CONTROLLING
ACTIVATED SLUDGE
BULKING & FOAMING:
FROM THEORY TO PRACTICE

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Presentation Outline

- Brief Background/Theory Information
  - Bulking, Foaming, Filaments
  - Potential Controls
- Review 5 Case Studies
First Off, When We Talk...

➢ Bulking
  ▪ We Usually Mean Filamentous Bulking
  ▪ There Can Also Be Non-Filamentous Bulking (Slime, Zoolgleal)

➢ Foaming
  ▪ We Usually Mean Foaming Caused by Filaments
    • Nocardia
    • Microthrix Parvicella
  ▪ There Can Also Be Non-Filamentous Foaming
    • Young Mixed Liquor/Low SRT (startup/recovery from toxic loads)
    • Surfactants
Filaments are an Important Component of Mixed Liquor

Too Few Filaments

Moderate Filament Growth

Filamentous Bulking Condition

“Can’t Live With ‘Em, Can’t Live Without ‘Em”
Sludge Volume Index (SVI) – An Indicator of ML Settleability

- **SVI < 60 mL/g**
  - Too Low, Not Enough Filaments, Fine Solids in Effluent

- **SVI = 60-120 mL/g**
  - Good Settling ML, Clear Effluent, Compact Blankets

- **SVI = 120-180 mL/g**
  - Fair Settleability, Clear Effluent

- **SVI = 180-250 mL/g**
  - Marginal/Poor Settleability, Clear Effluent*

- **SVI > 250 mL/g**
  - Very Poor Settleability/Bulking, Very Clear Effluent*

* => As long as you aren’t losing your sludge blankets.
Primary Causes of Bulking/Foaming

- Needed Compound Lacking or in Short Supply
  - Nutrient Deficiency
  - Low Dissolved Oxygen Concentrations
  - Low Substrate (Food/BOD) Concentrations
- Septicity (Sulfides, Volatile Acids)
- High SRT

Different causes result in the propagation of different filamentous organisms.
Bulking Control Strategies

- Kill the Filaments – RAS Chlorination
  - Baseline Provision

- Modify Environmental Conditions to Eliminate What’s Causing the Filaments
  - Nutrient Addition
  - Aeration Upgrades
  - System SRT/Sludge Age
  - Basin Configuration/Feed Pattern (Add Selector Zones, Modify Tankage to Plug Flow Configurations)
RAS Chlorination Basics

- Preferred Feed Point Location
  - RAS Line
  - Good Mixing/Turbulence
  - Contacts All Mixed Liquor Several Times Per Day

- Feed Rate Basis
  - Pounds of Chlorine Applied Per Day Per 1,000 Pounds of Mixed Liquor Suspended Solids in the System (Bioreactor Tanks)
    - Usually Ignore MLSS in Clarifiers Unless Holding Significant Blankets
RAS Chlorination Feed Rates

- Maintenance Dosage
  - 1-2 lbs Cl2/1,000 lbs MLSS/day
  - Can Apply 24/7

- Toxic Dosage
  - Hit ‘em Hard for Limited Periods
  - Aggressive – 4-8 lbs Cl2/1,000 lbs MLSS/day
  - Very Aggressive – 8-12 lbs Cl2/1,000 lbs MLSS/day
  - Only Apply for 4-8 hours Every 3-4 days, Using Maintenance Dose Rest of Time
  - Be Very Careful, Particularly at Very Aggressive Rates
Modify Environmental Conditions to “Select” Against Filaments

- Potential Nutrient Deficiency
  - BOD:N:P Ratio of 100:5:1 is Good Target
  - Chemical P Removal – Ensure Enough P for “Bugs”
  - Nutrient Addition

- Potential Septicity - Sulfides
  - Treat with Chemicals
  - Eliminate Sources
    - Industries
    - Collection System
    - At Plant
Modify Environmental Conditions to “Select” Against Filaments

- Take Advantage of Differences Between Filaments and “Floc Formers”
  - Physical Differences
  - Kinetic & Metabolic Differences
Floc Formers Have Certain Advantages Over Most Filaments:

- Higher Substrate Uptake/Growth Rates
- Ability to Take Up and Store Substrate
  - Feast/Famine
Floc Formers Have Certain Advantages Over Most Filaments:

- Ability to Function Under Anoxic and/or Anaerobic Conditions
  - Denitrification
    - Other Benefits Can Include
      - Alkalinity Recovery
      - Decrease in Aeration Requirements
  - Biological Phosphorus Removal
Gaining the “Selector Effect”

Example:

- Convert Complete Mix to Plug Flow

![Diagram showing the conversion from Complete Mix Bioreactor to Plug Flow Bioreactor](image-url)
Gaining the “Selector Effect”

Example:

➢ Aerobic Selector
Gaining the “Selector Effect”

Example:

- Anoxic/Ambient Selector

![Diagram](image_url)
Keys to Successful Selectors

- High Substrate (Food) Concentration
  - Eliminates Filament Size Advantage
- Short Detention Time
  - Takes Advantage of Substrate Storage Capabilities of Floc Formers
- Anoxic or Anaerobic Conditions
  - Takes Advantage of Floc Formers Anoxic or Anaerobic Respiration Capabilities
Case 1: Fox River WPCC - Brookfield, WI

- Average Flow 6-10 mgd Receiving Primarily Domestic Wastewater
- Conventional Activated Sludge
  - MLE (Modified Ludzack-Ettinger) Configuration
  - Multiple Bioreactors in Series ~ Plug Flow
  - Non-Foam Trapping Aeration Basin Pattern
  - Year Round Nitrification Not Required
- Standard Secondary Clarifiers With Scum Removal
MLE Configuration Provides Anoxic Selector Zone For Filament Control
Winter 2008-2009: Filament & Foam Outbreak

- SVIs Steadily Increasing
  - December 2008: 100=>170 mL/g
  - January 2009: 170=>220 mL/g
  - February 2009: 220=>310 mL/g
  - March 2009: 310-400 mL/g

- Losing Control of Clarifier Blankets
  - Normally Nil/Now Ranging 6-10 Feet
  - Losing Solids In Effluent Under High Flow Conditions
Corrective Actions Taken By Staff

- Maximized RAS Pumping Rate
- Put Extra Clarifier Online
- March 2009 Decreased Wasting to Increase SRT
- Sent ML & Foam Sample for Filament Identification
Brookfield Aeration Basins – 3/26/09
Brookfield Aeration Basins – 3/26/09
Brookfield Clarifiers – 3/26/09
Brookfield Clarifiers – 3/26/09
Microscopic Evaluation Results

- **Mixed Liquor Sample**
  - Mature Population Indicative of Nitrifying A.S.
  - High Level of Microthrix Parvicella
    - 5.5 on Scale of 0-6
  - Moderate to High Level of Type 0041 Filaments
    - 4 to 4.5 on 0-6 Scale

- **Foam Sample**
  - Microthrix Parvicella
Interfloc Bridging Evident in ML Sample
Diluted Foam Sample
What Do We Know About Microthrix & Type 0041?

<table>
<thead>
<tr>
<th>Microthrix</th>
<th>Type 0041</th>
</tr>
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<tbody>
<tr>
<td>• Occurs in ML or as Foam</td>
<td>• Low F:M</td>
</tr>
<tr>
<td>• Low D.O.</td>
<td>• Slow Growing/Long SRT Systems</td>
</tr>
<tr>
<td>• Slow Growing/Long SRT Systems</td>
<td>• Immune to Selector Effect/BNR Configurations</td>
</tr>
<tr>
<td>• Immune to Selector Effect/BNR Configurations</td>
<td>• Often Occurs in Combination with Microthrix</td>
</tr>
<tr>
<td>• Seems to Propagate More in Cold Temperature Conditions</td>
<td></td>
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</table>
Brookfield Strategy

- Begin Program of RAS Chlorination to Quickly Reduce SVI
  - Maintenance Dosage of 1-1.5 lbs Cl2/1,000 lbs MLSS Solids/day
  - Higher Dosage of 5-6 lbs Cl2/1,000 lbs MLSS/day For ~ 6 Hours Every Other Weekday
- Reduce System SRT to ~ 10 Days
  - Account for Solids in Clarifiers (6-10 foot blankets) and Solids Lost in Effluent
Results Within ~ 2 Weeks

- SVI < 200 mL/g (From High of 400 mL/g)
- Filament Counts ~ 3 (on 0-6 Scale)
- Very Little Foam
- Clarifier Blankets < 2 feet in All Clarifiers
- Continuing Maintenance Chlorine Dosage & Using Higher Dosage 1-2 Times/Week for 4-6 Hours Per Time
Recall Before (3/26/09)
After 2 Weeks
Clarifiers Before (3/26/09) & After 2 Weeks
Current Status

- Practicing Temperature-Based SRT Control to Prevent Future Outbreaks

- Developed Operational Guideline Chart Based on Literature and Plant Experience
Case 2: Marquette, MI WWTP

