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Impact of Volatile Organic Acids on Activated Sludge Microbiology

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Impact of Septic Compounds on Filament & Floc Formation

- Volatile organic acids (VOA)
  - Acetic : CH_3COOH
  - Propionic : CH_3CH_2COOH
  - Butyric : $CH_3CH_2CH_2COOH$
- Reduced sulfur compounds
  - Sulfide : S^{2-}
  - Thiosulfate : $S_2O_3^{2-}$
- Cause primary clarifier odour and activated sludge filamentous bulking

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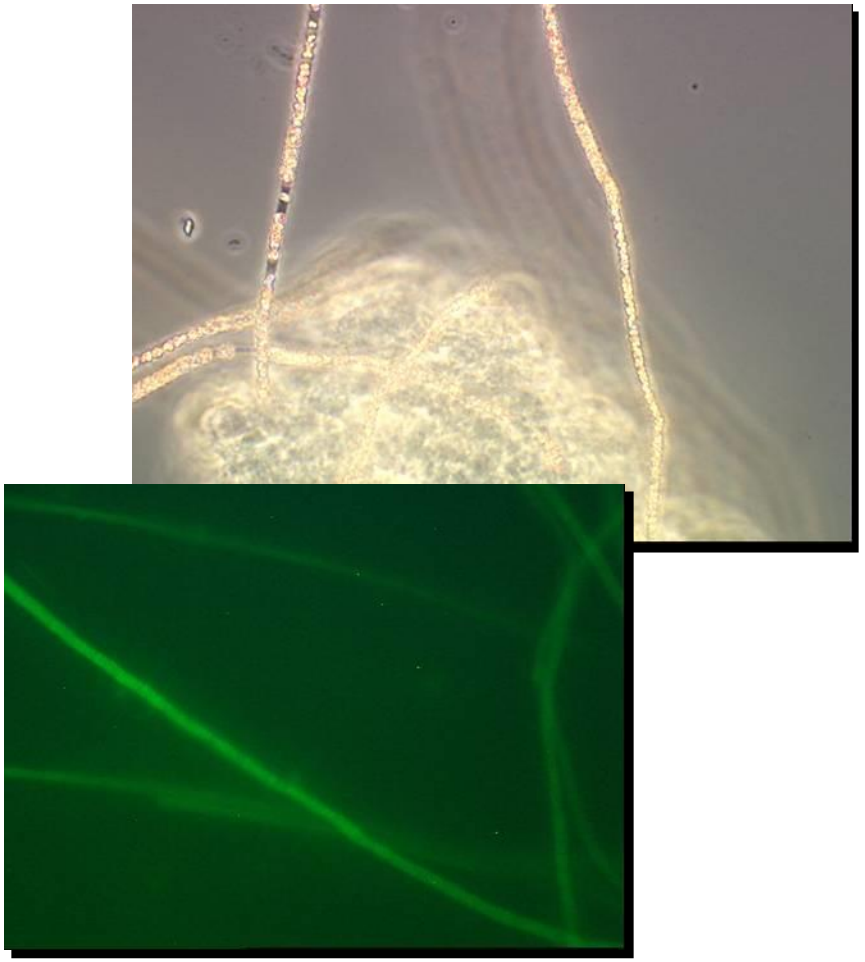
Type 021N / *Thiothrix* Bulking

- Type 021N is a common bulking filament
- Identified by:
  - Microscopy
  - Fluorescent in-situ hybridization (FISH)
- Now looking at quantitative polymerase chain reaction (qPCR)



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What Triggers Type 021N / *Thiothrix* Bulking?

- Low F/M ratio
  - (for 021N only)
- Low dissolved oxygen < 2.0 mg/L
- Nutrient deficiency (nitrogen & phosphorous)
- Septicity
  - Organic acids
  - Reduced sulfur compounds
  - Others readily biodegradable substrate
    - Alcohols, amino acids with sulfur, glucose

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What Triggers Type 021N / *Thiothrix* Bulking?

