



MDG

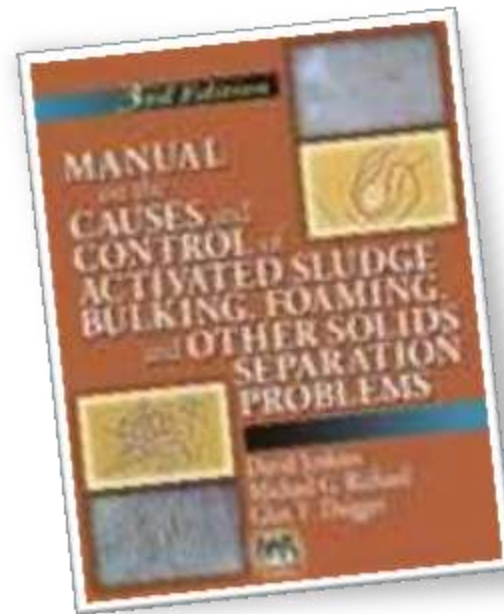
MICROBIAL DISCOVERY GROUP

**Activated Sludge Microbiology Problems
And Solutions**

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Presentation Outline

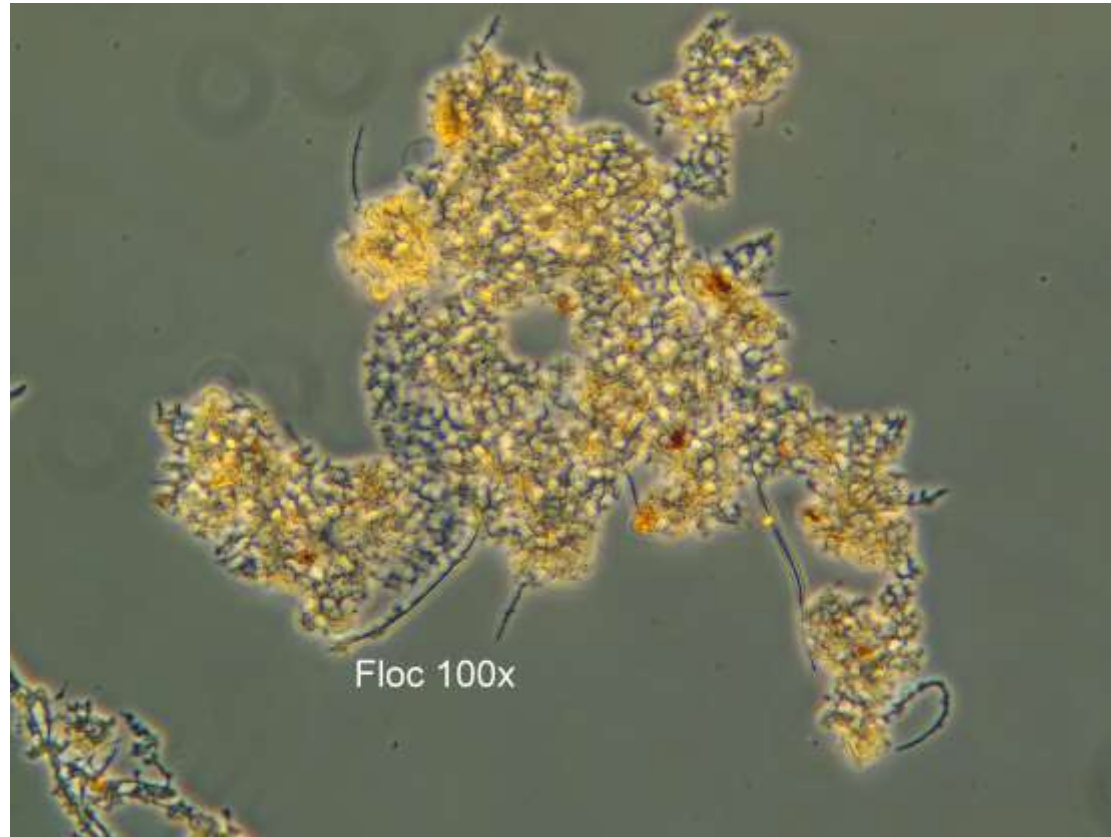
- Poor Floc Formation, Pin Floccs and Dispersed Growth
- Toxicity
- Nitrification and Denitrification Problems
- Nutrient deficiency and Polysaccharide Bulking and Foaming
- Zoogloea Bulking and Foaming
- Filamentous Bulking
- Filamentous Foaming
- Short Term Control Methods
- Long Term Control Methods



Based on the methods in the 3rd Edition Manual on the Causes and Control of Activated Sludge Bulking, Foaming, and other Solids Separations Problems and a presentation from Dr. Michael Richard entitled “Activated Sludge Microbiology Problems and Their Control”

- Flocs are made of biological and non-biological components
 - This includes a variety of naturally occurring bacteria (genera such as Pseudomonas, Archromobacter, zooglea, and Citromonas)
 - Biopolymes which make up about 15-20% of the MLSS by weight
 - 5-25% bacteria (dead and alive)
 - the rest organic and inorganic particulate material. The organic portion varies from about 60% to 95% of the MLSS (MLVSS).

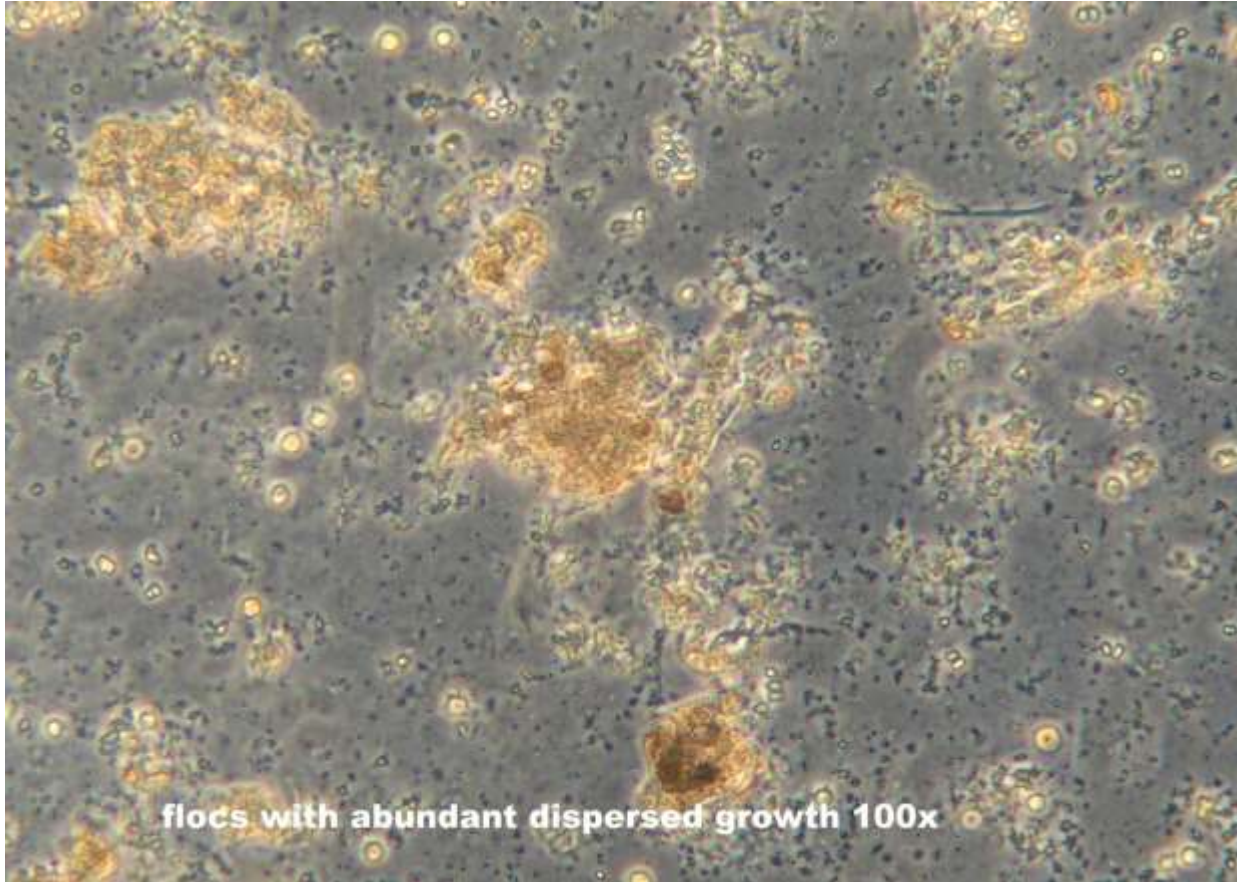
Flocs



- Floc forming bacteria contain an polysaccharide (“slime”) layer, known as a glycocalyx.
- The “slime” is made up of protein and carbohydrates and helps to cement the bacteria together
- This occurs at low F/M around 2 and lower
- To form irregularly shaped flocs with a strong “backbone”, a small abundance of filamentous bacteria are desirable.
- It is possible for both strong and weak flocs to exist without filaments