- Activated Sludge Replacing RBC Plant
- Average Flow 2-3 mgd Receiving Primarily Domestic Wastewater
- BNR Activated Sludge
  - Three 2-Pass Reactors ~ Plug Flow, Non-Foam Trapping
  - Future: Combination Anaerobic/Anoxic Selector Zones
- State of Art Secondary Clarifiers
- Flow Paced RAS Pumping
2008-2009 Issues

- Significant Digester Foaming Problems
  - No Excessive Foam in Activated Sludge System
- Chemical P Removal – Adding Ferric Chloride to Raw Wastewater Upstream of Primaries
- Experienced Increasing SVI From January – Early March 2009
  - Increase From 80-90 mL/g to 200-240 mL/g
  - Secondary Clarifier Blankets of 10-12 feet or more
Micro-Exam – Mixed Liquor
No Evidence of Filamentous Bulking
India Ink Stain Reveals Significant Exocellular Polymer
Typically Caused When Food (BOD) Plentiful, But a Required Nutrient (N, P, D.O.) May be Lacking

Bacteria Absorb Soluble BOD, Then Get Stuck and Expel Carbon as Slimy Polymer Coating on Exterior of Cell Walls

Exocellular Polymer Prevents Flocs From Compacting – Similar to Filament Bridging
Marquette Ferric Feed Through Early March

Excess P removal in Primaries causing nutrient deficient Primary Effluent?
Corrective Actions Taken Mid-March

- Brought 3rd Aeration Basin Online to Reduce MLSS Concentration & Minimize Clarifier Solids Loading
- Increased RAS Pumping Rate Out of Clarifiers
- Split Ferric Feed Between Primaries and Just Upstream of Secondary Clarifiers
Split Ferric Feed

Adding ~ 1/3 to Raw Wastewater, 2/3 to ML Just Before Clarifiers
Results – Early April

- SVIs Dropped Back to Normal Range of 90-120 mL/g
- Blankets Dropped to < 2 Feet
- No Change in Digester Foaming Problems
Case 3: Faribault, MN

- 2-3 MGD WWTP Serving Mix of Industrial & Residential

- Flow Train:  
  - Primary Clarification  
  - Roughing Trickling Filters  
  - Complete Mix Aeration Tanks  
  - Secondary Clarifiers  
  - Disinfection

- Try to Avoid Nitrification

- Undergoing Major Upgrade
  - TF Media Replacement  
  - Plug Flow Aeration Basins
Filament Outbreak Summer 2009

- High Secondary Clarifier Blankets (> 12 feet)
- Low SRT (~ 3-5 days), Partial Bypass of Roughing Filters, Adequate D.O. in Aeration Tanks
- SVIs Rising (250-300+ mL/g)
- Losing Blankets Under High/Storm Flows
Actions Taken

- Initiate Chlorination of Aeration Tank Effluent
  - ~2.5 lbs Cl2/1,000 lbs MLSS/day
- ML Sample Sent for Microscopic Examination
  - Predominant Filament Identified as 021N
Micro Exam - Faribault
Filament 021N

- Large, Long Filament
- Reported Possible Causes
  - High Organic Acids
  - Hydrogen Sulfide/Septic Conditions
  - Nutrient Deficiency
- Organic Acids & Nutrient Deficiency Ruled Out
- Activated Sludge Influent Tested for Sulfides
  - > 2 mg/L
  - O21N Reported to Occur @ Sulfides of 0.4 mg/L
Suspected Culprit – Damaged Roughing Filters
Faribault Results

- **ML Chlorination**
  - 2.5 lbs Cl2/1,000 lbs MLSS/d
  - Lowered SVIs to <150 mL/g
  - Brought Clarifier Blankets Under Control

- **Evaluated AI Chlorination vs ML Chlorination**
  - AI Chlorination Would Require 200+ lbs/day Cl2
  - ML Chlorination Would Require 30-60 lbs/day Cl2
  - Result – Use ML Chlorination as Required

- **Long Term**
  - Plant Upgrade Has Resolved Septicity/H2S Problem and Filament Outbreaks Have Ended
Case 4: Grafton, WI
Prior to 2005, Filaments Common
- 021N & Spaerotilus/S.Natans Typical

Filamentous Outbreaks (6) in 2003
- Control w/CL Feed, 58 days/613 lbs

Filamentous Outbreaks (12) in 2004
- CL Feed Jan-Oct; 149 days/2,023 lbs

(93% Increase in 2004 CL Usage)
2005 Upgrade Retrofits Package Plants to Incorporate Aerobic Selector Zones

