SYSTEMATIC APPROACH TO WATER TREATMENT PLANT PROCESS OPTIMIZATION

Alex Yavich, Ph.D., P.E.
Optimization Solutions Environmental, LLC
Water Treatment Plant Operation

- Filtration
- Disinfection
- Carbon adsorption etc.
- Sedimentation
- Flocculation
- Coagulation
Key to Effective Operation

Identify cause and effect relationships between unit operations and processes

Be able to control the effects
How to Build Effective Operation?

- Chemical feed rate optimization
- Choice of coagulant
- Rapid and flocculation mixing
- UV254 monitoring
Chemical Feed Rate Optimization

- Improved effluent quality
- Reduced chemical and other operational costs
- Identification of other potential areas for improvement
Case 1

Three Rivers Filtration Plant, Fort Wayne, IN

- Total capacity: 72 MGD
- Source water: St. Joseph River
Case 1: Raw Water Quality
Case 1: Treatment train

Influent → **Primary Coagulation / Lime Softening Stage**

- $\text{Fe}_2(\text{SO}_4)_3$
- Lime
- PAC
- $\text{CO}_2$

Next stage:

- Second Coagulation Stage
- $\text{Fe}_2(\text{SO}_4)_3$

Effluent
Chemical Feed Optimization Timeline

- **2006**
  - Coagulation chemical feed control computer model implemented

- **2007**
  - Lime-softening model developed and integrated into chemical feed control program

- **2008**
  - 1st/2nd stage ferric sulfate feed optimization

- **2010**
  - Corrosion control model developed and integrated into chemical feed control program
Chemical Feed Control at Fort Wayne Plant

City of Fort Wayne Water Filtration Plant

Input Data

Temperature, F 56
Alkalinity, mg/L 187

Raw Water
pH 8.1
T. Hardn, mg/L 292
UV254, 1/cm 0.397

Turbidity, NTU 51

Ferric Sulfate (1st stage), mg/L 3

High Service Discharge

Alkalinity, mg/L 47
T. Hardn, mg/L 110
Ca Hardn, mg/L 61

Recommended Feed Rates

Lime, gpg 9.2
Ferric Sulfate (2nd stage), mg/L 10.3
Adjust CO2 to maintain HSD pH @ 8.9
and LSI @ .2

Feed Rates

Clear All
Print
About This Program
Exit
Case 1: Chemical feed optimization

1 All costs in 2011 chemical prices
Choice of Coagulant

- **“Optimal” coagulant** is the coagulant that best meets plant’s specific operational objectives.

- By choosing the right coagulant, a water treatment plant can significantly improve its process performance and the quality of finished water.
What are the Choices?

Metal salts

- Turbidity removal through charge neutralization and sweep coagulation of colloidal particles
- Alum, PACl, ferric sulfate, ferric chloride

Cationic polymers

- Charge neutralization is major coagulation mechanism
- Wide range of product is available (molecular weight, charge density, structure etc.)
Optimal Coagulant: Major Considerations

**Raw water Quality**
- Turbidity
- pH
- Alkalinity
- NOM etc.

**Operational Objectives**
- Effluent quality
- Chemical costs
- Sludge production
- Filter run etc.

**Plant Size**
- Small
- Medium
- Large

**Treatment train**
- Lime softening
- Carbon adsorption
- UV disinfection etc.

**Hardware**
- Flocculators
- Clarifiers
- Filter configuration etc.
Case 2

Holland Water Treatment Plant
Holland, MI

Capacity: 38.5 MGD

Source water: Lake Michigan
### Case 2: Raw Water Quality

<table>
<thead>
<tr>
<th>Raw Water Parameters</th>
<th>Typical Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °F</td>
<td>32 – 77</td>
</tr>
<tr>
<td>Alkalinity, mg/L as CaCO₃</td>
<td>100 – 145</td>
</tr>
<tr>
<td>Turbidity, NTU</td>
<td>0.3 – 40</td>
</tr>
<tr>
<td>Total organic carbon, mg/L</td>
<td>1.6 – 2.5</td>
</tr>
<tr>
<td>UV254, cm⁻¹</td>
<td>0.01 – 0.2</td>
</tr>
</tbody>
</table>
Case 2: Holland WTP Schematic

- Raw water
- Low lift pump
- Coagulant
- Flocculation Basins
- Settling basins
- Filters
- Clearwell
- High lift pumps
- Treated water
Operational Goal

- Alum was historically employed for coagulation
- Sludge production was problematic
- Goal – reduce sludge production
Alternative Coagulants Tested

- PACI
- Alumer (a premanufactured blend of alum and cationic polymer)
- “Seasonal” coagulation practice
  - Alum: December thru April
  - Alumer: May thru November
Coagulation Computer Models at HWTP

Holland Water Treatment Plant

Raw Water Parameters

- Temperature, F: 45
- pH: 8.1
- Alkalinity, mg/L: 115
- Turbidity, NTU: 4.1
- UV254, 1/cm: 0.032
- Flow, MGD: 12

Coagulant

- Alum
- PACI
- Alumer

Alumer Dose: 10.1 mg/L
### Results of Full-Scale Testing and Computer Simulation Analysis