- Nutrient deficiency
  - Nitrogen
    - < 1.0 mg/L of TIN
- Septicity
  - Organic acids (acetic, propionic, butyric)
    - VOA > 100 to 200 mg/L
  - Reduced sulfur compounds (TRS)
    - Hydrogen sulfide > 1 to 3 mg/L
    - Thiosulfate > ? mg/L (021N only)

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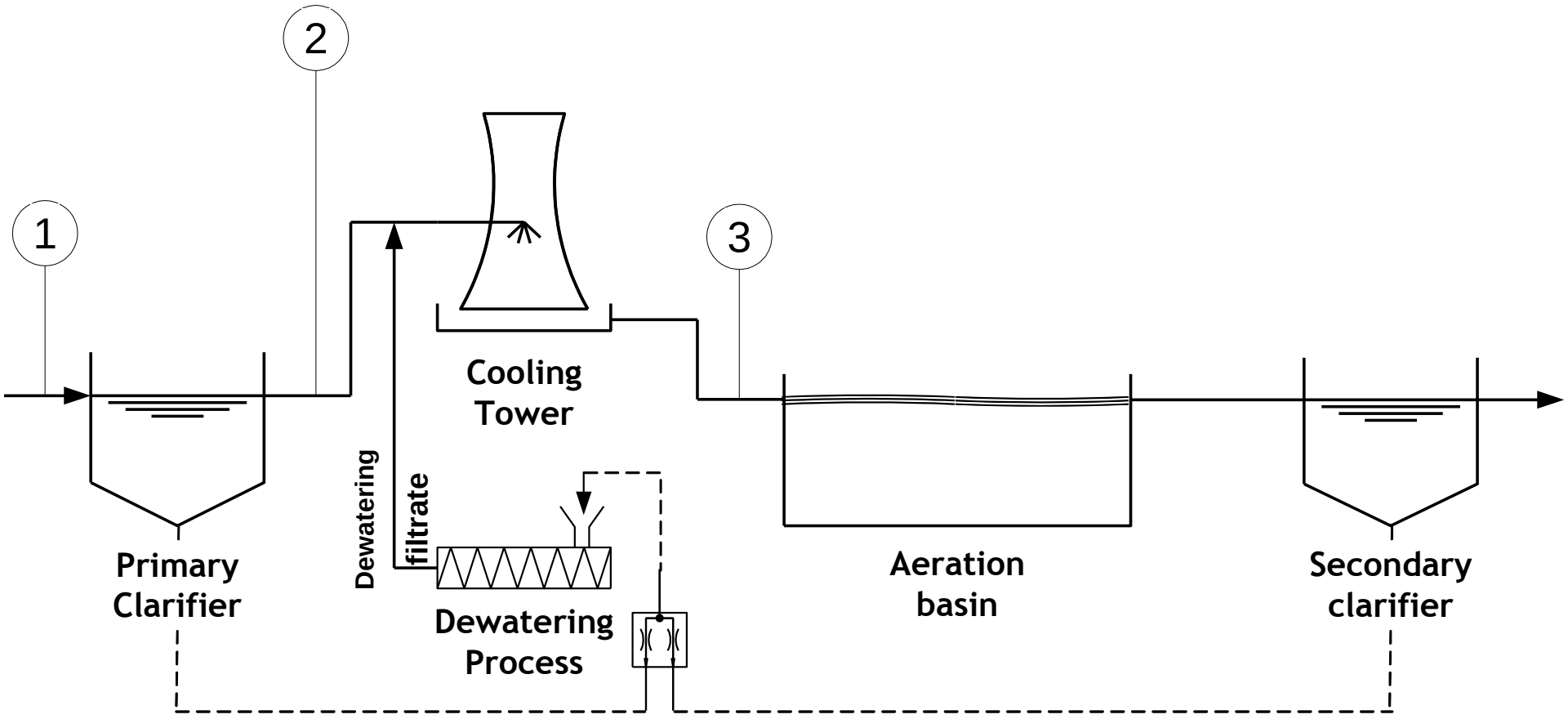
Newsprint Mill14-Week Sampling Campaign



