New and Innovative Rare Earth Technology for Low-Level Phosphorus Removal

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Discussion Outline

- Rare Earth Technology Introduction
  - What are rare earths?
  - Rare earth versus traditional P removal
- Preliminary Lab Studies
- Field Validation Trials
  - Equipment setup
  - Facility processes
  - Trial results
- Conclusions
Rare Earth Technology

- Rare earth elements are located in the lanthanide series (plus Sc and Y) of the periodic table.
- Most prominently known for high strength, permanent magnets.
- Unique reactivity with oxyanions, such as phosphate.
Phosphorus Removal Mechanism

- Rare earth elements form strong, crystalline bonds with phosphorus
  - Forms insoluble rhabdophane precipitate

- Iron and aluminum based products form amorphous “cloud” in solution
  - Adsorbs phosphate onto metal hydroxide flocc
Product Characteristics

- **Active Ingredient:** CeCl$_3$
  - Concentration: 31.5% CeCl$_3$
- **Density:** 1.47 g/mL
  - 12.3 lbs/gal
- **pH:** 3.5
  - Non-hazardous rating
Coagulant Comparison - 2.5 mg/L

Molar Ratios of Coagulants Versus Final Concentration P
2.5 mg/L PO₄-P Starting Concentration

- CeCl₃
- FeCl₃
- Fe₂(SO₄)₃ (as Fe)
- Alum (as Al)
- PAC (as Al)
- AlCl₃ (as Al)
- ACH (as Al)

Phosphorus Concentration (mg/L PO₄-P)

Molar Ratio (Ce,Fe,Al):P

0.0 0.5 1.0 1.5 2.0 2.5
0 2 4 6 8 10
Coagulant Comparison - 1 mg/L

Molar Ratios of Coagulants Versus Final Concentration P
1 mg/L PO₄-P Starting Concentration

- CeCl₃
- FeCl₃
- Fe₂(SO₄)₃ (as Fe)
- Alum (as Al)
- PAC (as Al)
- AlCl₃ (as Al)
- ACH (as Al)
Coagulant Comparison – Varying Initial P

Coagulant Required to Reduce P to 0.1 mg/L

- CeCl₃
- FeCl₃
- Fe₂(SO₄)₃
- Alum
- PAC
- AlCl₃
- ACH

Molar Ratio of Metal Required (Ce/Fe/Al:P)

Initial P Concentration (mg/L PO₄-P)
CeCl₃ Requires Lower Volume than Traditional Coagulants
Field Validation Trials - Equipment Setup
**Case Study #1**

- 45 MGD municipal WRF located in Mid-Atlantic United States
- Total phosphorus limit of 0.18 mg/L P
  - Target of 0.10 mg/L P
- Interested in seeking new coagulant with lower consumption rate, less chemical solids produced, and less staining of UV
Case Study #1

- CeCl₃ maintained phosphorus below limit with dosage rate 3x less than FeCl₃
  - CeCl₃ dosage rate: 11 ppmv; Ferric dosage rate: 34 ppmv
  - Molar ratios – 0.7:1 Ce/P ; 3.5:1 Fe/P
Case Study #2

- 11 MGD municipal WRF located in Northeast United States
- New total phosphorus limit of 0.10 mg/L P
  - Down from limit of 0.70 mg/L P
- Ferric chloride use has caused:
  - Corrosion damage
  - Staining of equipment and facility
  - Discoloration of water
- Facility wanted to discontinue use of ferric chloride due to above issues
Case Study #2

- CeCl₃ maintained effluent P of 0.05 mg/L using dose rate of 3 ppmv
- Solids being recycled through RAS stream continued to lower P upstream of addition point due to extended solids contact time
Case Study #3

- 12 MGD municipal WRF located in Mid-Atlantic United States
- Total phosphorus limit of 0.30 mg/L P
- Uses ferric chloride in addition to EBPR to meet limit
  - Experiences decline in biological phosphorus removal in summer
- Current coagulant unable to maintain required discharge during EBPR upset conditions
Case Study #3

- CeCl₃ maintained effluent P of 0.04 mg/L using dose rate of 1.5 ppmv.
- Like Case Study #2, solids being recycled through RAS stream continued to lower P upstream of addition point.
Conclusions

- Cerium chloride has ability to remove P using less volume than traditional Fe and Al based coagulants
  - Reacts at or below stoichiometric requirements
- RAS recycle increases P removal to above theoretical removal capacity
- General Rules of thumb
  - CeCl$_3$ removes 0.5 lbs P per gallon solution
  - Requires approximately 15 ppm$_v$ CeCl$_3$ per mg/L PO$_4$-P
Questions?

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