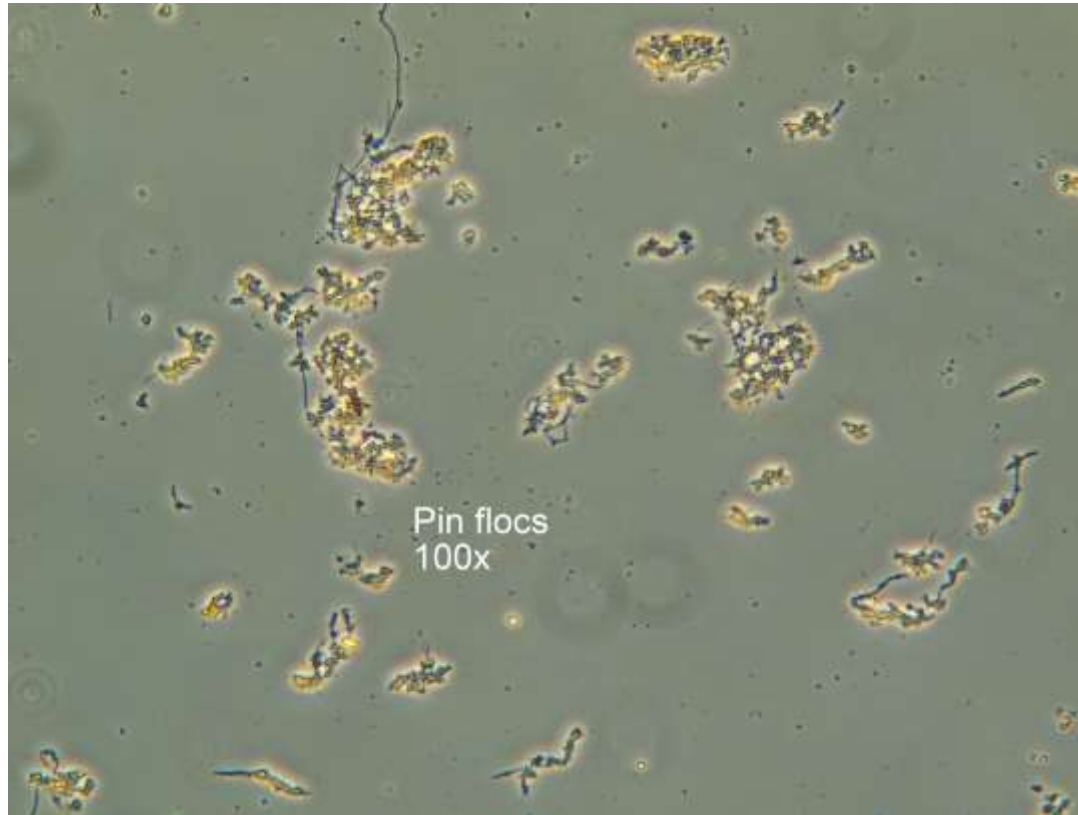
- May occur due to selection of single cells or filaments at high growth rates (high F/M)
- High concentrations of monovalent cations (like potassium and sodium) relative to the concentrations of divalent cations (calcium and magnesium)
- High temperatures (>40 degrees C) or rapid temperature change
 - Particularly going through the zone of 35 degrees C where different thermo-tolerant bacteria are selected
- Deflocculation
 - Poorly biodegradable surfactants
 - Toxic Materials

Dispersed Growth

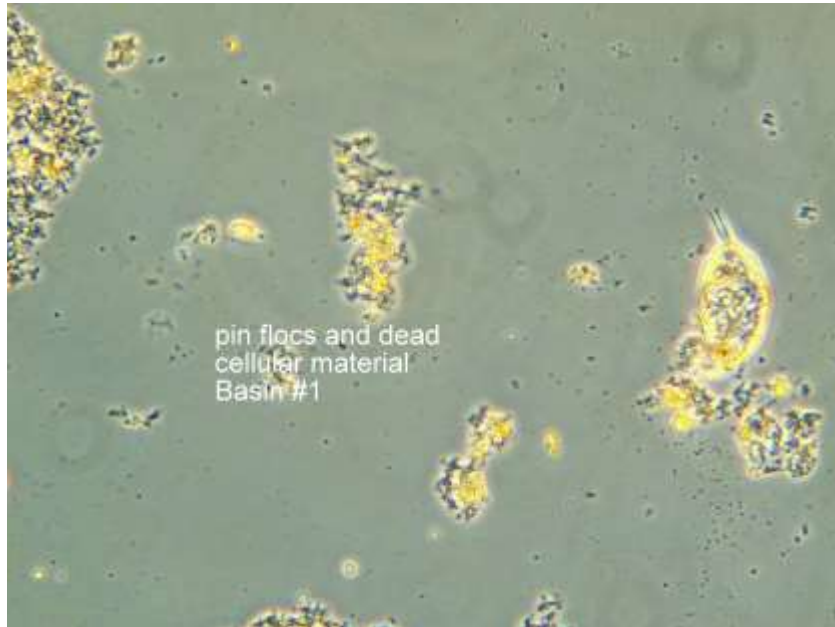


- Pin floc (<50um) is known to occur at starvation conditions associated with very low F/M ratio
- In these instances small dense flocs settle rapidly and leave behind a turbid supernatant
- Chronic toxicity/stress is also a cause of pin floc
- Pin flocs at high MLSS concentration can cause hindered settling

Pin Floccs



- More of a factor in smaller plants where there's less dilution
- Examples of toxicity
 - pH out of 7-9 range in aeration basin
 - Presence of heavy metals in high concentrations
 - Sulfides and elevated organic acids (present in septage)
 - Quantenary Ammonia in high concentrations



- May originate “in house” (septic primary clarifiers, aeration basins, sludge supernatant etc) or in the collection system or storage tanks
- While sulfide is toxic to many wastewater bacteria, it can be utilized as an energy source for certain filaments
 - (Type 0914, 021N, Thiothrix I, Thiothrix II, Beggiatoa)
- Highly pH dependent
 - At pH <7 in the form of H₂S and very toxic
 - At pH >7 H₂S begins to disassociate
 - It’s recommended to increase pH above 7.5 in these instances

- An initial flagellate “bloom”
- A sharp drop in SVI as the many of the filaments are killed
- Complete die off protozoa and other higher life forms, deflocculation, loss of BOD removal, and foaming
- Upon recovery, low DO (High F/M) filamentous bulking is common due to the low viability of the biomass