This mill has experienced chronic sludge bulking problems (Type 021N)

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Measured Septic Compounds at Sampling Sites 1, 2 & 3
(average of 14 samples)

	VOA_{total} (mg/L)	Sulfide (mg/L)	Thiosulfate (mg/L)
1-Prim. Clarifier In	77	0.5	1.4
2-Prim. Clarifier Out	140	0.8	2.5
3-After Cooling Tower (pressate included)	146	0.3	1.2

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Correlation Between Filaments Bacteria Counts and Septic Compounds in the Effluent

	Filaments ¤	VOA $_t$ *	Sulfide *	Thiosulfate*
n	14	14	11	14
Average	3.4E+06	146	0.3	1.2
Std. Dev.	9.5E+05	32	0.2	0.9
Pearson r	-	0.43	0.40	0.23

( ) Pearson r significance test passed *mg/L ¤ int. / g MLSS

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VOAs Entering Aeration Basin: Correlation with Filament Abundance
(average of 14 samples)

Acid	Average*	%	r Pearson
Formic	5	3.7	0.12
Acetic	119	82.1	0.39
Propionic	8.6	5.9	**(0.59)**
Butyric	12.1	8.3	0.35
Total	146	100.0	0.43

* mg/L

( ) Pearson r significance test passed

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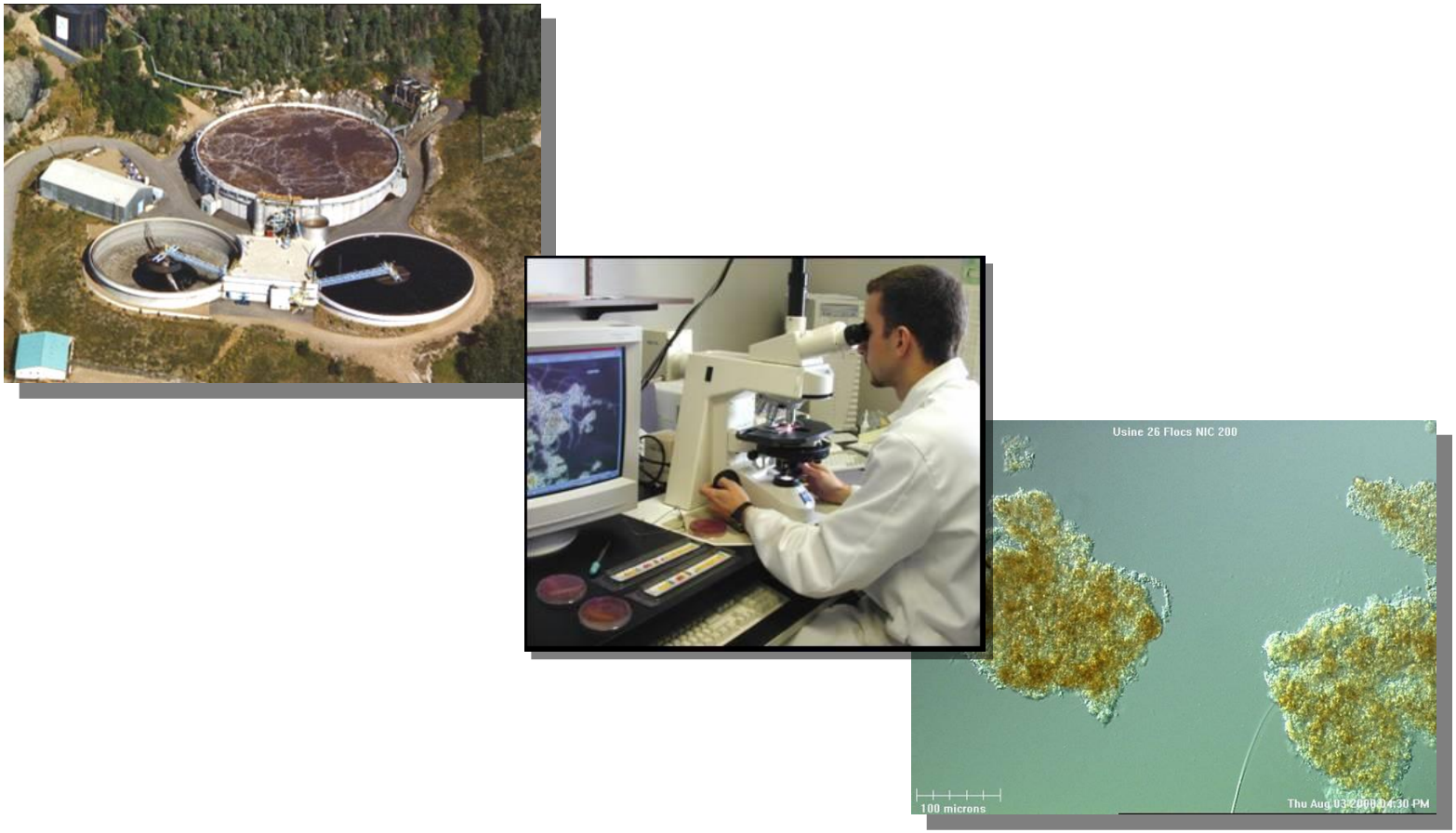
Measuring Floc Size Distribution