<table>
<thead>
<tr>
<th>Option</th>
<th>Sludge Reduction (%)</th>
<th>Cost Increase (%)</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACI</td>
<td>Up to 45%</td>
<td>Approx. 20%</td>
<td>Potential turbidity problems on IMS cap filters</td>
</tr>
<tr>
<td>Alumer</td>
<td>Up to 35%</td>
<td>5-15%</td>
<td>Not cost effective at increased UV254</td>
</tr>
<tr>
<td>Seasonal alternation between alum and alumer</td>
<td>Up to 25%</td>
<td>No cost increase</td>
<td>More complex operation</td>
</tr>
</tbody>
</table>
Plant’s Best Choice (current practice)

- Sludge reduced by up to 35 percent
- Cost reduction by 20-25 percent (compared to alumer)
- Consistent filtered turbidity
- Improved operational control
- Can be optimized to meet plant’s future goals

Separate feeding of alum and cationic polymer
Rapid and Flocculation Mixing

Mixing Intensity (G-value)

\[ G = \left( \frac{P}{\mu V} \right)^{1/2} \]

- \( G \) – velocity gradient, \( s^{-1} \)
- \( P \) – power input, \( \text{ft} \cdot \text{lb/s} \)
- \( \mu \) – dynamic viscosity, \( \text{ft} \cdot \text{s/ft}^2 \)
- \( V \) – volume, \( \text{ft}^3 \)
Rapid and Flocculation Mixing

<table>
<thead>
<tr>
<th>Operation</th>
<th>Mixing Time</th>
<th>G value, s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid mixing</td>
<td>1 – 60 sec</td>
<td>600 - 1500</td>
</tr>
<tr>
<td>Flocculation</td>
<td>20 – 30 min</td>
<td>40 - 70</td>
</tr>
</tbody>
</table>
Case 3

Saginaw Water Treatment Plant
Saginaw, MI

Capacity: 52 MGD

Source water: Lake Huron

Raw turbidity: 0.4 – 10 NTU

Coagulation: FeCl$_3$ and cationic polymer
Chemical Mixing

Riser Basin

Polymer
Lime

Ferric Chloride
Feed Point

Carbon & Fluoride
Chemical Feeds
Computer Simulation Analysis

![Graph showing the relationship between FeCl₃ concentration and Cat-Floc concentration with raw turbidity values of 5 NTU and 0.5 NTU.](image)
## Chemical Feed Optimization

<table>
<thead>
<tr>
<th>Description</th>
<th>Average dose, mg/L</th>
<th>Annual cost(^1)</th>
<th>Avg. filter turbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\text{FeCl}_3)</td>
<td>Cat-Floc</td>
<td>NTU</td>
</tr>
<tr>
<td>Before chemical feed optimization</td>
<td>5.6</td>
<td>1.0</td>
<td>$135,295</td>
</tr>
<tr>
<td>After feed rate optimization</td>
<td>5.2</td>
<td>0.45</td>
<td>$94,169</td>
</tr>
<tr>
<td>After rapid mixer installation</td>
<td>5.0</td>
<td>0.2</td>
<td>$69,720</td>
</tr>
</tbody>
</table>

\(^1\) Adjusted for 2011 chemical prices
Case 4

Holland Water Treatment Plant
Holland, MI

Capacity: 38.5 MGD
Source water: Lake Michigan
Case 4: Effect of Flocculation Mixing on Filtered Turbidity

Flocculation speed is adjusted seasonally
Water Quality Monitoring: UV254

- UV254 is a measure of ultraviolet absorption at a wavelength of 254 nm

- UV254 is a surrogate measure of natural organic matter (NOM) in water
Why Should Surface Water Treatment Plants Monitor UV254 in Raw Water?

- Coagulation
- Filtration
- Clarification
- DBP control
- Taste and Odor Control
- Disinfection
Case 5: Effect of UV254 on coagulant demand

Lake Michigan Filtration Plant, Grand Rapids, MI
Capacity – 130 MGD
Source – Lake Michigan
Case 6: Effect of UV254 on effluent turbidity

South Haven Water Treatment Plant, South Haven, MI
Capacity – 4 MGD
Source – Lake Michigan
UV254 Analysis is Fast and Simple
Benefits of UV254 Monitoring

- Improved chemical feed control
- Consistent effluent turbidity
- Reduced chemical costs
- Important for identifying the “optimal” coagulant
- Improved DBP control
- Helps optimize UV disinfection
Summary

✓ Ensure that chemical feed rates are satisfactory under all plant conditions

✓ Does the plant use the right coagulant?

✓ Verify that rapid mixing operation is adequate

✓ Adjust, if possible, flocculation speed at least seasonally

✓ Implement raw water UV254 monitoring (surface WTPs)
The authors would like to express their appreciation to the operators and laboratory staff of the Three Rivers Water Filtration Plant. The success of this project would not have been possible without their tremendous efforts and commitment to always meet plant treatment objectives and achieve best possible operational results.

Additional Information

Seminar: “Optimization of Water Treatment Plant Operations”

Presenter: Alex Yavich, Optimization Solutions, LLC

Earn up to 4 hours PDH’s or RTC hours

Dates & Locations:

6/20/2012       Evanston, IL
6/21/2012       Girard, IL

Contact:
Lisa Hoffhines
Education Coordinator
Illinois Section AWWA
(630) 377-1590
lisa@isawwa.org