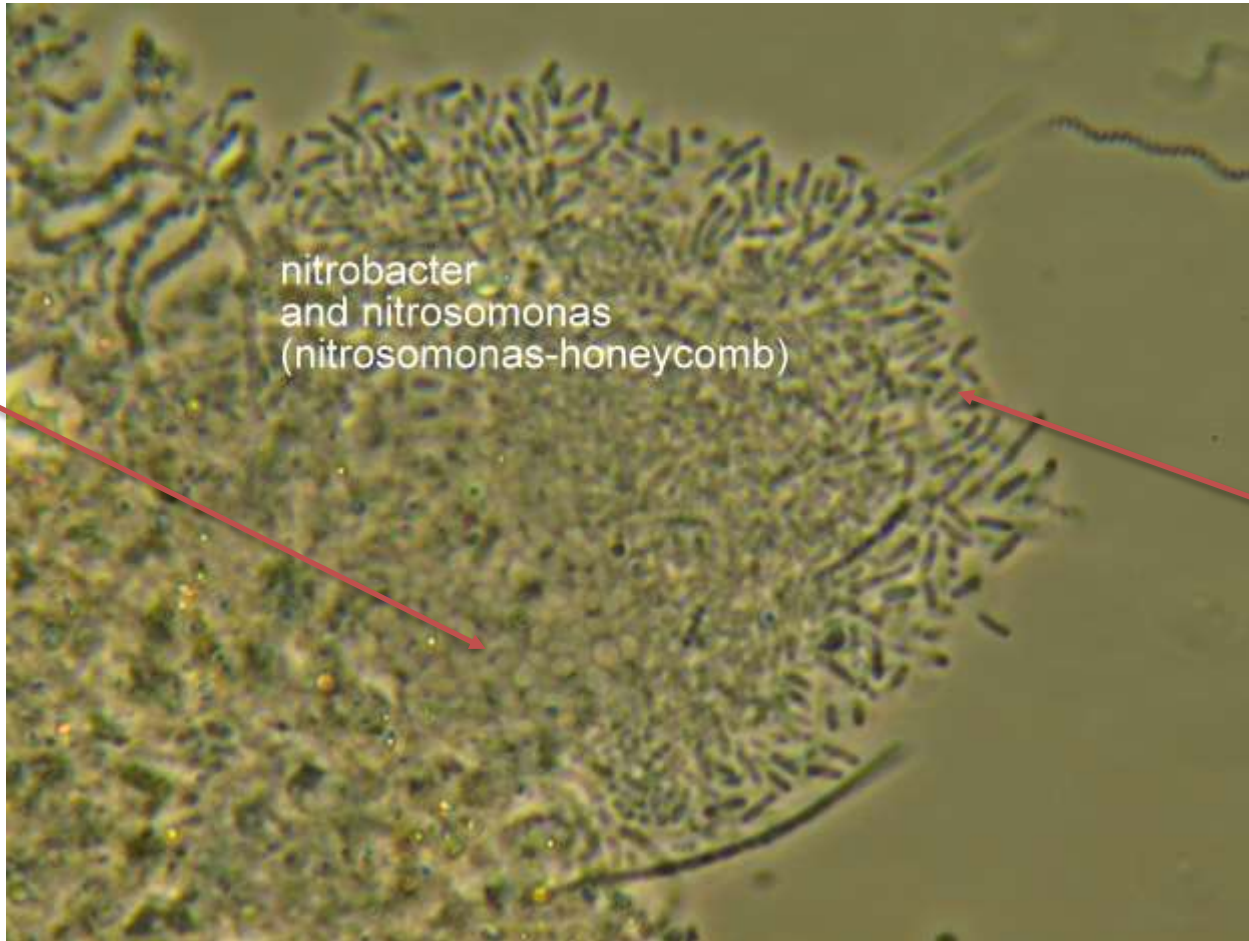
- A great method for diagnosing toxicity before the fact
- A sludge fed increasing amounts of a toxic waste will see a corresponding drop in the OUR.
- The normal fed OUR must be known before hand to apply these results.
 - This is done in a BOD bottle and adding appropriate % of RAS to simulate conditions in the aeration tank in the bottle
 - When deciding to accept new waste-streams such as septage this is a great tool



- For plants not intending to nitrify they may experience upset conditions when warmer weather introduces nitrification.
- These problems include
 - Drop in pH due to lack of buffering capacity
 - Nitrite buildup and correlating problems with disinfection

- Nitrosomonas and Nitrobacter can be visible at 1000x with phase contrast
 - While once believed that nitrosomonas and nitrobacter were the only nitrifying bacteria FISH has determined that Nitrospira and other nitrifying organisms perform the majority of nitrification.
 - Fungi can perform both steps of nitrification (slowly) and filament type 0092 can also nitrify.

Nitrosomonas and Nitrobacter



nitrobacter
and nitrosomonas
(nitrosomonas-honeycomb)

Nitrobacter

- Run with a lower DO concentration (1 mg/L or less)
 - This is not without risk of low DO filaments
- Add magnesium hydroxide, lime, or another source of alkalinity.
 - Ensure a minimal residual alkalinity of 60 mg/L
- Introduce denitrification
 - to recover 3.57 mg alkalinity of the original 7.14 mg lost per mg/L of TKN nitrified.

- Denitrification has three main causes:
 - Lack of/or low DO
 - Presence of Nitrate
 - Through Nitrification
 - A carbon source (soluble BOD or internally stored BOD such as PHB granules)

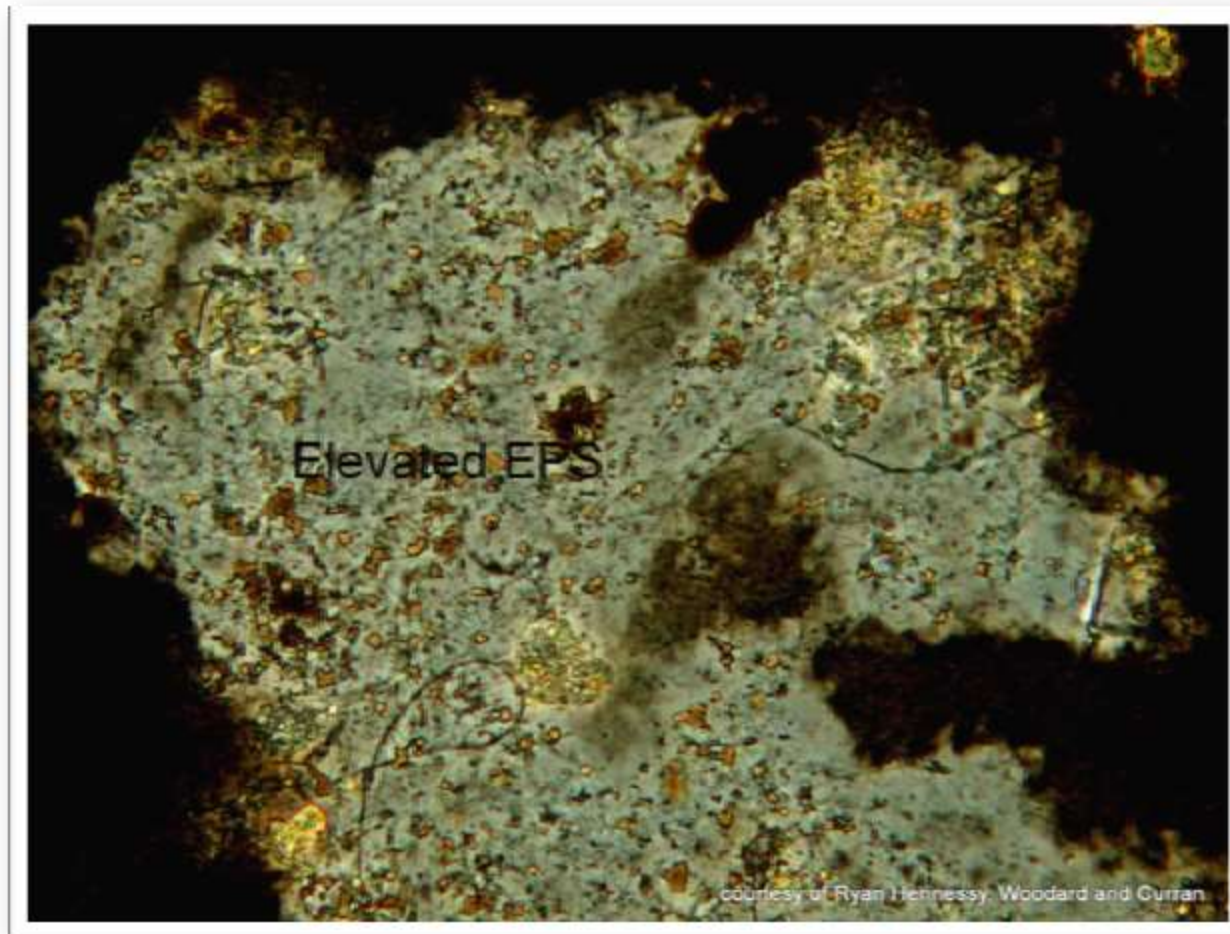


- Denitrification can be diagnosed by seeing the settled sludge rise in the settling test jar within 2 hours or less
- In filamentous sludges, these problems can be worse due to the trapping of the nitrogen gas in the open or bridged flocs
- Denitrification problems can occur when nitrogen is batch dosed due to high periods of nitrate build up.
- Denitrification and nitrification can occur simultaneously in the floc with no residual nitrate.
 - A good way to tell is comparing the floc sizes in corresponding foam and scum to the underlying MLSS. The foam/scum will have floc sizes 2-3x larger than the MLSS due to entrapment of nitrogen gas in their flocs

- Increase DO at end or aeration basin to keep the sludge aerobic in the clarifier
- Increase RAS rate to limit sludge retention time in the clarifier to a minimum
- Prevent nitrification (only possible if there is no ammonia limit)
- Improve sludge quality in filamentous sludges where less nitrate is needed (sometimes even at 5 mg/L) to cause floating problems

