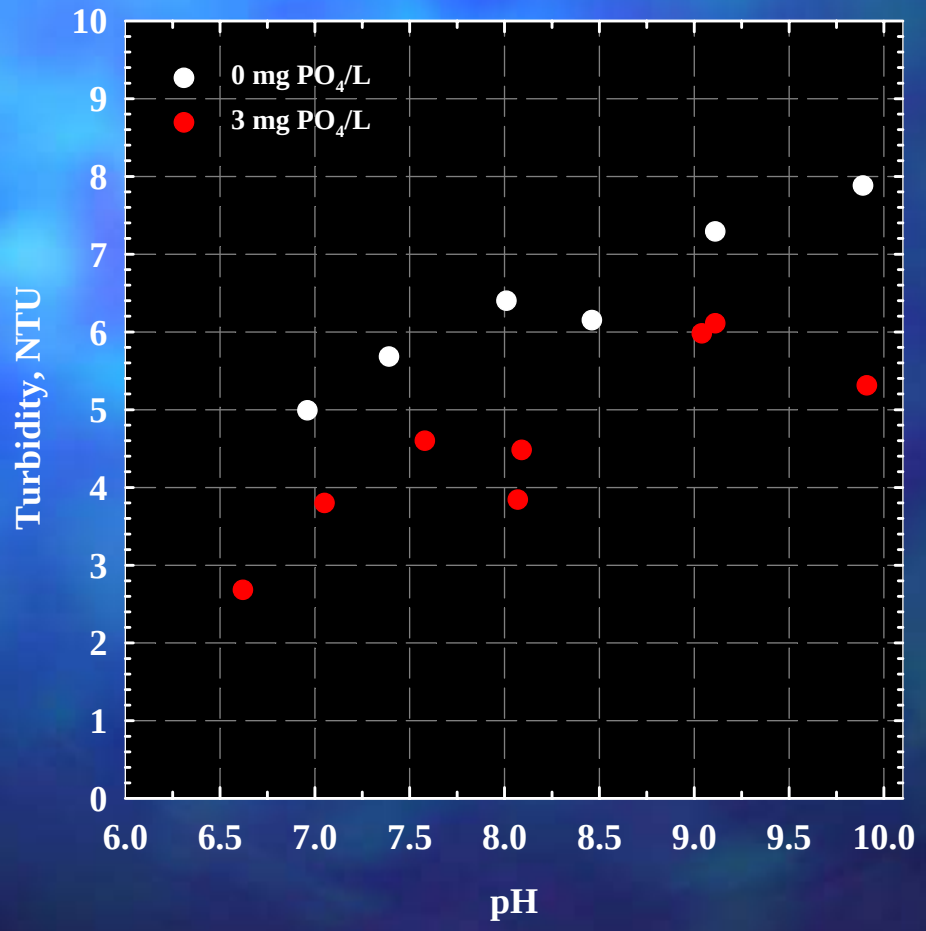


50 mg C/L

500 mg C/L

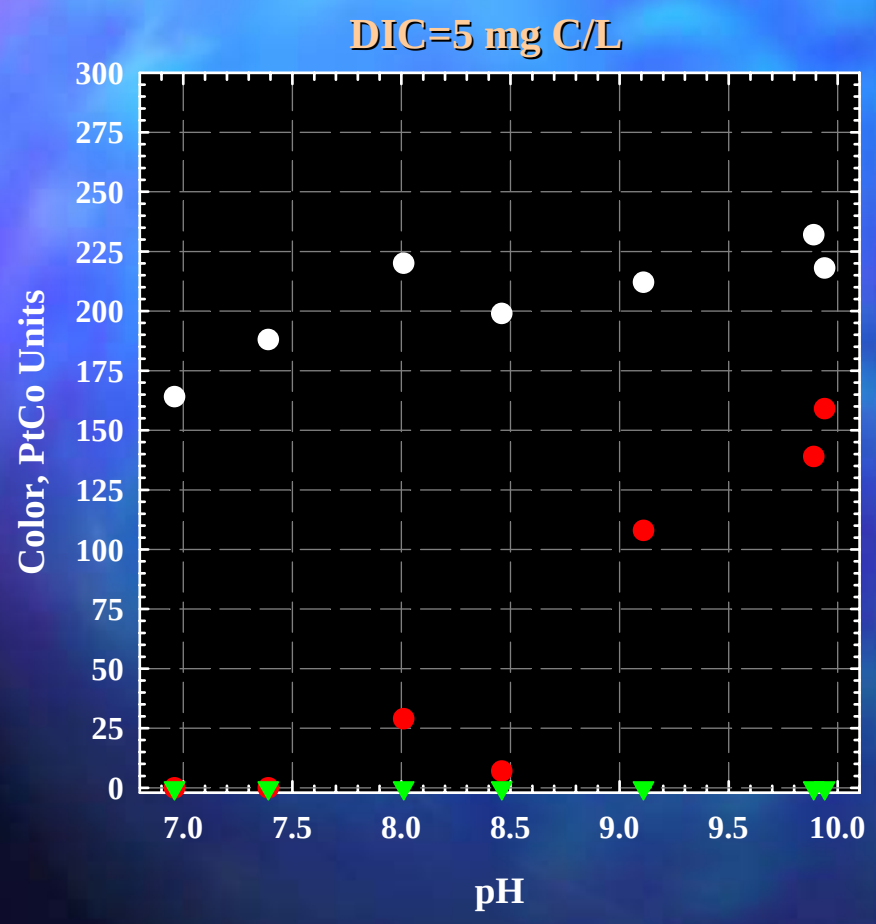
“Iron Release (chemical) Model” Research Team

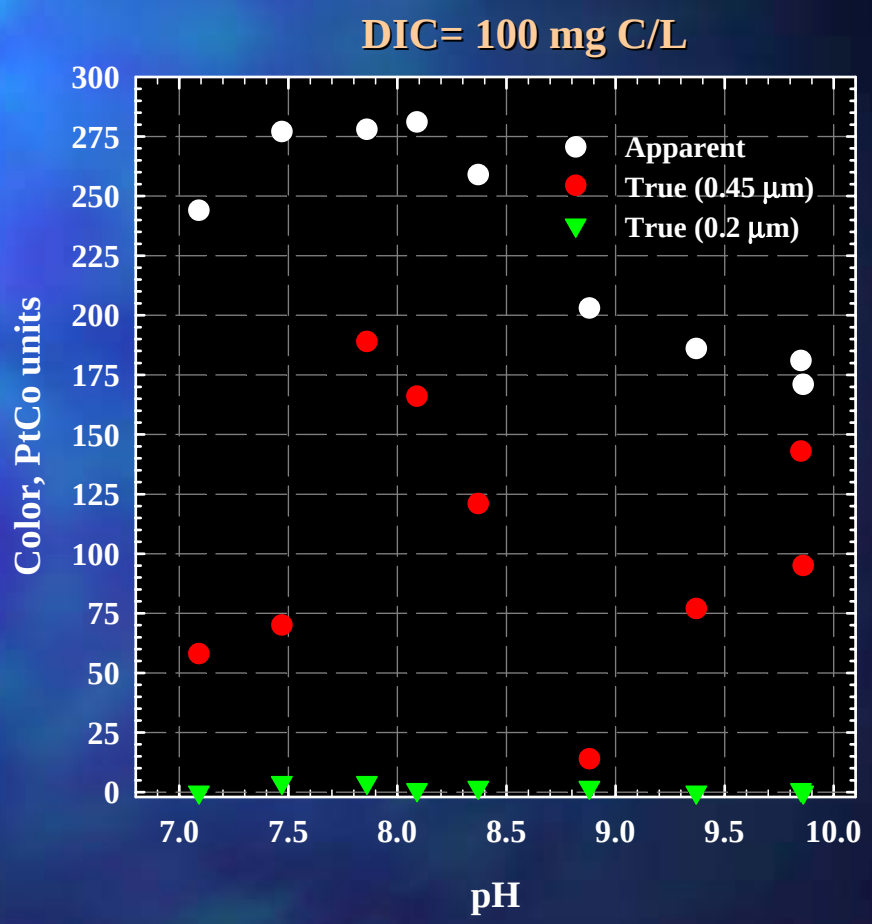
- **Research team:**
  - **University of Illinois (Prof. Snoeyink research group, Materials Science and CE Dept.)**
    - **pipe loops, iron release measurements**
    - **strong emphasis on scale analysis (Boston, Champaign)**
  - **U.S. EPA**
    - **colloid/particle properties**
    - **suspension properties**
    - **Fe(II) oxidation kinetics**


