Process and Performance Troubleshooting "Tabletop Evaluation"





Instructor:
Chuck Farley
MCET Instructor

PARTS 1, 2 and 3

Process Math, BNR Process, and Process Reviews

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1

Class Format and Participation

Course was designed to challenge operators of all levels of skill and years of experience. However the primary focus will be to provide helpful information for Intermediate to Advanced Level Operators.

Less experienced operators should gain valuable knowledge that will help them now and with their careers, but they may not be able to pass the Post Test especially if their math skills are weak. However taking the Post Test is a requirement to receive 7.0 TRE hours.

2

Class Format and Participation

Performing Process Evaluations and Troubleshooting requires advanced level skills that are developed through challenging operational experiences, moderate level math skills, basic understanding of water chemistry, developing and maintaining a reference library, and technical support from operators, engineers, and consultants.

No one will have the answer to all process and troubleshooting issues. Your class handouts should serve as a starting reference library.

3

Class Format and Participation

The class will cover some moderately difficult subjects. Don't feel like you must memorize a lot of facts and figures to pass the Post Test and receive full credit for the class.

Post Test is *(timed)* open book and notes. During class practice Math Problems will help prepare you for math problems on the Post Test.

Follow along in your Student Handout and take notes to help you with quizzes and the Post Test.

4

Class Format and Participation

We will take short approx. 5 min breaks normally around the top of each hour. Lunch will be an hour.

Attendance will be taken following breaks and throughout the class. As much as possible keep your video on. If you don't have video capabilities, you must keep your Chat Active or be counted absent.

You must take the Post Test and the Class Evaluation or be counted absent and will not receive credit for the course.

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Class Format and Participation

Post Test is 20 question with 70% (14) correct to pass and receive 1.5 x TRE credits. You will automatically receive your score by email.

There are 5 math problems in the Post Test.

The difficulty level of the Post Test is intended to be intermediate. Although key math formulas and concepts will be demonstrated in class, basic math skills will be necessary to pass the Post Test.

6

Class Format and Participation

Advance Topic

- Not likely to be on Post Test
- Intended to help the more advanced level operators

Important

- Important information, expect to see on quizzes or Post Test. Could be in the shape of an arrow.
- You may or may not be tested on slides without labels

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Required Class Handouts

- HO1 0322 PP and TS Parts 1 to 3
  - 42 pages
- HO2 2022 Process Performance Standards
  - 1 page
- HO3 BNR ENR Selector Setup
  - 2 pages
- HO4 Hadleyville WWTP Case Study
  - 2 pages
- HO5 Hadleyville WWTP Review
  - 3 pages

All files *.pdf

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Outline

Part 1- Process Math & Use of Standards

- Some High School Math Review
  - Circumference, Areas, Volumes
- Understanding Q+R Flows
- Performance Standards
  - Determining the Mode of Operation
- Detention Time (DT)
- Weir Overflow Rate (WOR)
- Surface Overflow Rate (SOR)
- % Efficiency Formula

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Outline

Part 1- Process Math & Use of Standards

(continued)

- Pounds Formula
- Organic Loading Rate (OLR)
- F/M Ratio
- Sludge Volume Index (SVI)
- Solids Loadings Rate (SLR) - Clarifiers
- Sludge Age (SA)
- SRT Vs. MCRT

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Outline

Part 2- Biological Nutrient Removal (BNR) Processes

- What is Considered BNR?
- BNR review
- Conventual Activated Sludge Process
- Nitrification and Extended Aeration Processes
- Contact Stabilization and Re-Aeration Processes

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Outline

Part 2- Biological Nutrient Removal (BNR) Processes *(continued)*

- De-Nitrification MLE Process
- Basic Bio-P & Denitrification Processes
- 4 and 5 Stage Bardenpho Processes

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Outline

Part 3 – Some Additional Tips for Process Reviews

- Limiting factors for MLSS Concentration
- BNR Operational Strategy and open discussions

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Outline

Part 4 – Group Discussions

- Hadleyville WWTP Case Study
  - Smaller Extended Aeration Plant having Effluent Violations

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Outline

Class Closeout

- Class Evaluations
- Post Test

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Part 1 Process Math and Use of Standards

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Some High School Math Review

- Circumference of a Circle
- Area and Volume

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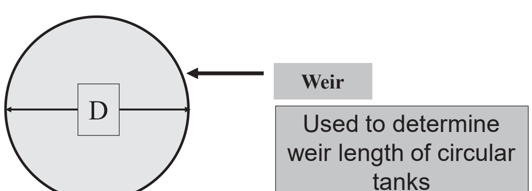
Circumference

- **Calculating Weir Length** – Circular clarifier or gravity thickener



Weir Circumference = **D** x 3.14

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Area and Volume

Square Feet, Cubic Feet and Gallons

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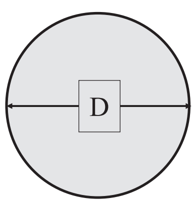
Area and Volume