- In general a BOD: Nitrogen: Phosphorus ratio of 100:5:1 is needed for complete BOD removal
- Normal sludge contains around 20% polysaccharide on a dry weight basis, if nutrients are limiting (or sometimes other stresses such as low DO or high F/M) the polysaccharide level will increase.
 - Elevated polysaccharide levels are known to cause poor settling known as “slime bulking” as well as foaming and complications with sludge dewatering

- Filamentous bulking
 - For lack of Phosphorus- N. Limicola III, S. Natans, type 1701
 - For lack of Nitrogen- Type 021N, Thiothrix I, Thiothrix II
 - *NOTE: For the above filaments there are other causes as well
- Viscous flocs with high levels of polysaccharide when “stained” in india ink
- Foam on the aeration made up polysaccharide (this “slime” has surface active properties to it)



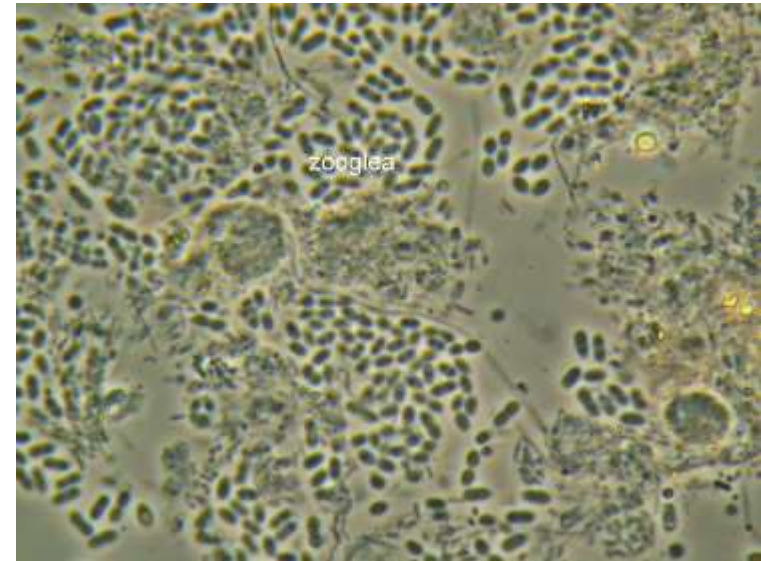
- Ensure there are nutrients “left on the plate” by testing the filtered MLSS at the end of the aeration basin.
 - This is preferred over the effluent because nutrients may be re-released in the clarifier under anaerobic conditions
- A residual of Total Inorganic Nitrogen (nitrate + nitrite + ammonia) of 1-2 mg/L is recommended
- A residual of Orthophosphate of 1-2 mg/L is recommended

- Zooglea growth is not related to nutrient deficiency, but zooglea have a thick slime layer that may cause settling problems, dewatering problems, and foaming
- Zooglea occur due to high F/M conditions and when specific organic acids and alcohols are elevated due fermentation of the wastestream
- If the reverse india ink stain is elevated the anthrone test can separate zooglea growth problems from low nutrient problems because the amino-sugars in zooglea don't react to polysaccharide test whereas there are elevated levels (>20%) in nutrient deficient sludges.

Fingered and Globular Zooglea



Fingered Zooglea 200x

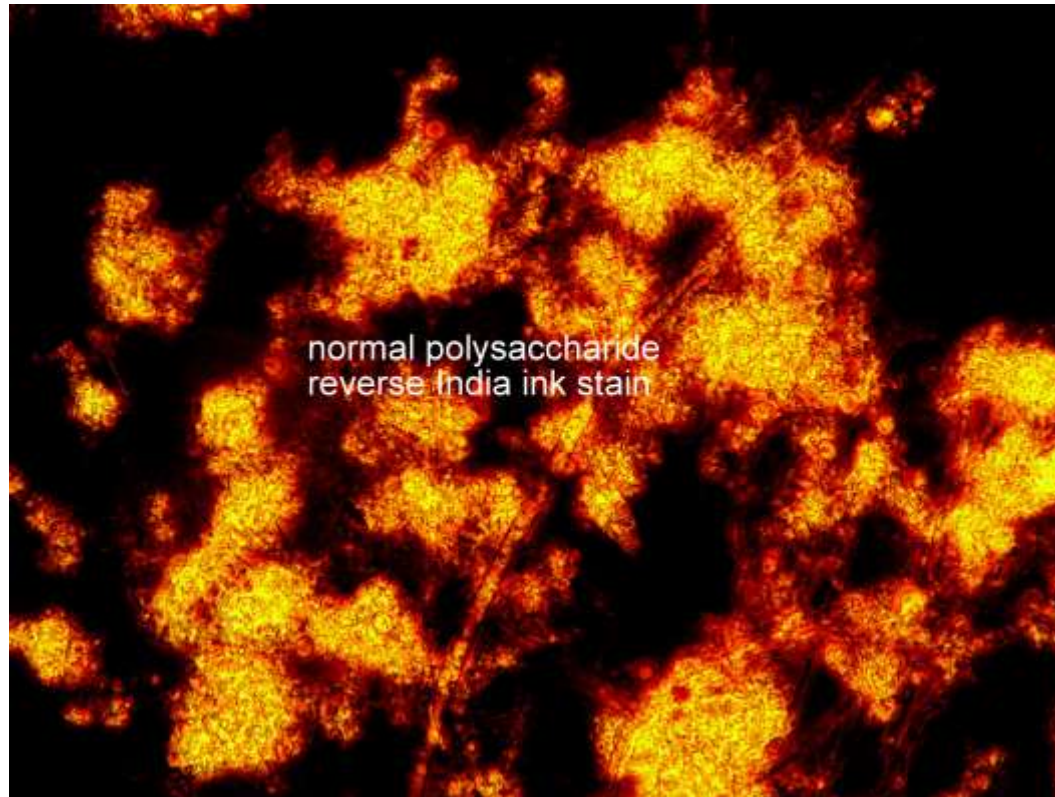


Globular Zooglea 1000x

Elevated India Ink due to zooglea



Normal Polysaccharide



- This is an extension of the mixed liquor settleability test and takes into account the MLSS concentration
- Normal range is from 50- 150 mL/g
 - As an example if your MLSS is 4000 mg/L and your 30 minute settle time is 400 your SVI is 100
- A lower SVI indicates that the sludge settles quickly, while higher numbers indicate slower settling
- By definition a bulking sludge has an SVI >150 mL/g
- The actual SVI where solids begin to be lost to the clarifier is plant specific depending on the hydraulic flow rate, the solids loading rate to the clarifier, and the retention time in the clarifier