0 mg PO4/L
3 mg PO4/L
Turbidity, NTU
pH
0
1
2
3
4
5
6
7
8
9
10
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0

The Effect of pH and DIC on Filtered Color

5 mg Fe/L, 23°C, PO_2=0.122 atm





The Effect of Filtration on Color and Total Iron in the Presence of Orthophosphate

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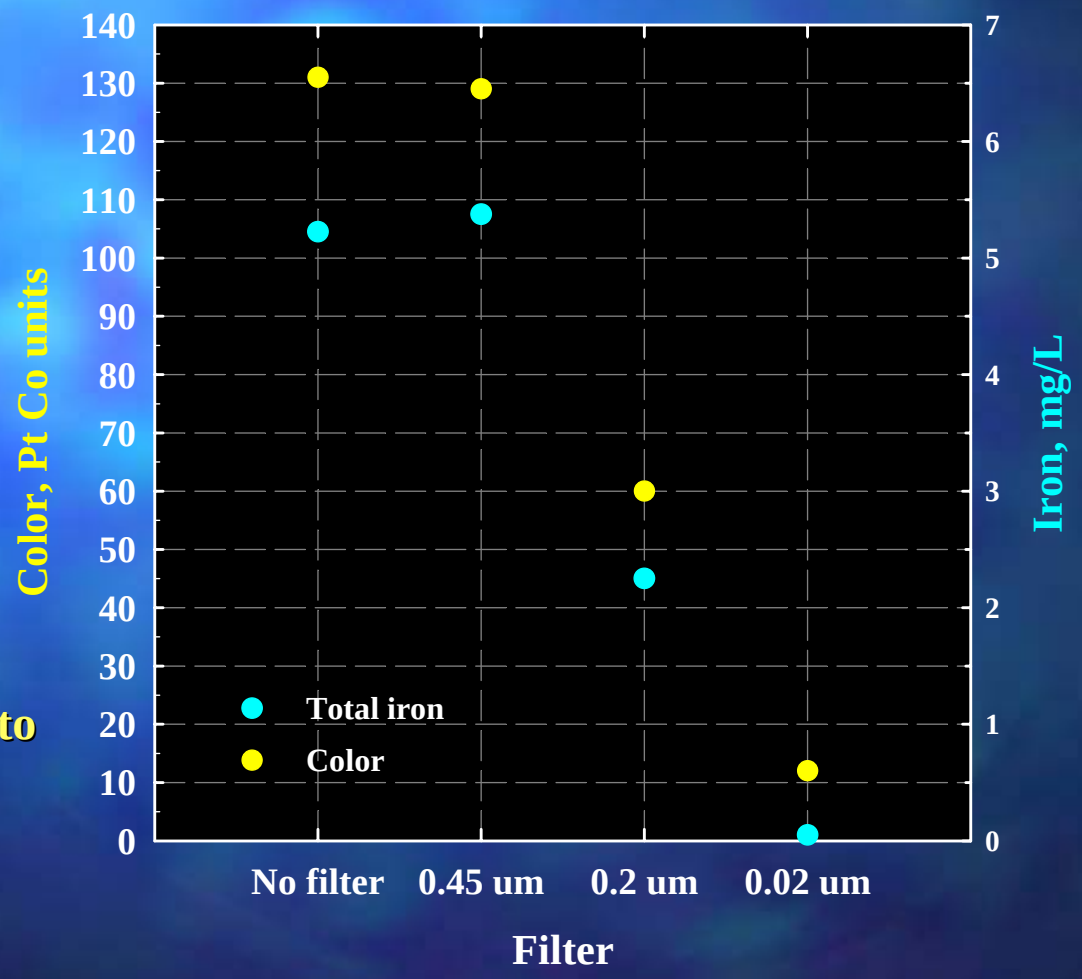
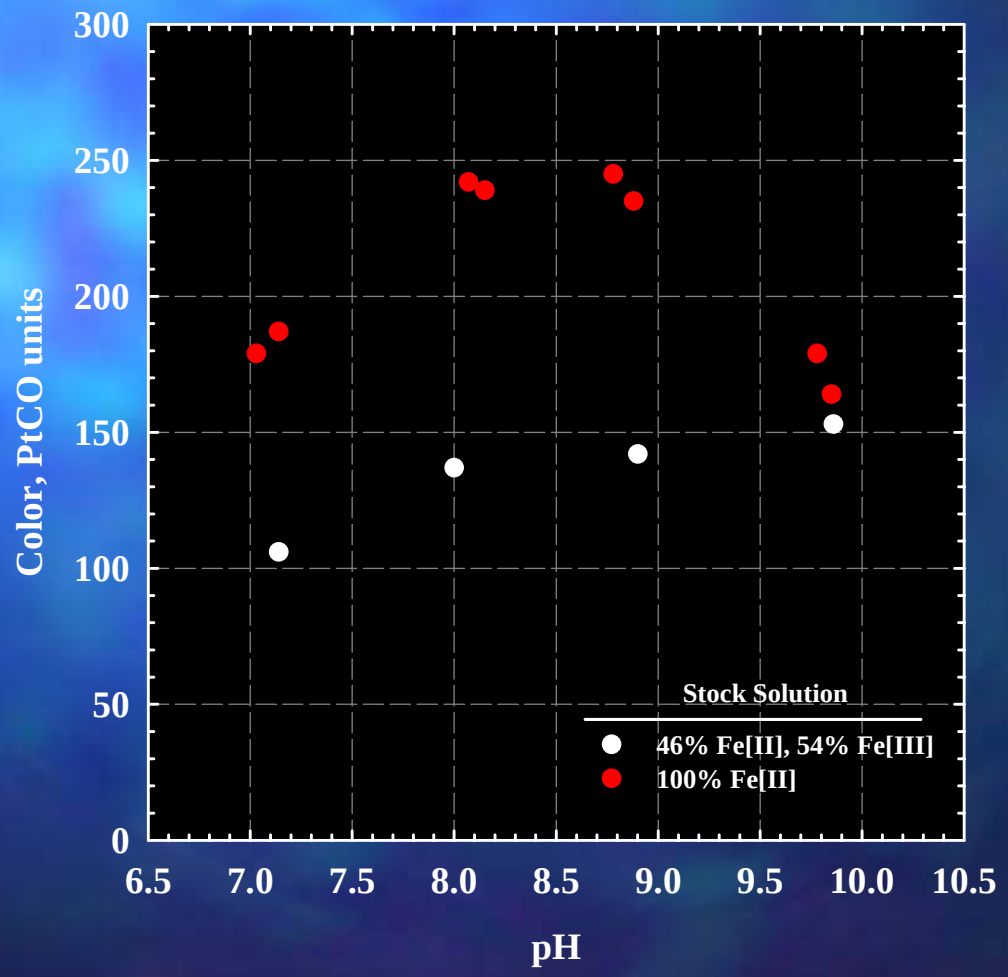


Light scattering particle size=200 to 225 nm

Effect of Stock Solution on Apparent Color