Controlling Activated Sludge Bulking & Foaming: From Theory to Practice

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Outline

- Basics
  - Filament Facts
  - Indicators
- Control Strategies
  - Temporary
  - Long Term
- Case Studies
  - Identification & Troubleshooting

First Off, When We Talk...

- Bulking
  - We Usually Mean Filamentous Bulking
  - There Can Also Be Non-Filamentous Bulking
- Foaming
  - We Usually Mean Foaming Caused by Filaments
    > Nocardia
    > Microthrix Pantroica
  - There Can Also Be Non-Filamentous Foaming
    > Young Mixed Liquor/Low SRT (Startup Conditions)
    > Surfactants
Filaments Are Important Components of Mixed Liquor

Too Few Filaments

Moderate Filament Growth

Filamentous Bulking Condition

"Can't Live With 'Em, Can't Live Without 'Em"

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Sludge Volume Index (SVI) – An Indicator of ML Settleability

- SVI < 60 mL/g
  - Too Low, Not Enough Filaments, Lots of Fine Solids in Effluent
- SVI = 60-120 mL/g
  - Good Settling ML, Clear Effluent, Compact Blankets
- SVI = 120-180 mL/g
  - Fair Settability, Clear Effluent
- SVI = 180-250 mL/g
  - Marginal/Poor Settleability, Clear Effluent
- SVI > 250 mL/g
  - Very Poor Settleability/Bulking

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So you think you have filaments?

- Don't jump to conclusions
- Stepwise Approach:
  A. Identify the Filament (or that it's not a filament)
  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
Primary Causes of Bulking

- Needed Compound Lacking or in Short Supply
  - Nutrient Deficiency
  - Low Dissolved Oxygen Concentrations
  - Low Substrate (Food/BOD) Concentrations
- Septicity
- 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
  - Basin Configuration/Feed Pattern
  - Aeration Upgrades
  - System SRT

RAS Chlorination Basics

- Preferred Feed Point Location
  - RAS Line
  - Good Mixing
  - 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
    A. Treat with Chemicals (oxidizers or ferric)
    B. Eliminate sources in collection system (industries)
    C. Minimize production of sulfides upstream (chemicals or reduce PC blanket/detention times)
Modify Environmental Conditions to "Select" Against Filaments

- Get the Competitive Advantage
  - Physical Differences
  - Kinetic Differences
  - Metabolic Differences

- Add “Selector” Zones Upstream of Aeration Basins.
  - Aerobic
  - Anoxic
  - Anaerobic

Physical Advantage

- Differences Are Obvious

  Filaments’ higher surface area provides a selective advantage when essential nutrients are limiting.

Kinetic Advantage

- Growth Rates

  Floc-formers’ Higher Growth Rate Provides Kinetic Advantage at High Substrate Concentrations
Kinetic Advantage

Example:

- Aerobic Selector or Convert to Plug Flow

The selector zone can actually be comprised of several zones in series.

Aerobic Selectors

Aerobic Selector Conversion of a Package Plant
Metabolic Advantage

- Uptake/Store Substrate
  - Utilize Floc-formers' Ability to Quickly Take Up and Store Substrate
  - Starve Out Filaments

Example:

- **Anoxic Selectors**
  - Many floc formers are facultative (can denitrify) while most filaments can't.

- **Anaerobic Selectors**
  - Some floc-formers can attain energy through anaerobic fermentation or cleavage of high energy phosphate bonds to absorb soluble substrate.

Anoxic Selectors

Nitrate is supplied to the selector zone via mixed liquor recycle and RAS.
Anoxic Selectors Can Provide Additional Benefits

- **Reduced Aeration Requirements**
  - 2.86 mg of oxygen equivalent is supplied for every 1 mg of nitrate denitrified to nitrogen gas

- **Reduced Consumption of Alkalinity**
  - Nitrification consumes 7.1 mg alkalinity for each mg of ammonia nitrified to nitrate
  - Denitrification produces 3.6 mg alkalinity for each mg of nitrate denitrified to nitrogen gas

*Best Choice for Nitrification Systems*

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**Anaerobic Selectors**

Anaerobic/aerobic cycling provides environment selecting for PAOs.
Anaerobic Selector Upstream of Aerobic Zone for EBPR

Keys to Successful Selectors

- High Substrate 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

Selectors Are Not Always Effective

- You Must Prevent Bleed Through of Soluble Substrate to Bulk Aeration Basin
  - Target < 60 mg/L Soluble COD (20-30 mg/L SBOD5)
  - Function of Selector Loading and Configuration
- They Won’t Cure Other Problems
  - “Nutrient” Deficiency
  - Septicity
- Some Filaments Are Immune to Selector Effect
  - Long SRT Filaments
A Few Final Thoughts on Filaments, Selectors, Etc.