- **Calculating Area of a Circular Tank** clarifier or gravity thickener



(Surface) Area = .785 $\mathbf{D^2}$

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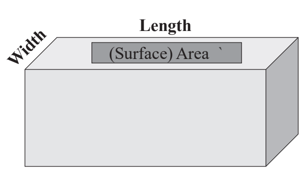
Area and Volume



- **AREA** of a **Square or Rectangular** tank
  - Length x Width = **Square Units (ft^2)**

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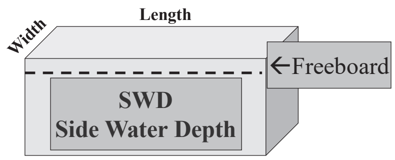
Area and Volume



- **VOLUME Square or Rectangular** tank
  - Length x Width x Water Depth = **Cubic feet**
    - Cubic feet x 7.48 = **Gallons**

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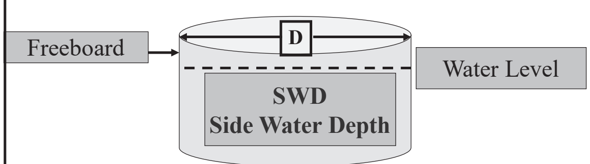
Area and Volume

- **VOLUME of a Circular tank**
  - **0.785 x D^2** x Water Level = **Cubic feet**
    - Cubic feet x 7.48 = **Gallons**



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Understanding Q+R Flows

Some formulas use forward flow

Some formulas use both forward and return/recycle flow

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Understanding Q+R Flows

Flows for Calculations

Q means forward flow

R means return/recycle flows

QR or Q + R means both `

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Performance Standards and Determining Mode of Operation

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Performance Standards

- **Standards and design criteria are always a good place to start when reviewing operations.**
  - **Have you ever had to troubleshoot or review a process or plant that you were not familiar with?**

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Standards for Activated Sludge Plants

–For aeration basins
- Detention Time (DT)
- MLSS Concentration
- Organic Loading Rate
- Food to Microorganism Ratio (F/M)

These Parameters determine the Mode of Operation

Standards for Activated Sludge Plants

–For Secondary Clarifiers
- Detention Time (DT)
- Weir Overflow Rate (WOR)
- **Surface Overflow Rate (SOR)**
- **Solids Loading Rate (SLR)**

Use "Peak Hourly Flow" for SOR and SLR when Evaluating Clarifier Performance

Standards for Activated Sludge Plants

–Used by Engineers and Sr. Operators for Design and Review of Activated Sludge Processes

–Defines the Mode of Operations for an Activated Sludge Process

–Provides Guidelines and Operational Targets for Process Control

Standards for the biological portions of BNR and ENR Processes

- Tend to vary more from process to process
  - However, in most cases the Total Detention Time of AN/AO/OX Selectors will be in the Nitrification or Extended Aeration range and those operating parameters will generally apply *(with some interpretation being required).*

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Detention Time (DT)

Can be in minutes or hours

Most of the time we'll use hours

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DT, hours =

$$\frac{\text{Capacity x 24 hrs}}{\text{Flow}}$$

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Detention Time (DT)

_Linked Files\ HO2 10 States 2014 Standards.pdf

0.75 MG Aeration Tank
Sized for nitrification

1 MGD flow

Lets do the math

0.75 MG x 24 hours
1.00 MGD

= hours DT

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Detention Time (DT)

_Linked Files\ BNR ENR Selector Setup.pdf

0.075 MG Anaerobic Selector

1 MGD flow

Let's do the math

0.075 MG x 24 hours
1.00 MGD

= **hours DT**

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Detention Time (DT)

_Linked Files\ HO2 2022 Process Performance Standards.pdf

0.25 MG Clarifier
Following ENR/BNR

1 MGD flow

Lets do the math

0.25 MG x 24 hours
1.00 MGD

= **hours DT (ENR/BNR)**

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Detention Time (DT)

- **<u>Clarifiers</u> (primary)**
  - Typically operated best at around
    - 2 hours or less Detention Time
- **<u>Clarifiers</u> (Secondary and Tertiary)**
  - In the past under Secondary Standards
    - 2 to 4 hours were common
  - Now 8 to 12 hours common
    - Due to greater SWD and square footage requirements

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Important

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Detention Time (DT)

- **<u>Aeration Basins</u>**
  - Conventional (6 to 8 hours) typical
  - Nitrification (12 hours minimum)
    - 12 to 18 hours (Mid-Atlantic States)
  - Extended Aeration (18 to 24+ hours)

See: 2022 Process Performance Standards

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Important

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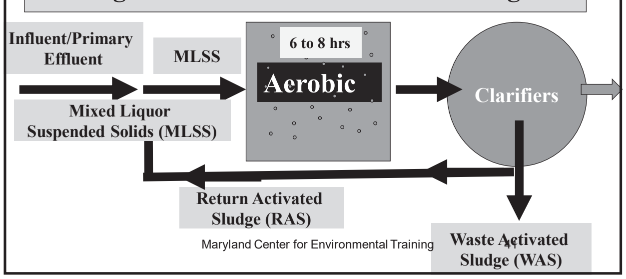
The Conventional Activated Sludge Process

