Process Control for Activated Sludge

June 27th, 2013

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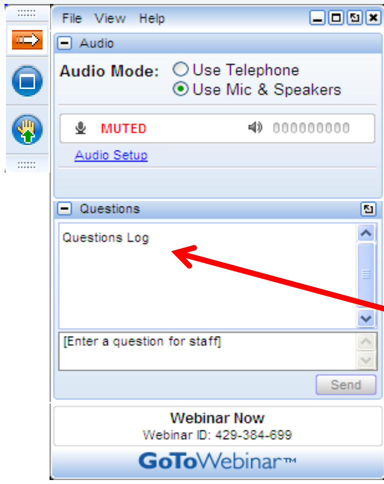

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Speaker

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Activated Sludge

Process Control

Jeanette Brown

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Presentation Outline

- Definitions
- Description of the activated sludge process
- Process Control
- Troubleshooting

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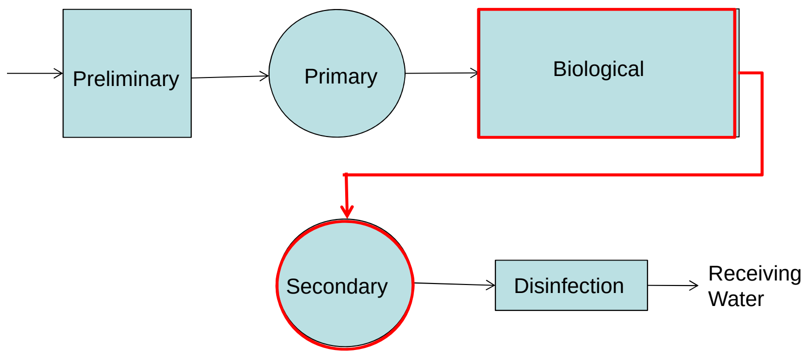
Definitions

- Heterotrophic-derive carbon for cell growth and energy from organic compounds
- Autotrophic-derive carbon for cell growth and energy from inorganic compounds
  - Nitrification-converting ammonia nitrogen to nitrate nitrogen

Definitions

- Aerobic-aerated with DO ~ 2mg/L
- SRT-The average time suspended solids are retained in a biological waste treatment system
- F:M-the loading rate expressed as pounds of BOD5 per pound of mixed liquor volatile suspended solids per day

Plant Flow Diagram-Liquid Treatment Processes



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Secondary Treatment

- Biological wastewater treatment that generally removes at least 85% of BOD and suspended solids.
- <30 mg/L BOD and TSS
- Two types
  - Biofilms (Attached Growth) (Fixed Film)
    - Trickling filters
    - Rotating Biological Contactors
  - Suspended Growth
    - Activated Sludge

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The Activated Sludge Process

- In 1913, H. W. Clark and S. De M. Gage from the Lawrence Experiment Station in Massachusetts, reported in the *45th Annual Report to the State Board of Health of Massachusetts,* the results of studies on the purification of sewage using aeration.
- They found that if you aerated sewage you achieved a clarified sewage and a reduction of TKN.

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The Activated Sludge Process

- In1914, British researchers Edward Ardern and W.T. Lockett, added the concept of recycling sludge and patented the process.
- The paper they published in 1914, first used the term “Activated Sludge”.

Davyhulme Sewage Works, Manchester, UK, first full-scale activated sludge plant.

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Classification of Activated Sludge Processes

- The activated-sludge process is often classified on the basis of loading rate
  - may be expressed as a volumetric loading rate, SRT, or F:M
- Classified as
  - High rate
  - Conventional
  - Low rate

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Conventional Activated Sludge

- Conventional systems
  - provide BOD_5 removal efficiencies of 85 to 95%
  - typically carry MLSS concentrations varying from 1000 to 3000 mg/L
  - typically have an SRT between 3-15 days
  - F:M between 0.2 and 0.4 lb/lb.d (kg/kg.d)

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Basic Components

- Single or multiple biological reactors (aeration tanks).
- Aeration source to provide
  - Oxygen
  - Mixing
- Clarifier(s)
- Collection and delivery mechanism for RAS
- Means of removing excess solids (WAS)

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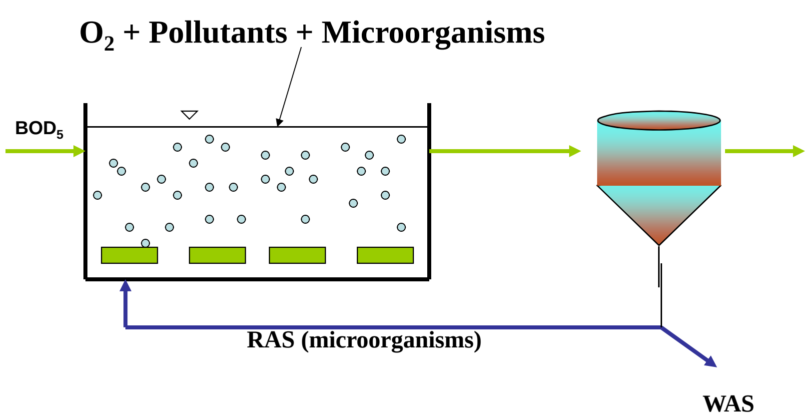
Basic Activated Sludge Process