- **Optimal Performance Requires:**
  - Practicing Good Activated Sludge Process Control
    - Including Regular Microscopic Examinations and Filament Identifications
- **Good Reference:**
  - Manual on the Causes and Control of Activated Sludge Bulking and Foaming
  - by Jenkins, Richard & Daigger, 3rd Edition

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Brookfield, WI WPCP

- **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**

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MLE Configuration Provides Anoxic Selector Zone For Filament Control

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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
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**
Gram Stain of Diluted Foam

What Do We Know About Microthrix & Type 0041?

**Microthrix**
- Occurs in ML or as Foam
- Low D.O.
- Slow Growing/Long SRT Systems
- Immune to Selector Effect/BNR Configurations
- Seems to Propagate More in Cold Temperature Conditions

**Type 0041**
- Low F:M
- Slow Growing/Long SRT Systems
- Immune to Selector Effect/BNR Configurations
- Often Occurs in Combination with Microthrix

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

- SVIs < 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
**Current Status**

- Practicing Temperature-Based SRT Control to Prevent Future Outbreaks
  - Developed Operational Guideline Chart Based on Literature and Plant Experience
Marquette, MI WWTP

- Activated Sludge Replacing RBC Plant
- Average Flow 2-3 mgd Receiving Primarily Domestic Wastewater
- BNR Activated Sludge
  - Eventually VIP/MUCT Configuration for Bio-P
  - Three 2-Pass Reactors ~ Plug Flow, Non-Foam Trapping
- 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

Possible Cause – Viscous (Non-Filamentous) Bulking?

- 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

Faribault, MN

- 2-3 MGD WWTP Serving Mix of Industrial & Residential
- Flow Train:  Primary Clarification
  Roughing Trickling Filters
  Aeration Tanks
  Secondary Clarifiers
  Disinfection
- Try to Avoid Nitrification
- Undergoing Major Upgrade

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

Micro Exam - Faribault

Gram Stain Confirms as O21N
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

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 Should Resolve Septicity/H2S Problem
  - Add Permanent RAS Chlorination Facilities to Upgrade Project

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 Control
  - Control P Removal Chemical Dosages to Avoid Nutrient Deficient Conditions
  - Maintain Provisions for RAS Chlorination
Simple Spreadsheets Can Help A Lot

- Example: Wasting Calculator

<table>
<thead>
<tr>
<th>Daily Inputs</th>
<th>Date</th>
<th>MLSS Concentration (mg/L)</th>
<th>RAS Concentration (mg/L)</th>
<th>30 Minute Settling Volume (mL)</th>
<th>Yesterday’s WAS Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>03/24/11</td>
<td>2,748</td>
<td>8,795</td>
<td>315</td>
<td>77,000</td>
</tr>
</tbody>
</table>

Process Inputs

- Range of Typical Values

<table>
<thead>
<tr>
<th>Aerated Basins in Service (1, 2 or 3)</th>
<th>Aerobic Sludge Age (days)</th>
<th>Target Aerobic Sludge Age (days)</th>
<th>6-20 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13.0</td>
<td>2</td>
<td>1, 2 or 3</td>
</tr>
</tbody>
</table>

System Monitoring

<table>
<thead>
<tr>
<th>Actual Sludge Age - 7 Day R.A. (days)</th>
<th>Actual MLSS Conc. - 7 Day R.A. (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.7</td>
<td>2,984</td>
</tr>
</tbody>
</table>

For Reference:

- Range of Typical Values:
  - 6-20 days
  - 1,500-3,500 mg/L
  - 4,000-10,000 mg/L
  - 40,000-100,000 gal/day
  - 1, 2 or 3
  - 150-800 mL

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Simple Spreadsheets Can Help A Lot

- Example: Ferric/Alum Addition Estimator

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

Ferric Chloride Usage

| Specific Gravity of FeCl₃ Solution | 1.33 |      |
| % of Ferric Chloride in FeCl₃ Solution | 38% |      |
| Weight Basis % of Iron in FeCl₃ Molecule | 34% |      |
| Ferric Chloride Solution Unit Weight (lb/gal of FeCl₃ Solution) | 11.1 |      |
| Lbs Iron Per Gallon FeCl₃ Solution | 1.45 |      |
| Mass Iron Added Per Day (lb Fe/d) | 156 |      |

FeCl₃ Solution Daily Usage (gal/day) | 108 |
FeCl₃ Solution Feed Rate (gal/hour) | 4.5 |
FeCl₃ Feed Rate (lbs FeCl₃/day) | 454 |
FeCl₃ Solution Feed Rate (lbs FeCl₃ Solution/day) | 1195.4 |

Note: Values in Red Bold are inputs, other values are calculated.

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Finally – Use the Proven Stepwise Approach to Address the Problem

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
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