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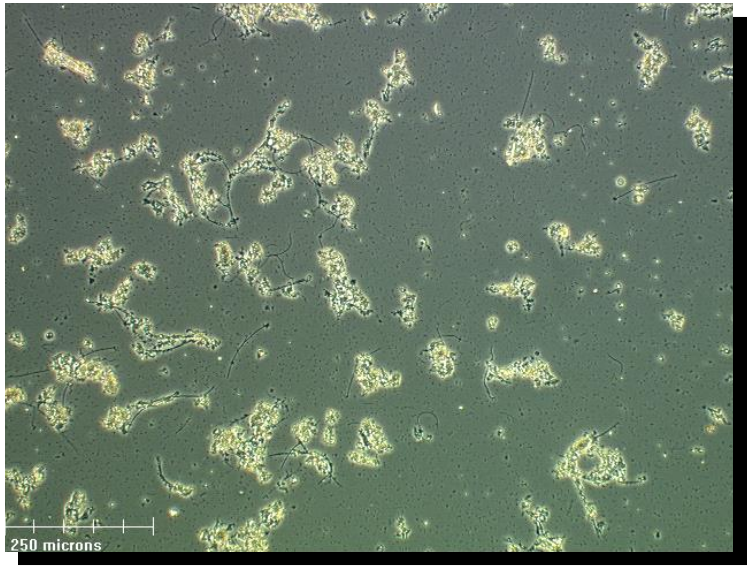
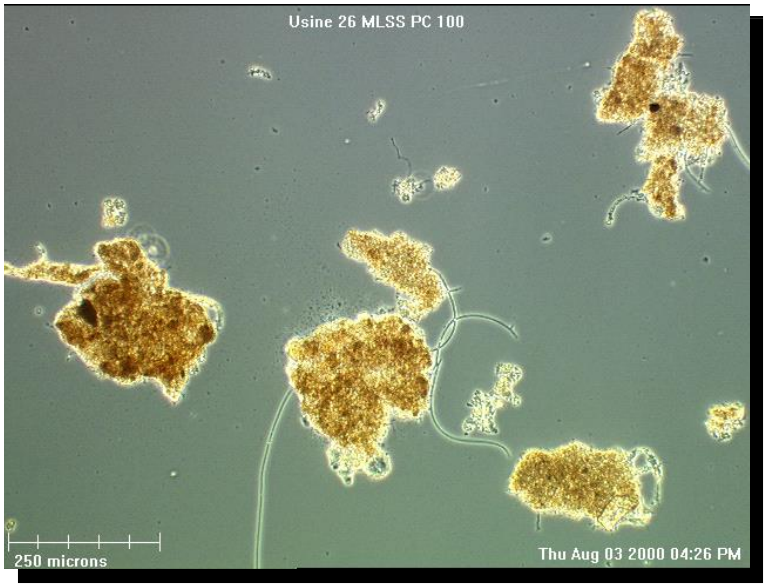
Viewing Toxic Effects