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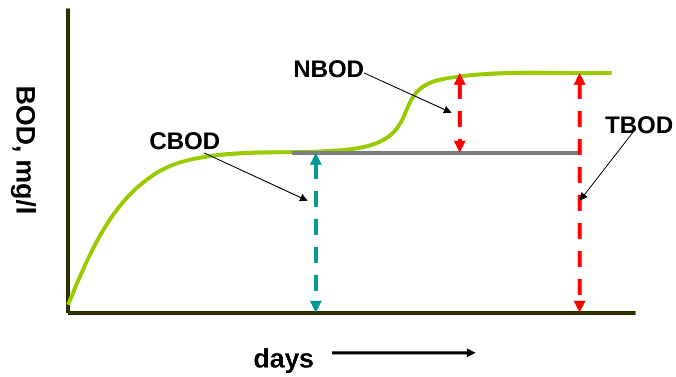
Biochemical Oxygen Demand



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Process

- Remove carbonaceous BOD
- Remove carbonaceous BOD and oxidize ammonia (nitrify)
- Design is based on
  - Length of time the solids are kept within the process; solids retention time (SRT)
  - Amount of food provided to the bacteria; food to microorganism ratio (F/M)
  - Hydraulic retention time

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Basic Process

- Organic matter is the carbon and energy source for cell growth
- Carbon is converted to cell tissue, water, oxidized products mainly CO_2
- Contents of aeration tank is MLSS, MLVSS

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Microbiology and Biochemistry

- Activated sludge process is a big biochemical factory
  - Bacteria
  - Fungi
  - Protozoa
  - Rotifers
  - Nematodes
- Bacteria are the significant organisms for consuming organic matter

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Microbiology and Biochemistry

- Predominant species of microorganisms depends on
  - Characteristics of the influent wastewater
  - Environmental conditions
  - Process design
  - Plant operation

Microbiology and Biochemistry

- A successful plant depends on cultivating a biological community that will
  - remove and consume (assimilate) waste material,
  - Flocculate together
  - Settle well to produce a concentrated solids for recycling
  - Produce a clear effluent

Microbiology and Biochemistry

- Two general types of microorganisms
  - Floc formers
  - Filament formers
- Floc formers
  - Clump together
  - Form gelatinous floc which is heavy enough to settle
- Filament formers
  - Stringy, threadlike structures
  - Light-weight, doesn't settle

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Microbiology and Biochemistry

- Activated sludge process uses
  - Heterotrophic bacteria for carbonaceous BOD removal
    - Organisms that use organic carbon for the formation of cell tissue
- Organic matter + oxygen +nutrients + $C_2H_7O_2N$ (microorganisms) $\longrightarrow$ $C_2H_7O_2N$ (new microorganisms) + CO_2 + H_2O

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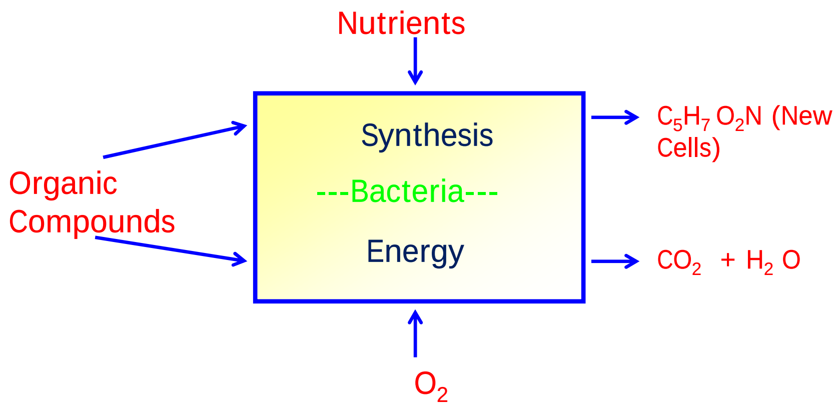
Aerobic, Heterotrophic Metabolism



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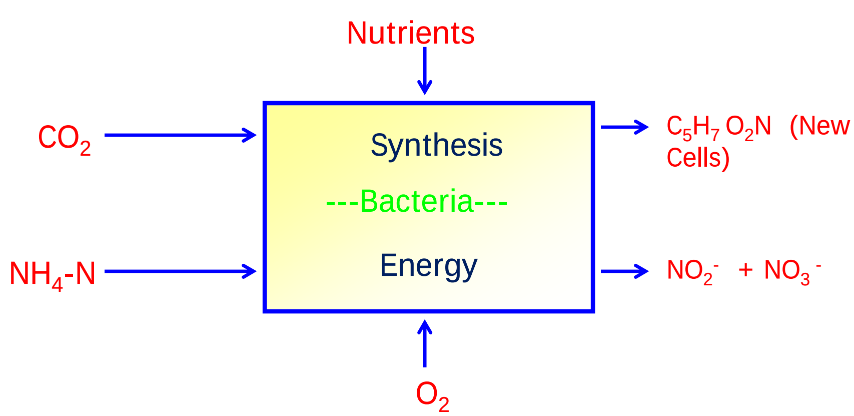
Aerobic, Autotrophic Metabolism



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Solids Separation

- An important feature of the activated-sludge microbial system is its ability to separate by gravity under quiescent conditions.
- This property is achieved by
  - selecting the culture that settles,
  - recycling the settled sludge, and
  - operating the process under loading conditions that will select for a flocculent culture.