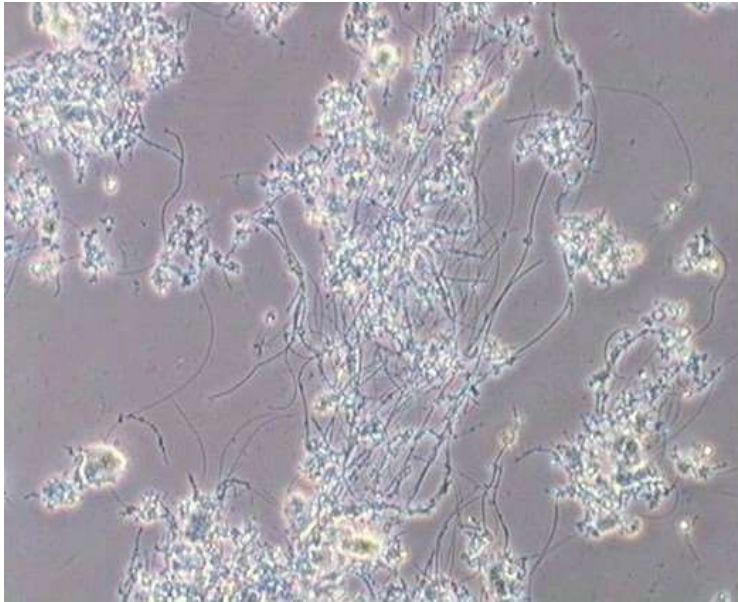
Settleability Test



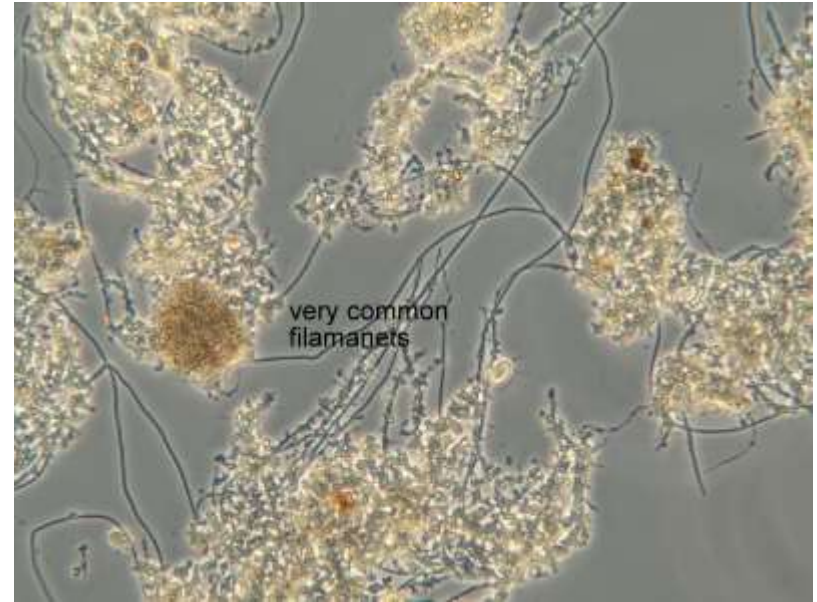
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- Filamentous bulking is the number one cause of environmental violations
- A bulking sludge settles slowly, and has an SVI >150.
- Many sludge thickening and dewatering problems are actually problems due to a bulking sludge
- Filaments can cause bulking due to interfloc bridging, or open floc structure.

Diffuse flocs and bridging



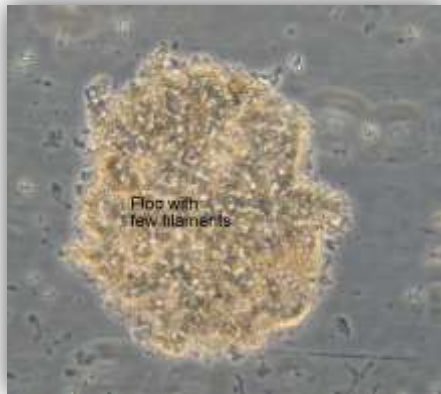
Diffuse Flocs



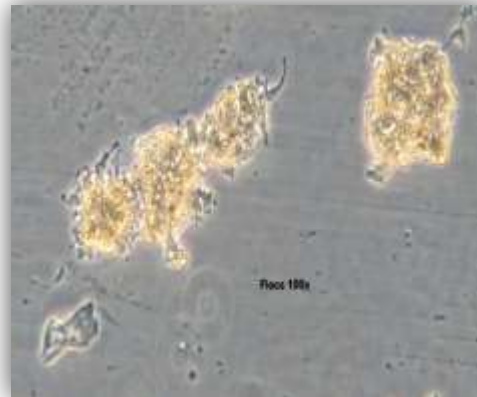
Bridging

- 1 (few)- filaments observed in occasional floc
- 2 (some)- filaments observed in half the flocs
- 3 (common)- filaments observed in all the flocs, but at low abundance (1-5 filaments per floc)
- 4 (very common)- filaments observed in all flocs at medium density (5-20 filaments per floc)
- 5 (abundant)-filaments observed in all flocs at high density (>20 filaments per floc)
- 6 (excessive) filaments dominate with little floc

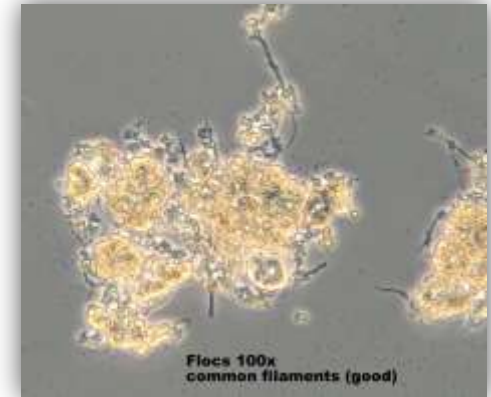
Filamentous Bacteria Abundance



Zero- Few



Some



Common



Very Common



Abundant



Excessive

- Usually problems occur or begin once filaments reach the very common level or greater
- A common abundance of filaments can confirm a condition exists, but is not causing a problem (actually beneficial to floc formation)
- Predominant filaments based on the numerical ranking system can diagnose the cause of a problem.
- Don't link filaments to their causes unless common abundance or greater of that particular filament



These filaments growth is based on the DO concentration in relation to the F/M. The higher the F/M ratio, the more DO is needed to prevent their growth. Usually a DO over 2 mg/L controls them, but in higher F/M systems a higher DO (sometimes 4 mg/L or greater) may be needed



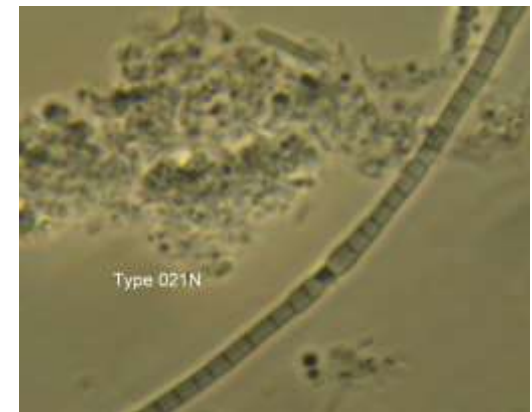
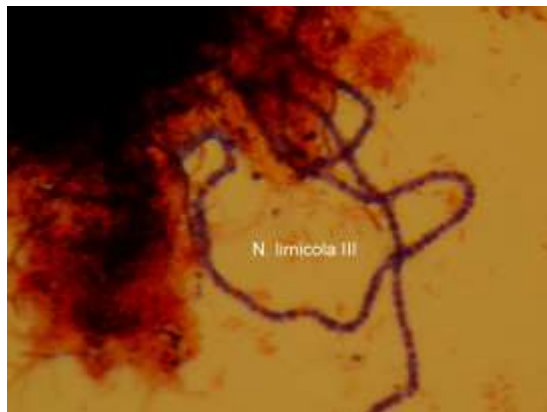
- S. Natans
- Type 1701
- H. Hydrossis

- These organisms grow at low food conditions
- To discourage their growth, more food, or a lower MLSS concentration is needed.
- Selectors control these well
- Plug flow is favored to control these vs step feed

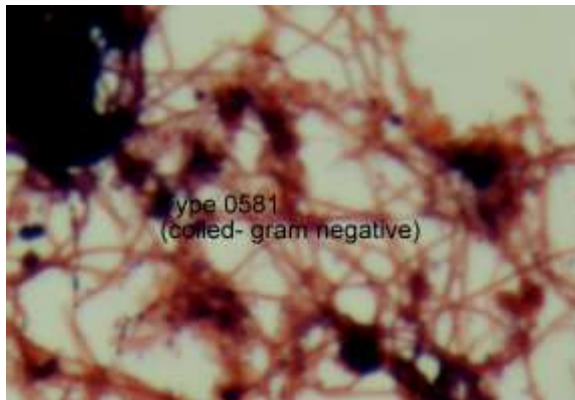


- Organic acids are formed at fermentative conditions and low redox values (-100mV and less).
- Levels >100 mg/L are known to be a cause of filament growth.
- Possible sources: originate in house (primary clarifiers, aeration tanks, sludge handling supernatant) or other areas such as the collection system or EQ tanks.