Ammonia levels high in effluent

Designed for Effluent BOD 20 to 30 mg/L



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Contact Stabilization

1960's 1970's

Designed for Effluent BOD 20 to 30 mg/L

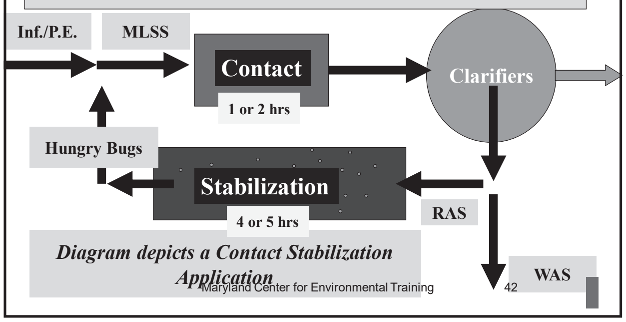

Diagram depicts a Contact Stabilization Application

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Contact Stabilization

Process Control Advantages

- Protection against solids wash out (clarifiers) as a result of high (peak) flows.
- Smaller Footprint
- Protection against toxic loads
  - Solids in the Stabilization basin are protected from short duration toxic loads
  - Faster recovery from a toxic hit
- BOD Uptake rate is high (bugs are hungry)
  - Can operate in a slightly higher F/M range

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Contact Stabilization

Applications

- Contact Stabilization processes did not nitrify very well.
- **However, the Sludge Re-aeration process has been** modified and used in BNR processes.

By increasing the size of the Contact basin and adding anoxic selectors

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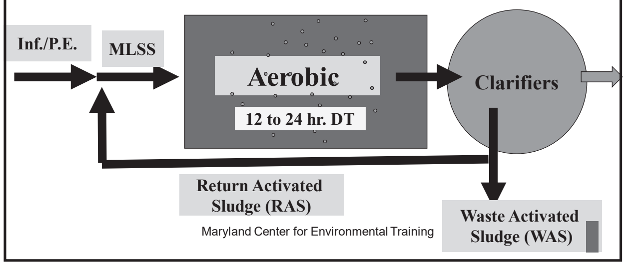
Extended Aeration and Nitrification Processes

Designed for Effluent BOD 10 to 30 mg/L And 1 to 3 mg/L Ammonia



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Extended Aeration and Nitrification Processes

Advantages and Applications

- Aeration tanks sized large enough for nitrification and additional BOD removal.
- Produces less sludge then conventional systems.
- Often utilized in BNR and ENR upgrades.
- A lot of operational material is available.

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Activated Sludge Parameters

For Nitrification Process

- Detention Time
  - 12 hours minimum (design)
- Organic Loading
  - F/M Ratio 0.08 to 0.16
  - 20 lbs BOD/1000 cu. ft.
- MLSS
  - 2,000 – 5,000 mg/L

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Activated Sludge Parameters

For Extended Aeration Process

- Detention Time
  - 18 to 24 hours + (design usually 24 hrs)
- Organic Loading
  - F/M Ratio 0.05 to 0.10
  - 15 lbs BOD/1000 cu. ft.
- MLSS
  - 3,000 – 5,000 mg/L

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Weir Overflow Rate (WOR)

Clarifier Design Standard

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Weir Overflow Rate (WOR)

Weir Overflow Rate (WOR), gpd/ft

- Primary and Secondary Clarifiers
- Typically, 10,000 to 30,000 **gpd/ft**
  - Use Hourly Peak for Secondary Clarifiers
  - Requires level weirs
  - Lower values for package plants
  - Too High - Solids will carry over Weir
  - Use forward (Q) flow only `

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Weir Overflow Rate (WOR)

Weir Overflow Rate (WOR), gpd/ft

$$\frac{\text{Gallons per Day (Q)}}{\text{Feet of Weir Length}}$$

Example:

$$\frac{450{,}000\ \text{gpd}}{210\ \text{ft of Weir}}$$

gpd/ft --- note how the units help to set up formula

Result: ______ gpd/ft

See: 2022 Process Performance Standards

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Surface Overflow Rate (SOR)

Surface Overflow Rate (SOR), gpd/ft²

Formula:

$$\frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$$

Used for Clarifiers `

Notes:

Surface Overflow Rate – (Q) flow only

Use Hourly Peak Flows to evaluate clarifiers

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Surface Overflow Rate (SOR)

Surface Overflow Rate (SOR), gpd/ft²

Example problem:

What is the Surface Overflow Rate (SOR) for a 50' Diameter final clarifier receiving a peak hourly flow of 2.5 MGD?