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Process Control

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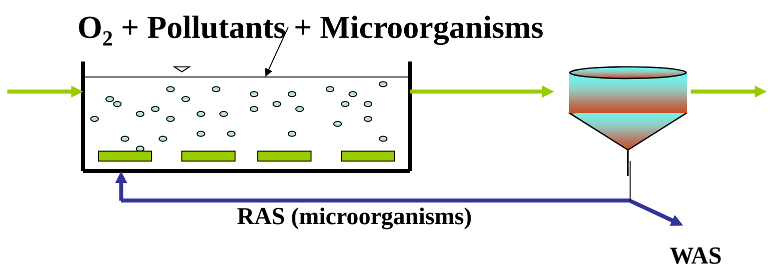
Process Control

- Need to provide sufficient nutrients and food
- Need to keep a balance population of bacteria and protozoa
- Need to provide sufficient oxygen
- Need to provide mixing



Food and Nutrients

- Incoming wastewater
  - BOD
  - Nitrogen
  - Phosphorus
  - Trace minerals
- Need 100 parts of BOD, to 5 part of nitrogen, to 1 part of phosphorus

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Balanced Population

- RAS
  - Source of microorganisms to aeration tanks
  - Typically 30 to 50% Q
- WAS
  - Removal of excess organisms

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Oxygen and Mixing

- Need sufficient energy to mix as well as aerate
- Accomplished by aeration devices
  - Mechanical
  - Diffused air
    - Fine bubble
    - Coarse bubble

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Aeration

- Aeration consumes 50%-65% of net power demand for treatment
- Important to select design that meets mixing and oxygen requirements at lowest cost possible

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Key Process Control Parameters

- – MLSS and MLVSS
- – SRT-solids retention time also called MCRT (mean cell residence time)
- – F/M-food to microorganisms
- – SVI-sludge volume index
- – RAS rate
- – WAS
- – Dissolved oxygen

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MLSS

- MLSS-concentration of suspended solids in activated-sludge mixed liquor, expressed in milligrams per liter (mg/L)
  - Typically 1500 to 3500 mg/L
  - Plant specific
  - Can be measured *in-situ*

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MLVSS

- MLVSS-the fraction of the suspended solids in activated-sludge mixed liquor
  - that can be driven off by combustion at 550 ° C (1022 ° F);
  - indicates the concentration of microorganisms available for biological oxidation
    - Not an exact measurement because dead cells are also volatile

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Solids Retention time

- SRT, MCRT, Sludge Age-How long the solids remain in the system, terms used interchangeably
  - Dependent on growth rate of the organisms (bacteria).
  - Used as a process control and design parameter.

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SRT

- SRT = Solids under aeration divided by the solids leaving the system.
  - For BOD removal, typically 3 to 5 days
  - For nitrogen removal, greater than 6 days.

Note: If there is a blanket in the secondary clarifiers, those solids must also be taken into account.

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SRT(MCRT)-US Units

Solids Under Aeration = V_{aer} (million gallons) x 8.34 lbs/million gallons-mg/L x MLSS, mg/L

Solids leaving the system = Q_{was} million gallons/d x 8.34 lbs/million gallons-mg/L x C_{was}, mg/L + Q, million gallons/d x 8.34 lbs/million gallons-mg/L x $TSS_{eff,}$ mg/L

Therefore;

SRT =(V_{aer} (MG) x 8.34 lbs/million gallons-mg/L x MLSS, mg/l)/(Q_{was} MGD x 8.34 lbs/million gallons-mg/L x C_{was}, mg/L) + (Q, MGD x 8.34 lbs/million gallons-mg/L x TSS_{eff})

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SRT(MCRT)-SI Units

Solids Under Aeration = V_{aer} (m^3/d) x MLSS, g/m^3 (mg/L) x kg/1000 g

Solids leaving the system = [Q_{was} m^3/d x C_{was}, g/m^3 (mg/L) x kg/1000 g] + [Q, m^3/d x $TSS_{eff,}$ g/m^3 (mg/L) x kg/1000 g]

Therefore;

SRT =[V_{aer} (m^3/d) x MLSS, g/m^3 (mg/L) x kg/1000 g]/[Q_{was} m^3/d x C_{was}, g/m^3 (mg/L) x kg/1000 g] + [Q, m^3/d x $TSS_{eff,}$ g/m^3 (mg/L) x kg/1000 g]

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Example

- Given:
  - V_{aer} = 1.4 million gallons (5,300 m^3)
  - Q = 3.1 MGD (11,735 m^3/d)
  - MLSS = 2650 mg/L
  - Q_{was} = 70,000 gpd (265 m^3/d)
  - TSS_{eff} = 20 mg/L
  - WAS =RAS = 5960 mg/L

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Example-US Units

- Solids under aeration = (1.4 million gallons x 8.34 lbs/million gallons-mg/L x 2650 mg/L) = 30,941 lbs
- Solids leaving system = (0.07 million gallons x 8.34 lbs/million gallons-mg/L x 5960 mg/L) + (3.1 million gallons/d x 8.34 lbs/million gallons-mg/L x 20 mg/L) = 3997 lbs/day