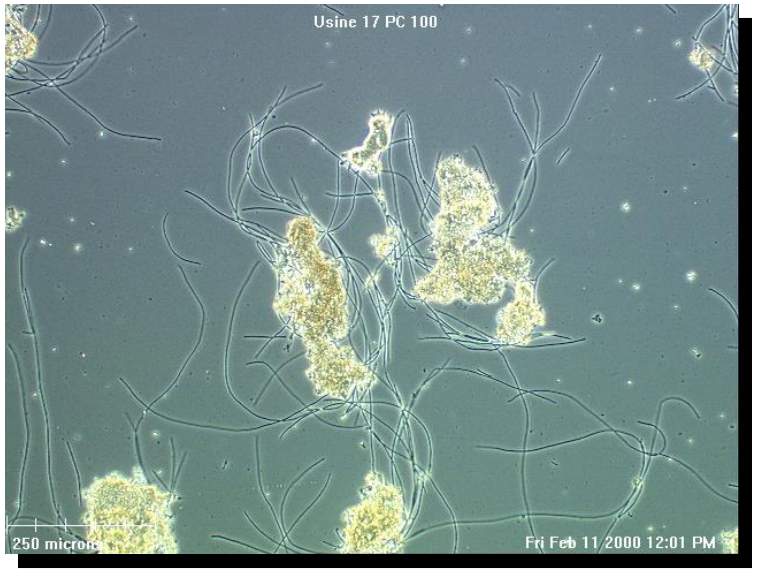
< 50 µm, 50 – 150 µm, 150 – 500 µm →





150 – 500 µm, 50 – 150 µm, < 50 µm

50 – 150 µm, < 50 µm, 150 – 500 µm →



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Correlation of Septic Compounds with Floc Size Distribution
(14 samples)

	Formic acid	Acetic acid	Propionic acid	Butyric acid	Total sulfur	Thiosulfate
< 50 µm	0.03	0.23	**(0.57)**	0.24	-0.30	-0.30
50-149 µm	-0.26	0.10	-0.01	0.16	0.13	0.16
150-500 µm	0.22	-0.36	**(-0.56)**	-0.42	0.23	0.12
> 500 µm	0.38	0.25	0.37	0.22	0.12	-0.12

( ) = Pearson r significance test passed (tr > t0.05)

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Correlation of Floc Size Distribution with Confounding Factors

	TIN[1*¤]	BOD : N	O-PO_4[2*¤]	BOD : P	F/M Ratio[3]	D.O.[4¤]
< 50 µm	-0.26	0.37	-0.40	0.08	-0.14	-0.08
50-149 µm	0.30	-0.20	0.30	-0.21	0.05	0.03
150-500 µm	-0.05	-0.13	0.07	0.19	0.04	0.07
> 500 µm	-0.45	0.10	-0.32	-0.19	0.32	-0.21

[1] Total inorganic nitrogen

[2] Orthophosphate

[3] kg BOD / kg MLSS.day

[4] Dissolved oxygen

( ) Pearson r significance test passed

* Residual

¤ mg/L

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Propionic Acid (PA) Toxicity Impact