Date

SVI

Pounds Chlorine

SVI Plant # 2 Chlorine

SVI Plant # 2 Before Selector

0
50
100
150
200
250
300
0.1
5.1
10.1
15.1
20.1
25.1
30.1
12/30/02 4/9/03 7/18/03 10/26/03 2/3/04 5/13/04 8/21/04

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2005 Upgrade Retrofits Package Plants to Incorporate Aerobic Selector Zones
2005 Upgrade Retrofits Package Plants to Incorporate Aerobic Selector Zones

Date
1/1/03 7/20/03 2/5/04 8/23/04 3/11/05 9/27/05 4/15/06

SVI
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341

Selector On-Line

Date
1/1/03 7/20/03 2/5/04 8/23/04 3/11/05 9/27/05 4/15/06
Case 5: Two Rivers, WI

- 2 mgd Nitrifying Activated Sludge Plant
- Late Winter/Early Spring – Significant Bulking Episode
  - SVIs Typically 80-100 mL/g
  - Mid-January SVIs Began Rising – Exceeding 400 mL/g by Mid-March
- Predominant Filament Identified as 021N
021N
Two Rivers Response

- Begin RAS Chlorination at 1.5-2 lbs Cl2/1,000 lbs MLSS/day
- Adjust FeCl3 Feed Practice Using Excel Based Spreadsheet
  - Overfeeding Ferric to Primary Influent Causing Nutrient Deficient Condition
- Practice SRT-Based Wasting Using Excel Based Spreadsheet

*SVIs Below 140 mL/g Within a Month of Implementing RAS Chlorination*
021N During RAS Chlorination
Concluding Thoughts

- Not All Filaments Can Be Controlled By Selectors
- Not All Bulking Caused By Filaments
- Microscopic Examination/Identification Provides Very Valuable Information
  - Potential Causes
  - Corrective Actions
- Key Fundamentals Can’t Be Taken For Granted
  - SRT Based Process Control with Regular Micro Exams
  - Control P Removal Chemical Dosages to Avoid Nutrient Deficient Conditions
  - Maintain Provisions for RAS Chlorination
### Two Rivers Influent Ferric Chloride Dosing Estimate

#### Inputs/Dosage Calculations

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Influent Flow</td>
<td>MGD</td>
<td>2.0</td>
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<tr>
<td>Raw Wastewater Influent P</td>
<td>mg/L</td>
<td>4.0</td>
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<tr>
<td>Target Fe to P Molar Ratio</td>
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<td>2.00</td>
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<tr>
<td>Target Primary Effluent TP Concentration</td>
<td>mg/L</td>
<td>1.4</td>
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<tr>
<td>P to be Removed Chemically</td>
<td>mg/L</td>
<td>2.6</td>
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<tr>
<td>P Atomic Weight</td>
<td></td>
<td>30.97</td>
</tr>
<tr>
<td>Fe Atomic Weight</td>
<td></td>
<td>55.85</td>
</tr>
<tr>
<td>Moles P to Remove</td>
<td>moles/day</td>
<td>651</td>
</tr>
<tr>
<td>Moles Fe to Add</td>
<td>moles/day</td>
<td>1,301</td>
</tr>
<tr>
<td>Fe Dosage</td>
<td>mg/L</td>
<td>9.4</td>
</tr>
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</table>