- SRT = $\frac{30,941 \text{ lbs}}{3997 \text{ lbs/d}}$ = 7.7 days

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Example-SI Units

- Solids under aeration = (5300 m^3 x 2650 g/m^3 x kg/1000 g = 14,045 kg
- Solids leaving system = [(265 m^3/d x 5960 g/m^3 x kg/1000 g)] + [(11,735 m^3/d x 20 g/m^3) x kg/1000 g] = 1814 kg/day

- SRT = $\frac{14{,}045 \text{ kg}}{1814 \text{ kg/d}}$ = 7.7 days

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Process Control Calculations

- F/M Ratio
  - Food to microorganism ratio
  - Mass of food entering biological reactors, lbs (kg) BOD
  - Mass of microorganisms in the biological reactors, lbs (kg) MLVSS
  - MLVSS typically is 80% of the MLSS

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F/M Ratio-US Units

- F/M Ratio
- Food = Q, MGD x 8.34 lbs/MG-mg/L x BOD, mg/L
- Microorganisms = $V_{bio,}$ MG x 8.34 lbs/MG-mg/L x MLVSS, mg/L

$$F/M = \frac{(Q, \text{MGD} \times 8.34\ \text{lbs/MG-mg/L} \times BOD_5, \text{mg/L})}{(V_{bio} \times 8.34\ \text{lbs/MG-mg/L} \times \text{MLVSS, mg/L})}$$

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F/M Ratio-US Units

Example: MLSS=3000 mg/L; 82% volatile; Q = 16.5 MGD; V = 7.5 MG; PE BOD = 135 mg/L

F/M = (Q, million gallons/d x 8.34 lbs/million gallons-mg/L x BOD, mg/L)/(V_{aer} x 8.34 lbs/million gallons-mg/L x MLVSS, mg/L)

$$F/M = \frac{(16.5\ \text{MGD}) * 8.34\ \text{lbs/ MG-mg/L} * 135\ \text{mg/L}}{(7.5\ \text{MG}) * 8.34\ \text{lbs/MG-mg/L} * (3000*0.82)\ \text{mg/L}}$$

$$F/M = \frac{2228}{18450} = 0.12$$

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F/M Ratio-SI Units

- F/M Ratio
- Food = Q, m^3/d x BOD_5, g/m^3 x kg/1000 g
- Microorganisms = $V_{bio,}$ m^3 x MLVSS, g/m^3 x kg/1000 g

$$F/M = \frac{[(Q,\ m^3/d \times BOD_5,\ g/m^3 \times kg/1000\ g\ ]}{[(V_{bio,}\ m^3 \times MLVSS,\ g/m^3 \times kg/1000\ g)]}$$

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F/M Ratio-SI Units

Example: MLSS=3000 g/m^3 ; 82% volatile; Q = 62,460 m^3/d ; V = 7.5 MG; PE BOD = 135 g/m^3

F/M = (Q, million gallons/d x 8.34 lbs/million gallons-mg/L x BOD, g/m^3)/(V_{aer} x 8.34 lbs/million gallons-mg/L x MLVSS, g/m^3)

$$F/M = \frac{(62{,}460\ m^3/d) * 135\ g/m^3 * kg/1000\ g}{(28{,}391\ m^3) * (3000*0.82)\ g/m^3 * kg/1000\ g}$$

$$F/M = \frac{8432}{69842} = 0.12$$

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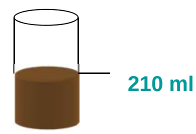
Sludge Volume Index

- SVI= a measurement of the ability of the floc to settle
- Typically 80 to 150



- SVI = ml/MLSS,g
- SVI = 210 ml/2.2 g = 95

(2200 mg = 2.2 g)

WAS and RAS Rates

- RAS is the source of microorganisms
- Microorganisms use the food (BOD) to make new cells. For every pound of BOD used, there are about 0.5 to 0.6 pounds of new cells produced. This is known as Cell Yield.
- WAS is used to remove excess cells (solids) from the process.

WAS and RAS Rates

- How do I know how much to waste or return?
  - Based on mixed liquor concentration
  - Based on F/M ratio
  - Based on SRT (MCRT)
- Depends on what you are trying to achieve.

WAS and RAS Rates

- Typically, RAS is 30-50% influent Q, but can be higher. Designers generally give capability of returning 100%, but high rates can negatively impact clarifier performance.
- Calculate WAS by rearranging the SRT formula solving for WAS.

WAS Rate

$$SRT = \frac{\text{lbs (kg) of solids biological system}}{\text{WAS, lbs/d (kg/d)} + TSS_{Eff}\text{, lbs/d (kg/d)}}$$

$$WAS = \frac{\text{Solids biological system}}{SRT} - TSS_{Eff}$$

WAS Rate

$$\text{WAS, lbs/d (kg/d)} = \frac{\text{Solids biological}}{SRT} - TSS_{Eff}$$

WAS, MGD = (WAS, lbs/d)/(8.34 MG-mg/L x WAS,mg/L)

WAS, m^3/d = (WAS, kg/d)/(WAS,g/m^3 x kg/1000 g)

Waste time, minutes = (WAS, gal (m^3)/Pump rate, gpm (m^3/min)

WAS Rate Example-US Units

WAS = 6774 lbs/d

WAS, MGD = 6774 lbs/d / (8.34 lbs/MG-mg/Lx 8600 mg/L)

WAS = 0.094 MGD =94,000 gpd

Pump rate = 250 gpm

Pump time = 94,000 gal/250 gpm = 376 min = 6.2 hrs.