Organic Acid Filaments



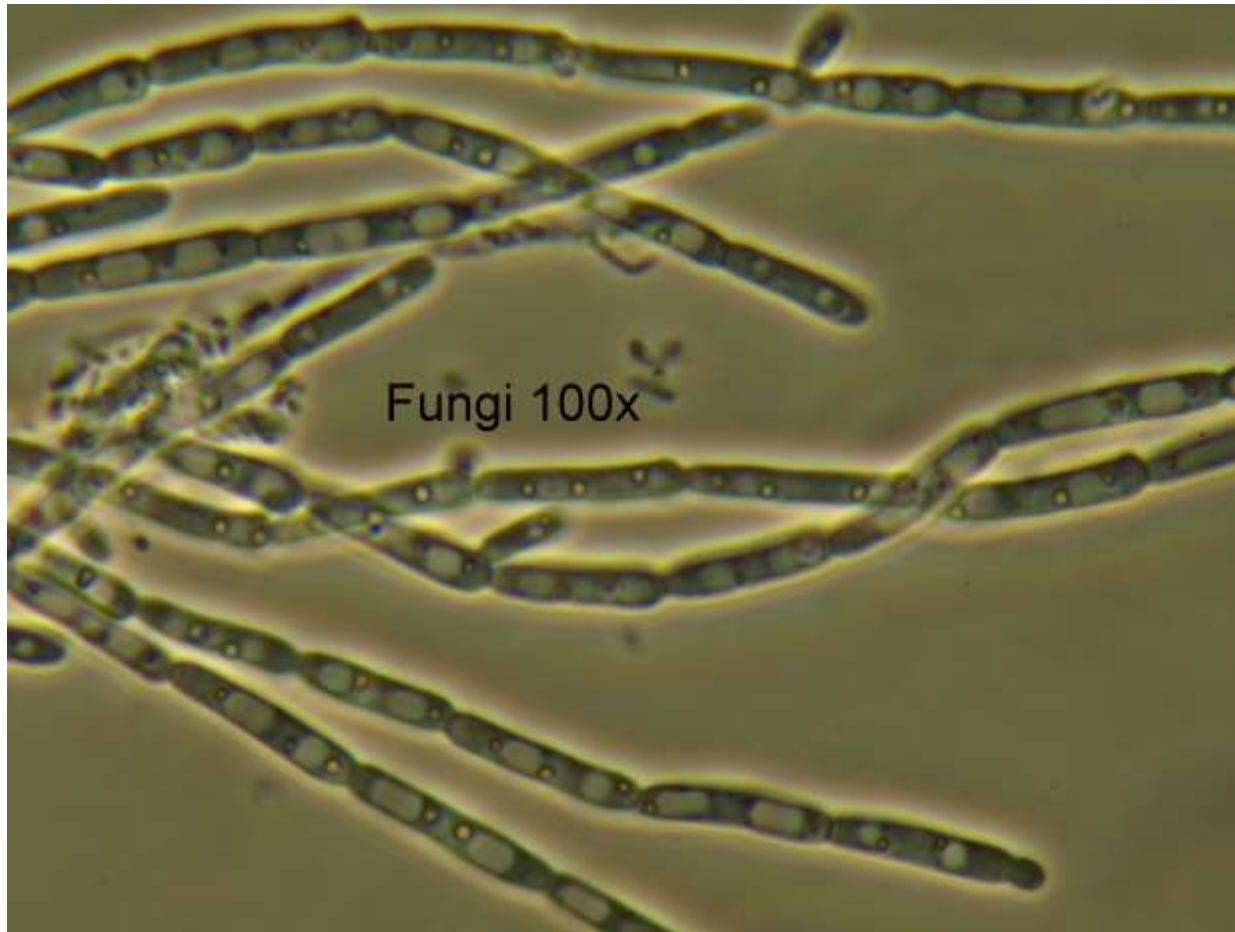
Organic Acid Filaments (Cont)



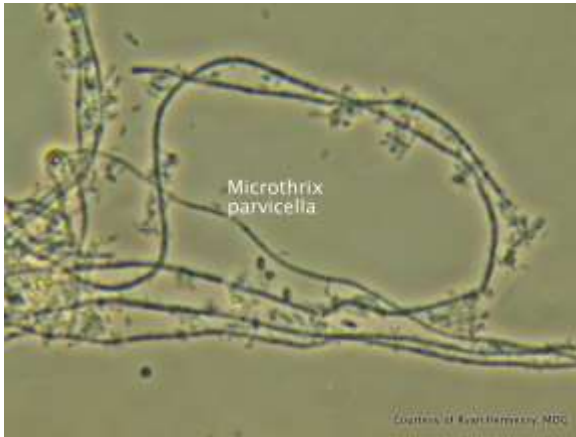
- These filaments can utilize sulfide for growth in addition to organic acids
 - Beggiatoa
 - Thiothrix I
 - Thiothrix II
 - Type 0914
 - Type 021N



- Lack of Phosphorus
 - *H. hydrossis*
 - *S. natans*
 - *N. limicola* III
- Lack of Nitrogen
 - Type 021N
 - *Thiothrix* spp



Oil and Grease Filaments



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Filamentous Foaming

- *Microthrix parvicella*
- Nocardioforms
- Type 1863 (less common)



- Occurs as a thick, brown foam or scum
- May be inches to many feet thick
- Easy to diagnose due to strongly gram positive branching filaments
- A nocardia foam will have substantially more nocardia present than the underlying MLSS
- Occur in all types of plants and all modes of operation

- Odors
- Visual appearance
- Safety hazards (due to overflowing of aeration basins)
- Freezing in the winter time
- Foam may escape basin and leave plant as TSS and interfere with disinfection
- May trap floc forming bacteria in the foam and compromise treatment
 - This interferes with process control calculations

Similar appearance and problems as
Nocardioform Foams



- All filamentous bacteria that cause foaming grow on grease and oil
- Systems that lack primary clarification often suffer from filamentous foaming
- Enforcing grease and fat ordinances helps control at the source
- Septage is known to have substantial oil and grease content and can cause foaming in smaller activated sludge plants

- Nocardia and M. parvicella occur at a longer sludge age
- Type 1863 commonly occurs in sludge ages 4 days or less
- Nocardia is often controlled by reducing the sludge age to less than 6-8 days
- M. parvicella is often controlled by lowering the sludge age below 8-10 days
 - This is not always practical if nitrification is needed

- Physical control uses enlarged scum traps to trap the foam and the surface and dose with powerful water sprays (50 mg/L chlorine common in the spray)
- Foams should be removed entirely from the system, not recycled back into the plant or sent to a digester where it can cause problems there as well
- Changing sub-surface flow to surface overflow between basins prevents foam from being trapped where it's SRT is essentially infinity
- Chlorination of the RAS is often successful for controlling *M. parvicella* foams.
- Nocardioforms grow mostly in the flocs or on the aeration basin surface and are hard to control with RAS chlorination. Still this often helps
- Cationic Polymer dosing to the RAS line has worked to control Nocardioform foaming by bringing the filaments back into the floc where they can be wasted out
- Reports indicate PAX-14 dosing can inhibit the growth of *M. parvicella*
 - Often when dosing is stopped the filaments and the foaming comes back rapidly

- All three causative factors have to be addressed
 - Reduction in the grease and oil content of the wastewater
 - Reduction of sludge age
 - Septicity from all areas of the plant controlled (including aeration tank- maintaining proper DO)
 - Note that some operators try reducing DO to reduce foaming but this only makes problems worse in the long run
 - Anaerobic bacteria break down fatty acids by first making them into an unsaturated foam which is what they grow best on
 - Filamentous foaming has become more of a problem in the last generation due to a change in the people's diets from saturated to unsaturated fatty acids

- For bulking sludge
 - Sludge Juggling
 - Polymer and Coagulant Addition
 - Chlorination

- This will not resolve a problem, but is useful in intermittent bulking problems
- Involves increasing the RAS flow rate to prevent loss of solids to the effluent
 - There is a limit to this as it will put extra hydraulic stress on the clarifier and too much will increase effluent TSS
- Some operators report success by holding solids in the clarifier for long periods of time
 - This likely works by encouraging septic conditions in the clarifier (most filaments are aerobic)
 - This however can encourage hydrogen sulfide development which is a cause for other filaments as well as cause re-release of nutrients in the clarifier

- A reduction in solids loading to the clarifier can be achieved by lowering the mixed liquor concentration
 - This may worsen the problems for certain filaments and make the problem worse however (discussed later)
- Changing to step feed configuration can reduce the MLSS concentration in the clarifier without reducing the systems sludge inventory.
 - Here the MLSS concentration is highest at the head end of the aeration basin and decreased
 - The redistribution of solids usually takes a day or less
 - Again this works for some filaments and not others (for low F/M filaments makes the problem worse)

- A chemical supply company may jar test several anionic or cationic polymers to see if polymer dosing can improve the SVI of a bulking sludge
- These systems are relatively easy to install on short term or long term basis to be available as needed
- Jar testing must be done frequently to ensure the correct dosage and the correct polymer as changes in the biology will affect the chemistry of the waste
- Polymer does not significantly increase waste sludge production, but is expensive

- Inorganic coagulants have been used to increase settling speed and lower the SVI
- These chemicals have a “sweeping” effect and can also coagulate small particles that are dispersed
 - Common chemicals include
 - Ferric chloride
 - Aluminum Sulfate
 - When these chemicals are dosed they will increase sludge production and also careful monitoring of the alkalinity is needed not to drop the pH

- It's common for plants that lack primary clarifiers to have lower SVIs as a result of the inorganic material in the flocs that aids weight and increases settling
 - The downside is higher BOD entering the aeration basin as well as potential for problems with oil and grease (foaming, filaments etc)
- It's common practice in some pulp and paper wastewater plants to intentionally waste paper fibers or paper coating materials (like clay) to the plant to add weight to improve the SVI
- The PACT process uses powdered activated carbon to add weight the flocs
- The Kraus process recirculates anaerobic digester contents through the aeration basin to add inorganic material to the sludge
 - All of these methods are not without some risk- There's a chance inert solids may help the settling, but if this is not successful there's potential for higher TSS losses.