#### Ferric Chloride Usage

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity of FeCl₃ Solution</td>
<td>1.33</td>
</tr>
<tr>
<td>% of Ferric Chloride in FeCl₃ Solution</td>
<td>%</td>
</tr>
<tr>
<td>Weight Basis % of Iron in FeCl₃ Molecule</td>
<td>%</td>
</tr>
<tr>
<td>Ferric Chloride Solution Unit Weight</td>
<td>lb/gal of FeCl₃ Solution</td>
</tr>
<tr>
<td>Lbs Iron Per Gallon FeCl₃ Solution</td>
<td>lb Fe/gal of FeCl₃ Solution</td>
</tr>
<tr>
<td>Mass Iron Added Per Day</td>
<td>lb Fe/d</td>
</tr>
<tr>
<td>FeCl₃ Solution Daily Usage</td>
<td>gal/day</td>
</tr>
<tr>
<td>FeCl₃ Solution Feed Rate</td>
<td>gal/hour</td>
</tr>
<tr>
<td>FeCl₃ Feed Rate</td>
<td>lbs FeCl₃/day</td>
</tr>
<tr>
<td>FeCl₃ Solution Feed Rate</td>
<td>lbs FeCl₃ Solution/day</td>
</tr>
</tbody>
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Note: Values in **Red Bold** are inputs, other values are calculated.
# Faribault WWTP RAS Chlorination Calculator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number Aeration Basins in Service:</td>
<td>1</td>
</tr>
<tr>
<td>Volume Per Aeration Basin (MG)</td>
<td>0.434</td>
</tr>
<tr>
<td>MLSS Concentration (mg/L):</td>
<td>3,500</td>
</tr>
<tr>
<td>Number of Clarifiers in Service:</td>
<td>2</td>
</tr>
<tr>
<td>Volume Per Clarifier (MG)</td>
<td>0.536</td>
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<tr>
<td>Sludge Judge Concentration (mg/L):</td>
<td>2,500</td>
</tr>
<tr>
<td>Activated Sludge MLSS Inventory (lbs):</td>
<td>35,001</td>
</tr>
<tr>
<td>Sodium Hypochlorite Solution Strength (%):</td>
<td>12.5%</td>
</tr>
<tr>
<td>Sodium Hypochlorite Solution Density (lb/gal)</td>
<td>9.8</td>
</tr>
<tr>
<td>Hypochlorite Pump Maximum Feed Rate (gal/day)</td>
<td>70</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Target RAS Chlorination Dosage (lb Cl₂/1,000 lbs MLSS/day)</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comment on Target Dosage:</td>
<td>Maintenance</td>
<td>Maintenance</td>
<td>Moderate</td>
<td>Very High</td>
</tr>
<tr>
<td>Required Sodium Hypochlorite Solution Feed Rate (gal/hour)</td>
<td>1.25</td>
<td>2.50</td>
<td>6.25</td>
<td>12.49</td>
</tr>
<tr>
<td>Equivalent Sodium Hypochlorite Daily Feed Rate (gal/day)</td>
<td>30.0</td>
<td>60.0</td>
<td>97.4</td>
<td>108.7</td>
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<tr>
<td>Approximate Hypochlorite Pump Speed Setting (0-10):</td>
<td>4.3</td>
<td>8.6</td>
<td>10.0</td>
<td>10.0</td>
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<tr>
<td>Actual Estimated RAS Chlorination Dosage (lb Cl₂/1,000 lbs MLSS/day)</td>
<td>1.0</td>
<td>2.1</td>
<td>2.4</td>
<td>2.4</td>
</tr>
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**Precautionary Warning:** When RAS chlorinating it is extremely important that you monitor the mixed liquor through daily microscopic examination for signs of excess toxicity to the entire microbial population, as evidenced by high amounts of dispersed bacteria outside of flocs, increase in presence of amoebas and flagellate protozoans, loss of stalked ciliates, free swimming ciliates, rotifers. Other signs of excess toxicity include loss of nitrification, turbid supernatant in settleometer test, increase in effluent TSS/BOD. If signs of excess toxicity appear you should immediately stop RAS chlorinating, then as conditions improve you can begin again at maintenance dosages, if necessary.
## Simple Spreadsheets Can Help A Lot

<table>
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<tr>
<th>Daily Inputs</th>
<th>Date: 03/24/11</th>
<th>For Reference:</th>
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<tbody>
<tr>
<td>MLSS Concentration (mg/L):</td>
<td>2,748</td>
<td>1,500-3,500 mg/L</td>
</tr>
<tr>
<td>RAS Concentration (mg/L):</td>
<td>8,795</td>
<td>4,000-10,000 mg/L</td>
</tr>
<tr>
<td>30 Minute Settling Volume (mL):</td>
<td>315</td>
<td>150-800 mL</td>
</tr>
<tr>
<td>Yesterday’s WAS Flow:</td>
<td>77,000</td>
<td>40,000-100,000 gal/day</td>
</tr>
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</table>

### Process Inputs

| Target Aerobic Sludge Age (days):         | 13.0           | 6-20 days                       |
| Aerated Basins in Service (1, 2 or 3):   | 2              | 1, 2 or 3                      |
| **Today’s Wasting Target (gal/day):**     | **67,225**     |                                 |

### System Monitoring

| Actual Sludge Age - 7 Day R.A. (days):    | 10.7           |
| Actual MLSS Conc - 7 Day R.A. (mg/L):     | 2,984           |
Finally – Use a Stepwise Approach

A. Identify the Filament (or that it’s not a filament)
   - If It’s Filamentous Bulking Start RAS Chlorination

B. Research What Factors Favor That Filament (or Condition)

C. Evaluate Your Situation For What Might Be Contributing

D. Identify and Implement a Solution if Possible
Thanks for your attention!

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