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WAS Rate Example-US Units

- SRT = 10 days
- MLSS = 3100 mg/L, V_{bio} =3.1 MG
- TSS_{Eff} = 8 mg/l, WAS = 8600 mg/l
- Q = 18.6 MGD

S_{bio} = 3100 mg/L x 8.34 lbs/million gallons/d-mg/L x 3.1 million gallons= 80147 lbs/d

$TSS_{eff,}$ lbs/d = (8 mg/L x 8.34 lbs/million gallons/d-mg/L x 18.6 million gallons/d) =1241 lbs/d

WAS, lbs/day = $\frac{80147 \text{ lbs/d}}{10}$–1241 lbs/d

WAS = 6774 lbs/d

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WAS Rate Example-SI Units

WAS = 3073 kg/d

WAS, MGD = 3073 kg/d / (8600 g/m^3 x kg/1000 g)

WAS = 357 m^3/d

Pump rate = 0.95 m^3/min

Pump time = $\frac{357\ m^3}{0.95\ m^3/min}$ =376 min = 6.2 hrs

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Process Control-Microbiology

- Indicator microorganism
  - Amoeba
  - Flagellates
  - Motile ciliates
  - Stalked ciliates
  - Rotifers
  - Nematodes

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Free Swimming and Crawling Ciliates

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Stalked Ciliates

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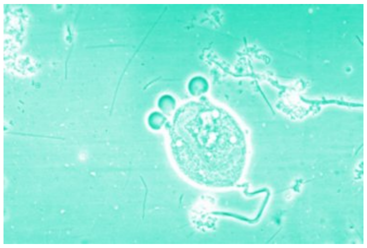
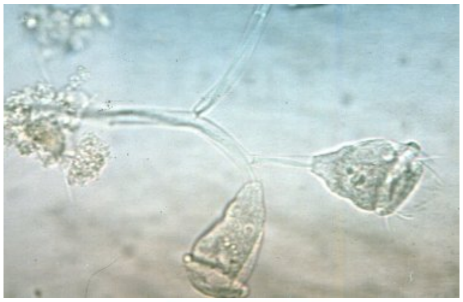
Stalked Ciliates





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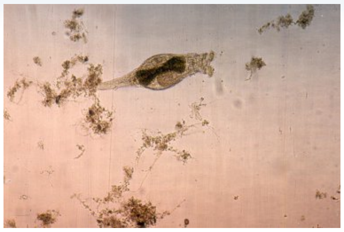
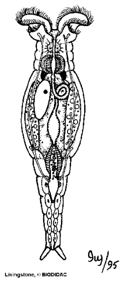
Rotifers





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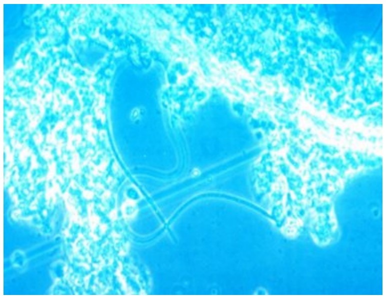
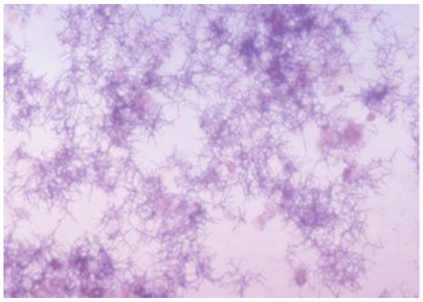
Filamentous





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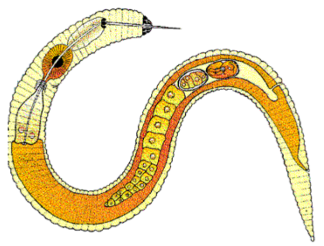
Nematodes/Worms



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Control Strategies

- Operators have a preferred method for calculating the amount of solids to waste to maintain an optimum solids inventory.
  – What is right for one plant may not be right for another
  – Strategies include F:M, constant MLSS or SRT

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Control Strategies

- F:M Control
  - Wasting rates determined by F:M will depend on the variations of influent BOD,
- Constant MLSS
  - wasting rates determined for a constant MLSS will depend on changes in activated-sludge growth rate (resulting from influent variations). Easiest control strategy for small treatment plants

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Control Strategies

- SRT control is most often the method chosen for municipal WWTPs.
  - For a given target SRT, the same portion of activated-sludge inventory is wasted every day regardless of the variations occurring in the influent wastewater.
  - For example, if you set a target SRT of 10 days, you will waste 10% of the MLSS every day.