- Average PA concentration in primary clarified effluent was 8.6 mg/L for 14 samples collected
- Literature indicates toxic effect appears between 5 to 10 mg/L

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1. PA interferes with biosynthesis and accumulation of poly-ß-hydroxybutyrate (PHB) in some species of flocculating microorganisms
2. PA also interferes with metabolic activity of biomass by reducing respiration rate

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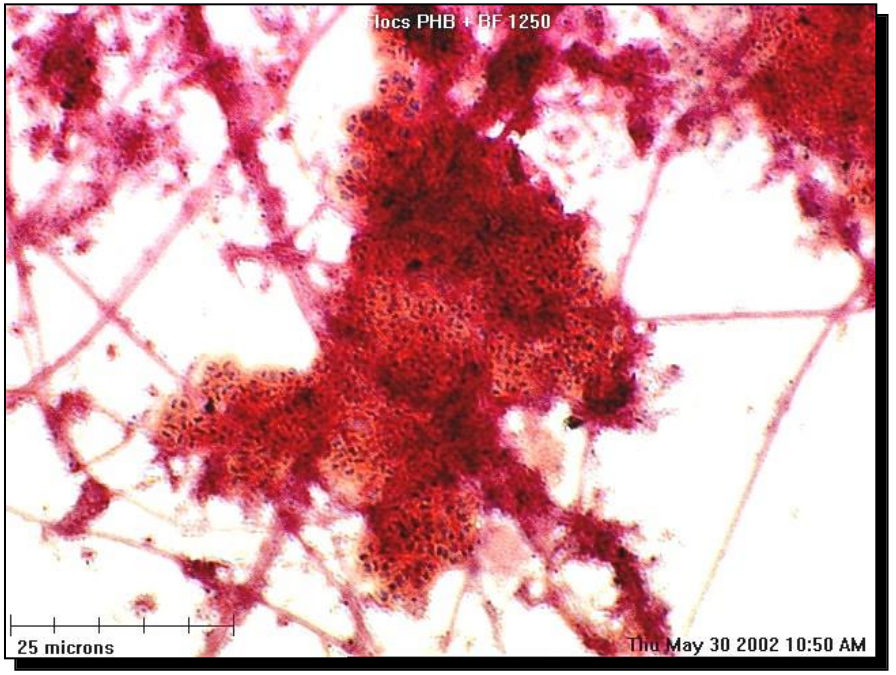
Propionic Acid Inhibits PHB Storage

- Major carbon storage mechanism
- Results in competitive disadvantage of flocs during nutrient deprivation



Sudan Black / Safranin O stain

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PA Reduces Respiration Rate of Flocculating Bacteria

- BOD and nutrient uptake by flocs decreases
- Flocs grow more slowly
- More nutrients and BOD become available for filamentous bacteria (competitive advantage)
- Filamentous bacteria progressively out-grow flocculating bacteria, SVI increases

Summary

- Correlation between propionic acid and filamentous bulking is due to floc inhibition
- Inhibition of floc-forming bacteria allows filaments such as Type 021N to out-compete flocs, causing bulking
- Need to prevent propionic acid formation in primary clarifier and during sludge pressing

How to Minimize Propionic Acid Formation?

- Prevent seeding of mill streams and clarifiers
  - Biocide programs
  - Minimize phosphate availability
- Keep redox potential high in clarifiers
  - Pure oxygen or peroxide
- Perform pH shock
  - Must be sufficient to inhibit growth

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Microorganisms pH Range

Bacteria Type	Operational pH Range
Sulfate Reducing Bacteria *Desulfobulbus, Desulfovibrio*, etc.	5.5 - 9.0
Fermentative Bacteria *Clostridium spp. Propionibacterium spp.*	4.5 - 9.5
Coliforms *Klebsiella spp, E. coli, Enterobacter spp.*	4.5 - 8.0

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