Step 1: Clarifier Ft² = 50' Dia x 50' Dia x 0.785

Clarifier Ft² = ______

Use clarifier inside tank diameter

Step 2: Convert MGD to gpd

2.5 MGD x 1,000,000 = ______ gpd

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Important

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Surface Loading Rates

Surface Overflow Rate (SOR), gpd/ft²

Example problem:

Step 3: gpd/ Ft² = $\frac{2{,}500{,}000 \text{ gpd}}{1{,}962.5 \text{ Ft}^2}$

Step 4: Calculate

SOR = ____ gpd/Ft²

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Important

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% Efficiency Formula

Sometimes a % efficiency is required on NPDES Permits

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% Efficiency Formula

Efficiency Formula

$$\frac{(\text{In} - \text{Out}) \times 100}{\text{In}}$$

Example:

Influent BOD 200; Effluent BOD 27

$$\frac{(200 - 27) \times 100}{200}$$

Answer: ____ %

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Pounds Formula

To calculated pounds per day, pounds under air, and for chemical feed applications

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Pounds Formula

Pounds/day (ppd)

- ppd = mg/L x 8.34 x MGD
- mg/L = ppd / (MGD x 8.34)
- MGD = ppd / (mg/L x 8.34) `

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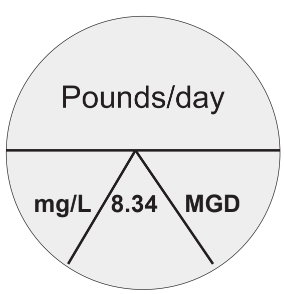
Pounds Formula



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Pounds Formula

ppd = mg/L x 8.34 x MGD

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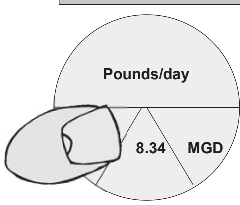
Pounds Formula

$$\text{mg/L} = \frac{\text{ppd}}{(8.34 \times \text{MGD})}$$



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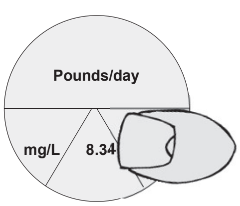
Pounds Formula

$$\text{MGD} = \frac{\text{ppd}}{(\text{mg/L} \times 8.34)}$$



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Pounds Formula

Pounds of MLSS in tank or selector

Example problem:

Calculate the pounds of MLSS in an Aeration tank or selector that is 100' long, 30' wide, and 14' deep with a MLSS Concentration of 3500 mg/L MLSS.

Step 1: Tank Capacity in Gallons

tank capacity gallons = 100' x 30' x 14' x 7.48

Capacity = ______ gallons

Capacity = ______ MG

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Important

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Pounds Formula

Pounds of MLSS in tank or selector

Example problem:

Step 2:

in tank = 0.314 MG x 3500 mg/L x 8.34

Calculate:

______ pounds of MLSS in tank

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Important

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Pounds Formula

Pounds of *MLVSS* in tank or selector

When calculating pounds of MLVSS you are either given the MLVSS in mg/L or the percent Volatile Solids (VS) such as 80% VSS.

Such as:

0.314 MG x **2800 mg/L (MLVSS)** x 8.34

= 7,333 pounds of MLVSS

Or:

9,166 pounds of MLSS x 80% VSS

= ______ pounds of MLVSS

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Important

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Organic Loading Rate (OLR)

Selectors (aeration basins)
Design Standard and
Troubleshooting Tool

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Organic Loading Rate (OLR)

Organic Loading Rate, ppd/1000 ft^3

BOD, pounds per day
Volume, 1000 ft^3

Note:
MDE Exams'
Formula Sheet
may use
ppd/ft3
instead of
ppd/1000 ft3

Example:

2,500 ppd
122.4 1000 ft^3

Result: ppd/1000 ft^3

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Organic Loading Rate (OLR)

Organic Loading Rate, ppd/1000 ft^3

Aeration Tanks

See: 2022 Process Performance Standards

- Conventional (activated sludge)
  - Less than 40 ppd/1000ft^3
- Nitrification less than 15 ppd/1000ft^3
  - Up to 20 ppd/1000ft3 OK for Nitrification
- Extended Aeration less than 15 ppd/1000ft^3
- Use Q flow only to calculate ppd `

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Food to Microorganism (F/M) Ratio

Activated Sludge
Design and Performance
Standard

Important

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Food to Microorganism (F/M) Ratio

Food is BOD entering the tank and Microorganisms are estimated using MLVSS #

- **FM Ratio** (based on MLVSS)

$$\frac{\text{ppd of BOD entering aeration}}{\text{pounds of MLVSS under aeration}}$$

Example:

$$\frac{16{,}680 \text{ \# BOD}}{312{,}750 \text{ \# under air}} = \underline{\qquad}$$

See: 2022 Process Performance Standards

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Let's do an F/M Ratio Problem together

- An Activated Sludge WWTP has a **Primary Effluent** flow of **2.0 MGD** with a **100 mg/L BOD** concentration.