- Chlorine and hydrogen peroxide have been used successfully to control filaments and stop bulking
 - Because chlorination is far more common (due to economic reasons) it will be the focus of this presentation
- The idea is to dose at a level that will damage the filaments that extend from the floc surface, but don't damage the floc formers
- The ideal chlorine dose is plant specific and generally in the range of 1-10 pounds chlorine/1000 pounds MLVSS/day

- Always keep in mind that chlorination is a “band-aid” rather than a cure all
- Often times when chlorination is stopped the filaments will grow back rapidly
- It’s important that the settling problem is properly diagnosed
 - Chlorination will make problems worse if the problem is non-filamentous (slime bulking) or due to poor floc development

- **2-3 lb Chlorine/1000 lbs MLVSS/day**
 - A typical maintenance dose when the SVI is generally under control and chlorination is needed to kill newly growing filaments
- **5-6 lb Chlorine/1000 lbs MLVSS/day**
 - A typical dose that will reduce SVI over several days and have little impact on effluent quality
- **10-12 lb Chlorine/1000 lb MLVSS/day**
 - Usually will destroy excess filaments and reduce the SVI rapidly/
Floc structure is likely to deteriorate at this dose
 - Keep in mind all doses are plant specific and this is just a general guideline. Always start conservatively and evaluate changes under the microscope (discussed later). Always error on the side of caution.

- Chlorine must be dosed at a point of excellent initial mixing. If not, a large part of the RAS may not be contacted and a large part may be overdosed.
- Chlorine should be added at a point where the chlorine demand is at a minimum
 - Competing reactions will reduce it's effectiveness in killing filamentous organisms
- Good chlorine addition points
 - RAS line (application point of choice)
 - Elbow in a pipe
 - Into and below the rising liquid level in the riser tube of airlift RAS pumps

- Aeration basin (generally causes floc dispersion and system damage)
- RAS wet wells
- Mixed liquor channels
- Any other point of poor mixing

- Ideally the RAS should come into contact with the chlorine 2-3x per day
- In long aeration basins with long hydraulic residence times a second RAS dosing point may be needed to obtain this
- It's common to dose the center well of the clarifier in addition to the RAS line to achieve the necessary contacts between the RAS and the chlorine
 - Use the same dosage for each/this counts as two exposures
 - Think of it as “a jab to the gut..followed by a right hook”

- A microscopic evaluation is recommended daily when chlorinating
- If the proper dose is reached settling usually improves in 1-3 days.
- Sheathed filaments take longer to get rid of because the cells within the sheath are killed and the sheaths remain in the system (which can still affect the SVI). They are generally wasted out within a few MCRTs
- Sometimes chlorination is stopped once a target SVI is reached

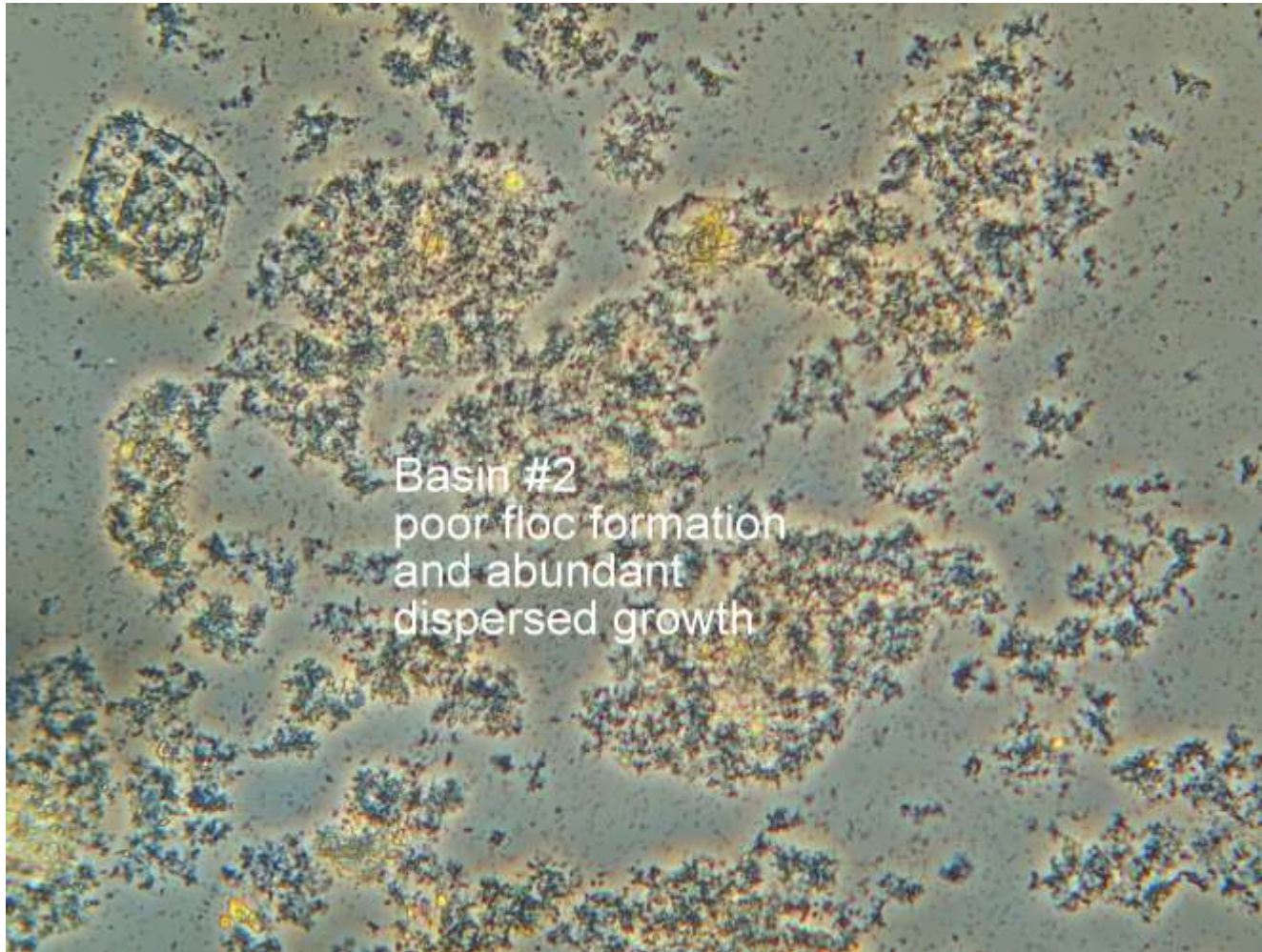
- Loss of sulfur granules
- Damaged cells, empty sheaths, and cytoplasm shrinkage
- Filament breakup
 - A good general rule is ceasing chlorination once about 70% of the cells are damaged or missing a filament
 - If chlorination is continued beyond this point the floc forming bacteria may be damaged (see toxicity from earlier in the presentation)

Empty sheaths and dead filaments



- A turbid milky effluent
- Significant increase in effluent TSS
- Loss of higher life forms (protozoa,metazoa)
- Reduction of BOD removal
- Disruption of nitrification
- Small broken up flocs under the microscope

Overchlorination



- Low Dissolved Oxygen Problems
- Wastewater Septicity and Organic Acids
- Low F/M Problems and Selectors
- Nutrient Deficiency

- When DO is measured, we are measuring the DO in the bulk liquid, the DO in the flocs is actually much less because DO is consumed as it penetrates into the flocs.
- The required DO concentration is a value that keeps the interior of the floc aerobic
- At F/M values around 0.5 mg/L and less, 2 mg/L is usually a satisfactory set point to control low DO filaments
- At higher F/M values, more DO is needed.
 - In some industrial systems with very high F/M DO concentrations >6 mg/L have been needed to prevent bulking by low DO filaments.