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Control Strategies

- SRT Control-
  - Easier for operators to maintain a constant SRT than a constant F:M or MLSS.
  - Gives operators more control and the process more stability when the SRT method is used.
  - Choose the one that is easiest for you and gives the best performance, but be open to changes

Solids Separation

- Clarifiers are part of the activated sludge process
- Need to understand and manage clarifier performance to ensure permit compliance
- Need to understand relationship of RAS flow to clarifiers performance

Solids Separation

- There are five parameters that will have the most influence over the performance of a well-designed secondary clarifier:
  - 1) MLSS concentration in the flow to the clarifier,
  - 2) wastewater flow,
  - 3) RAS flow,
  - 4) surface area of the clarifier, and
  - 5) settleability of the activated sludge

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Secondary Clarifiers

- Typically circular
- Have lower detention times than primary because solids are biological-1 to 2 hours
- Overflow rates at ADF = 800 gpd/ft^2
- With BNR =600 gpd/ft^2
- SLR = 30 $lbs/d/ft^2$
- With BNR =20 $lbs/d/ft^2$

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Surface Overflow Rates (SOR)

- Used to design and process control
- SOR, $gal/ft^2.day$ =Q,gpd/A,ft^2
- SOR,$m^3/m^2.day$ = Q, m^3/d / A, m^2

- Example:

A = 7,000 ft^2 (650 m^2) (Per unit)

Q=5,500,000 gal/d (20,820m^3.d) ((Per unit)

SOR = (5,500,000 gal.d)/ 7,000 ft^2 = 785 gal/ft^2.day

SOR = (20,820 m^3d)/ 650 m^2 = 32 m^3/m^2.day

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Solids Loading Rate

SLR = (Q,MGD + R, MGD) x MLSS, mg/L x 8.34 lbs/million gallons-mg/L/ A, ft^2

SLR = Solids loading rate (lbs/d-ft^2)

$$SLR = \frac{(Q, m^3.d + R, m^3.d) \times MLSS, g/m^3 \times kg/1000\ g}{A, m^2}$$

SLR = Solids loading rate (kg/d.m^2)

Q = Plant flow, MGD (m^3.d)

R = RAS flow rate, MGD (m^3.d)

MLSS = Mixed liquor suspended solids, mg/L (g/m^3)

A = Clarifier surface area, ft^2 (m^2)

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SLR Example

- Q = 18.2 MGD (68894 m^3.d)
- R = 7.7 MGD (29148 m^3.d)
- MLSS = 3350 mg/L, (g/m^3)
- A = 39,978 ft^2 (3714 m^2)

SLR = (18.2 + 7.7)million gallons/d x 8.34 lbs/million gallons-mg/L x 3350, mg/L / 39,978 ft^2

SLR = 18 lbs/d-ft^2

SLR = (68894+29148)m^3·d x (3350, g/m^3 x kg/1000 g) / 39,978 m^2

SLR =8.2 kg.d/m^2

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Process Control Tools

- Four steps are essential to manage any process:
  - gather information,
  - evaluate the data,
  - develop and implement a proper response,
  - reevaluate.

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Process Control Tools

- First, information is collected in the form of analytical data, hour meters, visual observations, and other miscellaneous facts.
  - Information is only as good as the device used for the analysis.
  - Reliable instrumentation carefully selected and properly maintained provides the best information

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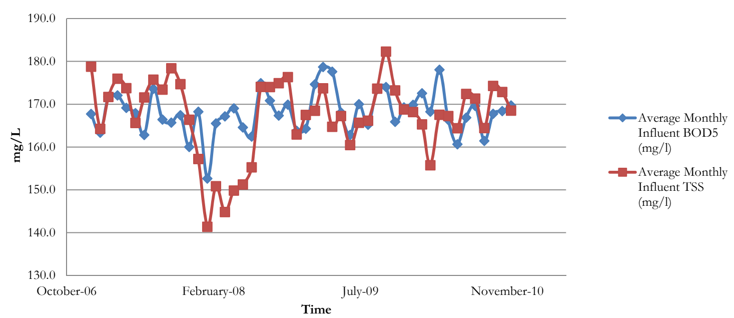
Process Control Tools

- Most data numerical
- Use graphs, mass balance analysis, and basic statistics



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Troubleshooting

Gathering Information

- Gathering information is a basic troubleshooting task that requires knowledge of
  - the specific plant,
  - waste constituents received, and
  - specific processes.

Gathering Information

- The following guidelines will assist in gathering information:
  - Determine whether a problem exists or the test results are in error.
  - Find out when the problem was first observed and what was done about it.
  - Examine the biomass with a microscope to evaluate the state of the microorganisms,their diversity, motility, and numbers.

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Gathering Information

- Determine whether the operation of the plant contributes to the problem. Check the upstream unit for contributory problems, including the sewer system and recycle streams.
- Complete flow and mass-balance analysis. Check each unit process separately because one weak process can overload the whole plant.

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Gathering Information

– Use a quality assurance program to improve the accuracy of test results.
– Check for pipeline leaks that can divert flows, including chemicals.
– Check for changes in treatment chemicals.
– Ensure that air-delivery systems work.
– Determine whether mechanical or electrical failures are causing problems

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Gathering Information

– Check for such failures when problems occur.
  - A brief power outage can stop equipment, requiring manual restart.
– Separate the symptoms from the problem.
  - Listen to everyone's observations but mistrust everyone's interpretation.
  - Identify the root cause, not the symptom.
  - Things are not always as they first appear; do not be too quick to jump to conclusions.