2.0 MGD x 100 mg/L x 8.34 = ____ ppd BOD

- The aeration tank has a **1 MG capacity** with a **MLSS of 3000 mg/L** and your technician told you the **VSS at 78%.**

1.0 MG x 3000 mg/L x 0.78 x 8.34 ____ # MLVSS

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Let's do an F/M Ratio Problem together

- Now the next steps

Food (F) = 1,668 ppd of BOD
Microorganisms (M) = 19,510 pounds of MLVSS

F/M = $\frac{\textbf{1,668 ppd BOD}}{\textbf{19,516 Pounds}}$

F/M =

See: 2022 Process and Performance Standards

Important

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Sludge Volume Index (SVI)

Activated Sludge
Process Control
Performance Standard

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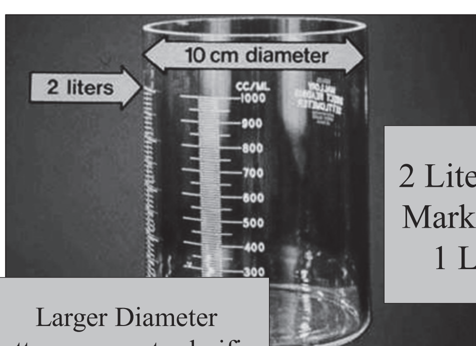
Settleometer



2 Liters but Marked as 1 Liter

Larger Diameter better represents clarifier

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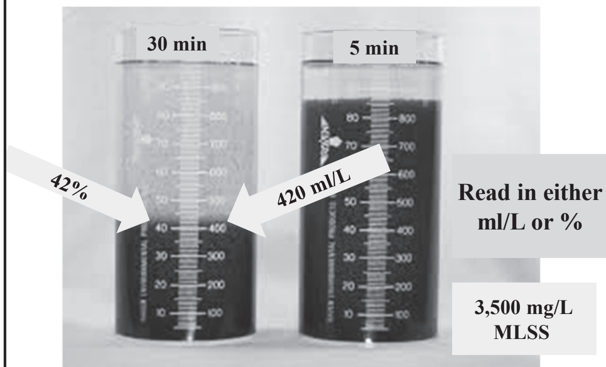
Settleometer



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Sludge Volume Index (SVI)
30 min. Settled Solids, ml/L

- **SVI, ml/gm** (milliliters/gram)
  - (SVI) Sludge Volume Index

$$\frac{\text{30 min. Settled Solids (SSV), ml/L} \times 1{,}000}{\text{MLSS, mg/L}}$$

Example:

$$\frac{420 \text{ ml/L} \times 1{,}000}{3500 \text{ mg/L MLSS}} = \square \text{ SVI}$$

1,000 ml x 1,000 = 1 Million

Important

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Sludge Volume Index (SVI)
30 min. Settled Solids, %

- **SVI, ml/gm** (milliliters/gram)
  - (SVI) Sludge Volume Index

$$\frac{\text{30 min. Settled Solids (SSV), \%} \times 10{,}000}{\text{MLSS, mg/L}}$$

Example:

$$\frac{42\% \times 10{,}000}{3500 \text{ mg/L MLSS}} = \square \text{ SVI}$$

100 % x 10,000 = 1 Million

Important

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Sludge Volume Index (SVI)

*True SBRs do not have flow entering tank when settling or decanting

SVI Volume Index

- 80 to 120 ml/g typical desired range
- Many activated sludge plants target 100
- Some *SBR plants may run SVIs 180 or higher
- Filamentous Bacteria
  - Bulky conditions and high SVI `

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Important

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Solids Loading Rate (SLR)

Design Standard and
Good Process Control and
Troubleshooting Tool for Clarifiers

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Solids Loading Rate (SLR)

Solids Loading Rate, ppd/ft²

$$\frac{\text{Solids, ppd to Secondary Clarifier}}{\text{Surface Area, ft}^2}$$ `

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Solids Loading Rate (SLR)

Solids Loading Rate, ppd/ft²

Example:

$$\frac{45{,}036 \text{ ppd}}{5{,}024 \text{ ft}^2} = 8.96 \text{ ppd/ft}^2$$

Nitrification and Extended Aeration
35 ppd/Sq. Ft. or less
at peak hourly flows

Note:

Use both Forward (Q) and Return (R) Flows

ppd = MLSS, mg/L x 8.34 x (Q + R), MGD

Use Peak (hourly) Flows

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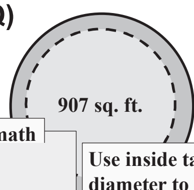
SLR, ppd/square foot

- **Typical Secondary Clarifier**
- **3500 mg/L MLSS**
- **1 MGD Forward Flow (Q)**
- **0.8 MGD RAS Flow (R)**

Use Peak Hour Flow



Lets do the math

Work Through this problem
Step and Step
Then determine if this is a good SLR.