- In high F/M systems the OUR is very high due to the bacterial growth curve. (logarithmic phase).
- Increasing the MLSS will reduce the F/M ratio, and thus the OUR
- It's not always true that "more bugs require more oxygen"

- **Lag**
 - Acclimatization, no reproduction
- **Logarithmic (log)**
 - Bacteria are multiplying by their greatest rate
 - F/M is high
 - High single celled bacteria/ dispersion rates
- **Stationary Phase**
 - Growth= death
 - F/M decreasing $F/M < 1$
- **Declining Growth Phase (death log)**
 - Logarithmic Death
 - Endogenous Respiration
 - F/M at it's lowest point
 - Old sludge
- **Death**
 - no viable cells

- Raising the MLSS (Opposite of what intuition would suggest)
- Raising the DO concentration
- Increasing the RAS rate
 - This minimizes the sludge retention time in the clarifier and can help lower the F/M ratio in the aeration tank
- Once low DO filaments take over, it often takes much more DO to cure the problem so short term chlorination is recommended

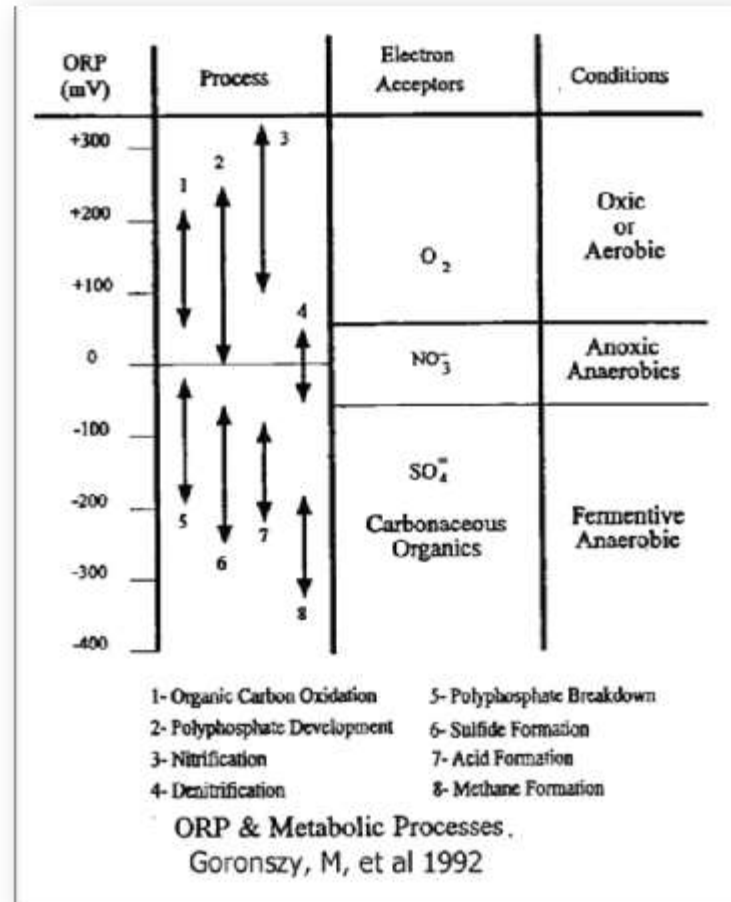
- **Septicity**
 - Defined as when wastewater becomes anaerobic
 - Sulfate reducing bacteria reduce sulfate to hydrogen sulfide
 - Anaerobic bacteria ferment organic materials to organic acids
 - Acetic, propionic, butyric, valeric

- **Septicity can occur ahead of the plant**
 - Lift stations
 - Long retention time in collection system
- **Industrial wastes**
 - Dairy, pickling, textile dyeing operations etc
- **Septage**
- **Within the Treatment Plant**
 - Equalization basins
 - Primary clarifiers
 - Co thickening WAS sludge can be a common cause
 - Sludge processing sidestreams

- Organic Acid concentration >100 mg/L
- Hydrogen Sulfide concentration $>1-2$ mg/L
 - These can be tested using various tests from Standard Methods or from test kits available from Hach chemical Co.



ORP Chart



- **Pre-aeration**
 - This will release odors
- **Chemical Oxidation**
 - Oxidizes sulfide and some organic acids
 - Chlorine, hydrogen peroxide, potassium permanganate
- **Chemical Precipitation**
 - Ferric Chloride will precipitate sulfide
- **Calcium Nitrate**
 - Often used in collection systems as an “oxygen source” to raise the redox potential
- **Diluting Influent**
 - Recirculating a percentage of treated effluent back to the head of the plant can reduce retention time in EQ tank/primary clarifier as well as dilute the sulfide and organic acid concentration
- **Switching modes of Operation**
 - Step Feed
 - Complete-mix
 - Plug flow is the worst mode for these conditions

- Three low F/M filaments are commonly recognized
 - Type 0041
 - Type 0675
 - Type 1863
- May be simply slow growing, grow on particulate BOD, or compete successfully because of low endogenous maintenance energy needs

- Lower the MLSS (the “M” component)
- Increase the incoming BOD (the food)
- Provide plug flow conditions with an initial high F/M ratio
- Intermittent feeding of wastes
- Use of a selector
 - Step feed and complete mix are the worst modes of operation for low F/M bulking

- Selectors describe a small zone where the RAS and the influent come into contact before the aeration basin at a high F/M ratio
- Selectors can be aerobic, anoxic, or anaerobic
 - Aerobic or Oxic
 - DO is present and aerobic respiration is the method for BOD removal
 - Anoxic
 - Free DO is absent. Nitrate is present and used to meet metabolic demands
 - BOD is either stored or denitrified
 - Anaerobic
 - No free or combined dissolved oxygen
 - PHA storage along with hydrolysis of stored inorganic polyphosphate or stored glycogen are the major activities
 - This is done by G bacteria and polyphosphate accumulating organisms. (PAOs- which are responsible for enhanced biological phosphorous removal)

- A selector commonly has a retention time of 15-40 minutes and achieves about 80% removal of soluble BOD
- The primary function of bacteria in the selectors is for floc formers to rapidly store BOD (pack a lunch bag) which they use later for growth in the aeration basin
- If a selector is too large the floc formers may not take up enough of the initial BOD to discourage filaments
- If the selector is too small, the floc formers may shunt BOD to exocellular polymer (polysccharide) which may lead to “slime bulking” and problems with thickening and dewatering
- It’s recommended to have adjustable baffles or exit gates to adjust selector size as needed
 - Overflow capabilities from channel to channel are also recommended to prevent trapping of foam

- This is a problem in industrial wastes and not municipal (unless very large percentage of industrial contribution)
- In general a 100:5:1 ratio of BOD: Nitrogen: Phosphorous is needed for BOD removal
- The above ratio is a starting point and less nutrients are needed as the temperature or the sludge age increases due to recycling of nutrients in the system because of increased endogeny

- A bulking sludge due to filaments that can outcompete floc formers at nutrient limiting conditions (discussed earlier).
- Viscous sludge with significant polysaccharide content on the reverse india ink stain
- Carbohydrate content >20% on the anthrone test
- Aeration basin and/or secondary clarifier scum containing large amounts of exo-cellular material (commonly neisser positive), but not containing foam-causing filaments

- **Commonly used sources**
 - Nitrogen
 - anhydrous ammonia
 - urea
 - Phosphorous
 - Phosphoric acid
 - Sodium phosphate
 - Ammonium phosphate

- The 100:5:1 BOD: N:P ratio is a starting point
- The actual required dose may change seasonally due to less nutrient requirements at higher aeration basin temperatures
- The nutrient dose should match the BOD fluctuations as closely as possible
 - Look at this in addition to the 24 hour average ratio
- Nutrients need to be readily available for the bacteria when they need them
 - In some cases dosing should be based off of the available nutrients in the influent (Ammonia and Orthophosphate) rather than TKN and total Phosphorous if there is not enough time for other forms of phosphorous to become available and for organic nitrogen to be hydrolyzed to ammonia

- Filter the MLSS prior to the clarifier (or for an SBR prior to the settling cycle)
 - This is preferred over the secondary effluent because nutrients can be released under anaerobic conditions in the clarifier
- A residual of at least 1 mg/L total inorganic nitrogen and at least 0.5-1 mg/L orthophosphate indicates that the bacteria have “left some on the plate”.
 - Total Inorganic Nitrogen (TIN)= nitrate + nitrite + ammonia

- Microscopic Evaluation is an essential tool in troubleshooting activated sludge problems
- Once the cause is known, the proper short term and long term actions can be evaluated
- It's always best to look at long term solutions rather than short term solutions, although short term solutions are commonly needed in to get through a problem as it develops
- Frequent microscopic evaluations (every couple SRTs) is recommended to help “head off” problems before they develop

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- All pictures courtesy of Ryan Hennessy, Microbial Discovery Group