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Effective Troubleshooting

- To troubleshoot effectively,
  - operators must determine the probable cause of a problem and
  - select one or more corrective measures to restore the process to full efficiency with the least adverse effect on the final effluent quality and at the lowest cost.

Effective Troubleshooting

- An operator needs
  - thorough knowledge of the plant's activated-sludge process
  - familiarity with influent wastewater characteristics, plant flow rates and patterns,
  - design and actual loading parameters,
  - performance of the overall plant and individual processes, and
  - current maintenance procedures

Effective Troubleshooting

- When a problem or situation arises, first evaluate the problem and determine if it fits into one or a combination of the following areas:
  - Hydraulic,
  - Mechanical, and/or
  - Process.

Hydraulic

- Hydraulic problems are easy to detect because of solids washout at the secondary clarifiers. These problems can be the result of several conditions.
  - rainstorms. This is especially true if the treatment facility is served from combined sewers.
  - not enough tanks in service because of maintenance or repairs.

Mechanical

- Mechanical problems can result in an effluent violation if it is not corrected or noticed immediately.
- Problems may include failure of:
  - clarifier collector mechanism,
  - return activated-sludge (RAS) pump,
  - blower, or mechanical aerator

Process

- Process problems are typically the most difficult to identify and correct.
- It is important to maintain good records.
  - can see warning signs of an impending problem
  - change in influent characteristics could result in a change in settling characteristics.

Process

- In-plant sidestream changes,
- differences in dissolved oxygen concentrations, and other parameters and
- plant conditions are important aspects that an operator must know to effectively troubleshoot a treatment facility.

- Good plant records will help to determine and correct the problem.

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Microscopy

- Another excellent process troubleshooting mechanism is microscopic examination
  - can determine the condition of the activated-sludge process by knowing and determining the predominance of various microorganisms.
  - microscopic examination of the mixed liquor will help identify the presence and type of filamentous organisms present in the facility, which in turn will help determine the best course of action to correct a process problem

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Troubleshooting Skills

- Troubleshooting requires several skills, including
  - investigative thinking and
  - logical use of all tools available to help solve a problem.
- It is important when troubleshooting not to make more than one change at a time.

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Troubleshooting Skills

- If multiple changes are made at once, it is difficult, if not impossible, to identify which process change was the most effective.
- Always remember that the activated-sludge system is a biological process so most responses will not be noticed immediately. <u>It may take days or weeks before a process improvement can be seen.</u>

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Keys to Successful Troubleshooting

- The following seven areas are critical for narrowing the search for solutions to most problems:
  - Thorough knowledge of the process being evaluated.
  - Thorough knowledge of all plant flow patterns, including sidestreams.
  - Thorough knowledge of the plant's design parameters and how actual loadings compare to design values.

Keys to Successful Troubleshooting

- Thorough knowledge of all maintenance procedures, including equipment maintenance considerations and staff responsibilities.
- Thorough knowledge of how to recognize an abnormal condition.
- Thorough knowledge of what alternatives are available when trouble develops.
- Thorough knowledge of the amounts and characteristics of any industrial waste that may be discharged to the plant.

Laboratory Testing

- Several simple laboratory tests that can help solve or troubleshoot operational problems include
  - the mixed liquor settleability test,
  - sludge volume index (SVI),
  - mixed liquor respiration rate,
  - dissolved oxygen (DO) measurement, and
  - sludge blanket level

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Settleability Test

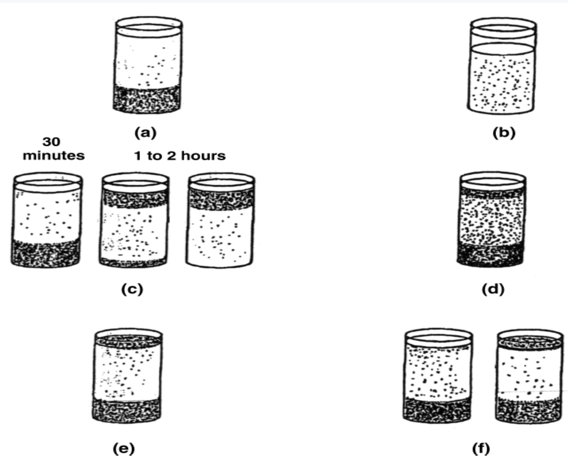

FIGURE 20.36 Index to troubleshooting guides based on settleability test results: (a) good settling sludge (effluent quality problem because of settling), (b) bulking sludge, (c) clumping/rising sludge (denitrification), (d) cloudy effluent, (e) ash on surface, and (f) pinpoint floc and stragglers.

Operational Problems

- The following are some common operational problems:
  - Foaming in bioreactors
  - Solids Washout
    - Hydraulics
    - Solids loading
  - Bulking

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Foaming

- Stiff white billowing foam, indicating a young sludge (low SRT) is found in either new or underloaded plants.
  - MLSS concentration is too low and the F:M is too high.
- The foam may consist of detergents or proteins that cannot be converted to food by bacteria that grow in the mixed liquor at a high F:M.