Use inside tank diameter to calculate sq. ft.

ng 85

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Solids Loading Rate (SLR)

Clarifiers following Conventional Activated Sludge basins

40 ppd/ Sq. Ft. (Peak Hour Flow)

Clarifiers following Nitrification, Extended Aeration Basins, or (BNR/ENR)

35 ppd/ Sq. Ft. <u>(at Peak Flows)</u>

At Peak Hourly Flow

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Sludge Age (SA)

Performance Standard
Sometimes Used by Operators

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Sludge Age

- **Sludge Age** *In Days*

$$\frac{\text{MLSS, lbs}}{\text{*TSS to aeration, ppd}}$$

Example:

$$\frac{312{,}750\ \#\ \text{under air}}{18{,}348\ \text{ppd TSS}} = \textit{17.05 Days}$$

*ppd of TSS in P.E. or Raw (not MLSS not RAS)

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SRT vs. MCRT
Solids Retention Time
vs.
Mean Cell Retention Time

Note:
WEF and other Industry Standards are defining when to use SRT and MCRT formulas.

Advance Topic

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SRT vs. MCRT

Example WWTP

1 MGD Flow

Aeration Capacity 0.75 MG

Clarifier Capacity 0.25 MG

MLSS 3,000 Mg/L

WSSS 7,000 mg/L @ 0.04 MGD

5 mg/L Effluent TSS

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SRT vs. MCRT

- **SRT**
  - (SRT) Solids **Retention** Time

$$\frac{\text{MLSS, lbs under aeration}}{\text{lbs SS wasted + lbs SS lost in effluent}}$$

Industry Standards (WEF and others) are recommending the use of SRT to monitor and optimize the Nitrification Process (within BNR plants).
As example: Higher SRTs are required with colder water temperatures and pHs below 7.0 s.u.

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SRT vs. MCRT

- **SRT (example)**

3000 mg/L MLSS x 8.34 x 0.75 MG =

18,765 MLSS lbs under aeration

7000 mg/L WSSS x 8.34 x 0.04 MGD =

2,335 ppd wasted

1 MGD Effluent Flow x 8.34 x 5 mg/L TSS =

41.7 ppd over weir

99

SRT vs. MCRT

- **SRT**
  – (SRT) Solids Retention Time

18,765 MLSS lbs under aeration

2,335 ppd Wasted + **41.7 ppd over weir**

2,377 ppd total waste

=

100

SRT vs. MCRT

- **MCRT**
  – (MCRT) Mean Cell Resident Time

MLSS, lbs under aeration **+ solids in Clarifier**

lbs SS wasted + lbs SS lost in effluent

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SRT vs. MCRT

- **MCRT (example)**

3000 mg/L MLSS x 8.34 x (0.75 MG + 0.25 MG) =

25,020 pound of solids in Aeration and Clarifier(s)

7000 mg/L WSSS x 8.34 x 0.04 MGD =

2,335 ppd wasted

1 MGD Effluent Flow x 8.34 x 5 mg/L TSS =

41.7 ppd over weir

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SRT vs. MCRT

- **MCRT**
  - (MCRT) Mean Cell Resident Time

25,020 pound of solids in Aeration and Clarifier(s)

2,335 ppd Wasted + **41.7 ppd over weir**

2,377 ppd total waste

=

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SRT Vs. MCRT

- For years now the SRT and MCRT formulas have been confused and/or considered the same.
- In Maryland, MDE now uses the ABC Formula Sheet which defines SRT and MCRT as both using aeration and clarifier capacity. So, expect to still find some confusion.
- WEF manuals are defining SRT and MCRT as shown here.

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Aerobic SRT

- For the most part the use SRT and MCRT should be left up the Operator unless specified by the Process Engineer or Supervisor.
- Many Process Engineers are now specifying the use of an Operating Aerobic SRT.

Use only the MLSS in The Aerobic Selector, Zone, or Basin.

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Aerobic SRT

- For BNR Processes an Aerobic SRT allows for tighter control and the ability to determine an Operating SRT for nitrification.
- An Operating SRT in a BNR plant will vary with pH, Temperature, and D.O. and will also allow the comparison of Operating SRT to BOD:N ratio and other plant specific parameters.
-

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Aerobic SRT

- pH lower than 7.0 may require a longer Operating Aerobic SRT
- Nitrification may require a longer Operating Aerobic SRT when D. O. is less then 2.0 mg/L
- A longer Operating Aerobic SRT will typically be necessary during winter months.

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Part 2 Biological Nutrient Removal (BNR) Processes

Knowing the Basics of BNR Helps with Troubleshooting all Activates Sludge Processes.

But remember it all started with Conventional Activated Sludge.

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What is considered Biological Nutrient Removal (BNR)

- Conventional Nutrient Uptake Rate is considered:
  - 5 parts Total Nitrogen
  - 1 part Total Phosphorus

  For every 100 Parts of BOD removed
- Any Biological Nutrient Uptake Rate greater than this would be considered BNR

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Important

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BNR In Review

De-Nitrification?

- Anoxic Conditions (typically 2 to 4 hours)
  - De-nitrification bacteria
  - Will consume the **Oxygen** in
    - N**O**$_3$-N and N**O**$_2$-N
    - Nitrogen escapes as N_2 gas `

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BNR In Review

Nitrification / De-Nitrification facts:

- Nitrification
  - 4.6 mg oxygen **required** per mg of nitrogen **oxidized**
  - 7.14 mg alkalinity **depleted (or consumed)** per mg of nitrogen **oxidized**

Don't be confused by units: mg to mg and pound to pound would be the some comparison.

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Important

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BNR In Review

Nitrification / De-Nitrification facts:

- De-Nitrification **Therefore Anoxic Selector is normally located ahead of the Aerobic selector.**
  - 2.9 mg oxygen **released** per mg of oxidized nitrogen **removed**
  - 3.6 mg alkalinity **recovered** per mg of oxidized nitrogen **removed** `

Remember Oxygen and Alkalinity are recovered in the De-Nitrification Process

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BNR In Review

Forms of Nitrogen

- Total Nitrogen (TN)
  - Total Kjeldahl Nitrogen (**TKN**)
  - Nitrites (NO_2-N)
  - Nitrates (NO_3-N)
- **TKN** = Ammonia (60%) + *Organic N (40%)

*** Guideline only, ratio may or may not be constant**

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BNR In Review

The Nitrification Process consumes?

Some Oxygen and Alkalinity are recovered in the process.

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BNR In Review

What is the dominate form of nitrogen in the Final Effluent and Return Sludge from?

- A Conventional Activated Sludge plant
- An Extended Aeration or Nitrification Plant

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BNR In Review

Why is knowing this important to an operator of a BNR Plant?

1)

2)

3)

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BNR In Review

Forms of Phosphorus

- Total Phosphorus (difficult/expensive test)
  - Soluble/Insoluble
- Orthophosphate (PO_4^{3-}) **Soluble**
  - (Soluble) Reactive Phosphorus
  - Test kits (may not be EPA approved)
  - (PO_4^{3-}) / 3.07 = P (soluble)

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BNR In Review

- Selectors (or zones)
  - Aerobic or Oxic
    - > 1.5 (2.0) mg/L D.O. or higher
  - Anoxic **True**
    - *Defined as 0 D.O. but with Nitrates
  - Anaerobic **True**
    - *Defined as 0 D.O. and 0 Nitrates

*0 D.O. and 0 Nitrates are difficult to achieve

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BNR In Review

- **Aerobic (Oxic) Zone**
  - Typical aeration basins
  - 1.5 to 3.0 mg/L D.O.
  - ORP (+100 to +300 mV)
  - 12 to 24 hours *HRT – Nitrification
    - First 6 to 8 hours *HRT – CBOD removal
    - Then Nitrification starts

***HRT = Hydraulic Retention Time**
Same as DT = Detention Time

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BNR In Review

- **Anoxic Zone (2 to 4 hours HRT)**
  - Mixing (no air)
  - Target 0.2 mg/L to 0.3 mg/L D.O.
  - ORP (-50 to +50 mV)
  - Bacteria consumes the Oxygen in NO_3 and De-nitrification (release of N as gas) `

Multiple Compartments tend to work better than single tank

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Simultaneous Nitrification and Denitrification

- Some Operators and Engineers have learned to combine Nitrification and Denitrification into one basin or selector
- Maintain D.O. around 0.7 mg/L
- ORP +50 to -100mV
- Longer Operating SRT

Advance Topic

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BNR In Review

- **Anaerobic Zone (Bio-P Removal)**
  - Uptake of BOD and release of P
  - Mixing only (1 to 4 hours HRT)
  - Target < 0.2 mg/L D.O. (entering)
    - or < 5 mg/L Nitrates
    - or ORP (-200 to -300 mV) `

Multiple Compartments tend to work better than single tank

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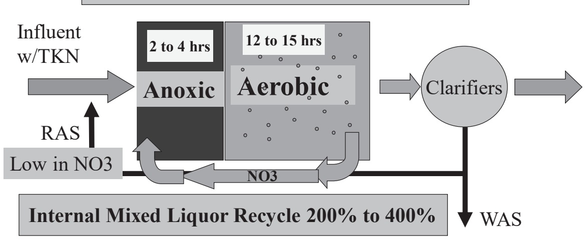
De-Nitrification
Modified Ludzak Ettinger (MLE) Process

TN removal down to 5 to 8 mg/L



Internal Mixed Liquor Recycle 200% to 400%

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Internal Mixed Liquor Recycle?

- Recycles Nitrates back to Anoxic Zone
- Bacteria and Microorganisms are also recycled back
- D.O. in recycle should be kept low (<1.0 mg/L) `

Important

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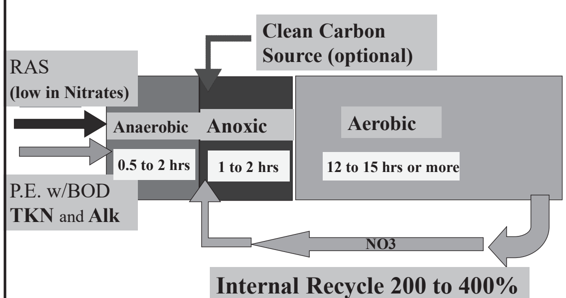
Basic Bio-P and Denitrification



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Why add a Carbon Source?