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Causes-white foam

- Causes include:
  - Problem with RAS flow
  - Low MLSS resulting from process startup or excessive sludge wasting
  - presence of a toxic or inhibiting material,
  - abnormally low or high pHs or insufficient DO
  - nutrient deficiencies,
  - activated-sludge biomass in the secondary clarifier effluent

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Potential Corrective Measures

- The following measures can be tried when applicable to correct the foaming problem:
  - Verify that return sludge is flowing to the biological reactor. Maintain sufficient return rates to keep the sludge blanket in the lower quarter of the clarifier, preferably between 0.3 and 0.9 m (1 and 3 ft) from the bottom.
  - Stop the sludge wasting for a few days to increase the MLSS concentration and SRT to target values.

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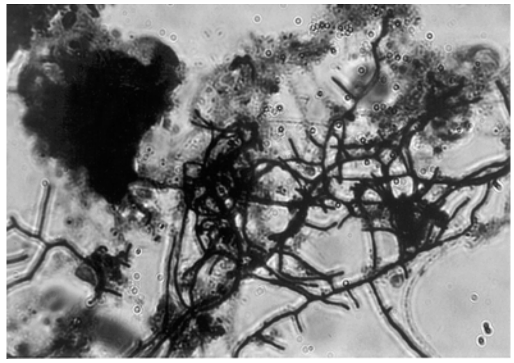
Brown Foam

- Greasy dark-tan foam typically caused by *Nocardia.*
- Can be caused by operating at a high SRT
- Trapped surfaces and recycle add to the problem



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Nocardia Foam

- Once established, *Nocardia* foaming can be extremely difficult to eliminate because
  - Foam is difficult to break with water sprays.
  - Foam typically does not respond to chemical antifoamants.

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Nocardia Foam

- Chlorinating RAS, although often helpful, does not eliminate *Nocardia* because most of it is in the floc and not exposed to chlorine.
- Increased wasting has its limitations because Foam is not wasted with the WAS.
- Even if foam and scum are removed from the process, they can cause problems in downstream units such as digesters and also can be recycled with decant or supernatant to the activated-sludge process.

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Potential Corrective Action

- The following measures can be tried when applicable to correct the foaming problems:
  - If possible, gradually increase the wasting rate to decrease the SRT.
  - If filaments appear, try to identify the cause
  - If the foam contains filaments, remove it from the surface of the water and send it to the solids-disposal facilities. Ensure that the foam is not recycled back to the treatment plant

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Clarifier Effluent Solids

- Washout due to
  - Hydraulic overload
    - Know design surface overflow rate (SOR)
    - Rainfall
    - Unequal flow distribution
    - Ensure weirs are level
  - Solids Overload
    - Know your design solids loading rate (SLR)
    - Problem with return rate
    - Increase in MLSS without consideration of SLR

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Filamentous Bulking

- Filamentous Bulking can be caused by:
  - Low-DO concentrations in biological reactors,
  - Insufficient nutrients,
  - Improper pH—either too low or widely varying,
  - Warm wastewater temperature,
  - Widely varying organic loading,
  - Industrial wastes with high BOD and low nutrients (N and P)

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Filamentous Bulking

- High influent sulfide concentrations that cause the filamentous microorganism *Thiothrix* to grow
- Very low F:M, allowing *Nocardia* predominance,
- Massive amounts of filaments present in influent wastewater or recycle streams

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Potential Corrective Action

- Chlorination
  - Location of the chlorine application point is critical.
  - The point should be located where there is excellent mixing, where the sludge is concentrated, and where the wastewater concentration is at a minimum

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Potential Corrective Action

- The three common application points are
  - in the RAS stream,
  - directly in the biological reactor at each aerator, and
  - in an installed side stream that recirculates mixed liquor within the biological reactor.
- Chlorine dose and the frequency at which organisms are exposed to chlorine are the two most important parameters.

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Potential Corrective Action

- The dose is adjusted so that concentrations are lethal at the floc surface but not within the floc.
- The chlorine dose should be based on the solids inventory in the process (biological reactors plus clarifiers)
- effective dosages are in the range of 1 to 10 g/kgd MLVSS (1 to 10 lb chlorine/d/1000 lb MLVSS).

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Non-filamentous Bulking

- Non-filamentous bulking may be caused by:
  - Improper organic loading—either too high or too low F:M,
  - Over aeration, and
  - Toxics.

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Potential Corrective Action

- If few or no filamentous microorganisms are present,
  - check the F:M to determine if in target range.
  - small, dispersed floc characteristic of an increased F:M.
  - If the F:M is higher than normal by 10% or more, the wasting rate should be decreased.
  - decrease in F:M should be reflected by the disappearance of the dispersed floc over a period of two to three SRTs

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Potential Corrective Action

- turbulence and DO in the biological reactor is also important.
- DO concentrations >4.0 mg/L indicate that excess air, reduce DO concentrations to 1.5- to 3-mg/L range
- Excessive turbulence (overaeration) may hinder MLSS floc formation and result in pinpoint floc
- Toxics such as industrial wastes may also cause dispersed-growth buildup.

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Summary

- Need to understand the activated sludge process and how it works at your plant
- Good process control requires good laboratory data and instrumentation
- Troubleshooting is a complex process especially with process problems
- More detailed information in MOP-11

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Questions?

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