Addition Carbon Source

- Is necessary when upstream processes depletes most of the available carbon ***BOD in sewage***
- Aerobic, Anaerobic, and Anoxic zones all require a source of carbon

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Why add a Carbon Source?

Addition Carbon Source

- When enhanced nutrient removal is required, most likely an additional carbon source will be necessary
- Most used <u>clean</u> carbon sources are:
  - –M**ethanol and Micro-C**

Clean means low amounts Nutrients and contaminates

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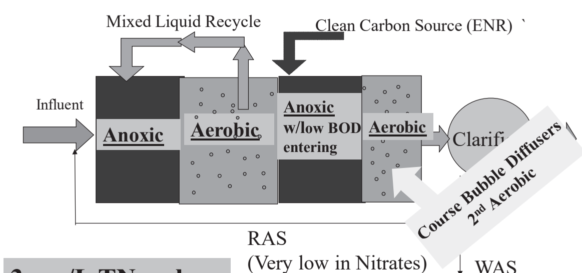
Nitrification, and Denitrification
Four Stage Bardenpho Process



3 mg/L TN or less

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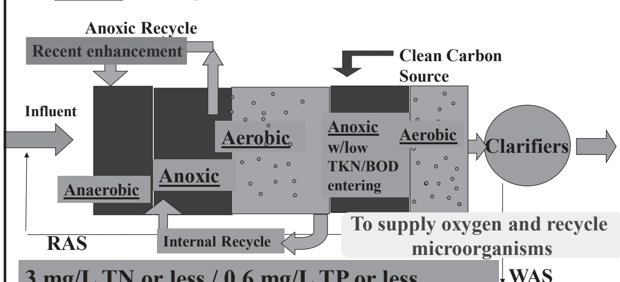
Enhanced Nitrification, and De-nitrification
<u>Five</u> Stage Bardenpho Process



3 mg/L TN or less / 0.6 mg/L TP or less

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Typical ***Setup*** for < 3 mg/L TN

- Anaerobic Selector (1.5 hours)
  - For Bio-P
- Anoxic Selector (3.0 hours)
  - Internal Recycle (200 to 400%)
- Aerobic Selector (15 hours)
- 2^{nd} Anoxic Selector (1.5 hour)
  - Clean carbon source
- 2^{nd} Aerobic Selector (30 minutes) `

Five Stage Bardenpho Process

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Part 3 Some Addition Tips for Process Reviews

- Limiting factors for MLSS Concentration
- BNR Operational Strategy and open discussions

Advance Topic

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Limiting Factors for MLSS Concentrations

- Nitrification and Denitrification process favors higher MLSS concentrations and longer SRTs
- Biological P removal favors lower MLSS concentrations and shorter sludge ages
- Since chemical feed applications are available for Phosphorus Removal, BNR operations will favor higher sludge ages and MLSS concentrations

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Limiting Factors for MLSS Concentrations

- Often the MLSS concentrations are limited by the plant's final clarifier's Solids Loading Rate (SLR)
- Mixing specifications can also limit the MLSS concentrations
  - Review design criteria and mixing unit specifications
  - Often mixing units will have a limitation such as 4,000 mg/L

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Limiting Factors for MLSS Concentrations

- If concerned about mixing capacity
  - Perform a MLSS Sampling Profile of the tanks
  - Samples should be within 10 to 15% spread or less
  - As an example a MLSS profile of samples ranged from 3800 to 4200 mg/L (400 mg/L spread) or within 10%
  - If the spread is much greater reduce your MLSS concentrations

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BNR Operational Strategy

BNR Rules of Thumb **50 degrees F**

- De-nit. falls off < 10 degrees C (higher SRT required)
- SBOD:SP at least 10 **or** 15**: 1**
  - for Bio-P **Add carbon if low**
- TBOD:TKN 5 **or** 10**: 1** **Add carbon if low**
  - lower ---Nitrification could suffer
- < 1 mg/L Nitrates leaving Anoxic (final) Zone
  - Adjust recycle rate, carbon source, and zone size to achieve `

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BNR Operational Strategy

- Bio-N removal vs. Bio-P removal
- Was plant really designed for both?
- What are your TN and TP Permit Limits?
- Are the (carbon) ratios good for both
- Should you favor Bio-N removal over Bio-P removal?
- Coarse Bubble Diffusers in 2nd aerobic selector helps with releasing N_2

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BNR Operational Strategy

- Frequently BNR (especially enhanced BNR) plants will set up to maximize Bio-N removal
  - Review your chemical feed application
    - Location of where you feed metal salts can make a difference
    - Ferrous Compounds are best fed in the aeration process to become oxidize
    - Ferric Compounds are best fed ahead of the final clarifiers

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BNR Operational Strategy

Bio-P Removal

- Bio-P removal is depended on solids removal
- Secret to Bio-P removal is to remove the bugs (in the sludge) at the point where they have stored P after aerobic treatment
  - Remember the concept of Luxury Uptake
- Be mindful of P-rich side streams such Anaerobic Supernatant and recycled sludge
- Tertiary sand or media filters will remove additional P

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