Operation of Biological and Chemical Phosphorus Removal Systems

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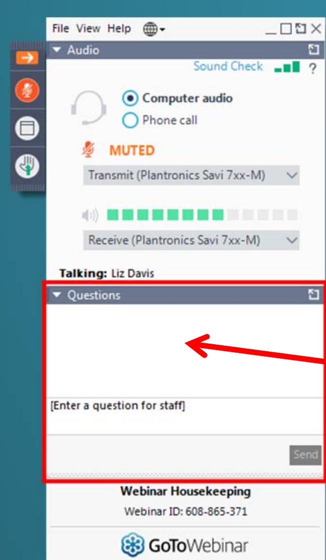
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Webinar Agenda

- Introductions
- Fundamental Mechanisms of Phosphorus Removal
- Simulator Description and Overview
- Biological Phosphorus Removal
- EBPR Simulator Examples
- Chemical Phosphorus Removal
- Chemical-P Simulator Examples
- Hydromantis Case Studies
- Questions

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Biological Phosphorus Removal

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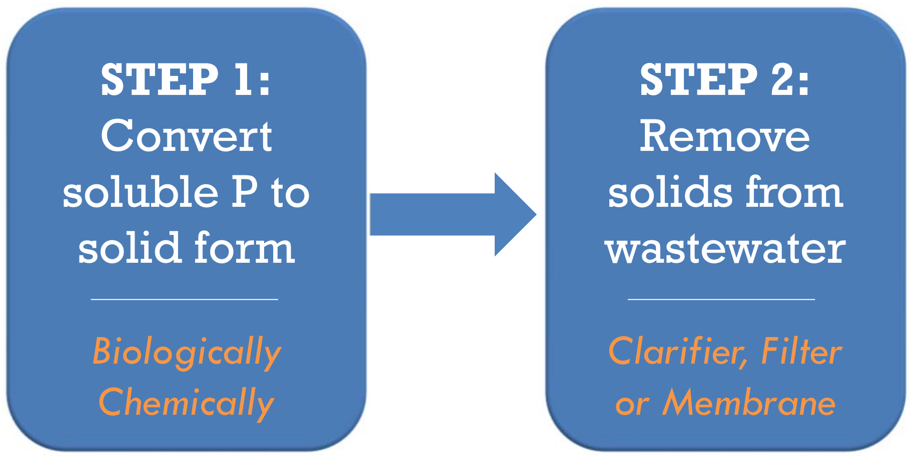
Phosphorus Removal



AND DON'T LET THE PHOSPHORUS RE-SOLUBILIZE!

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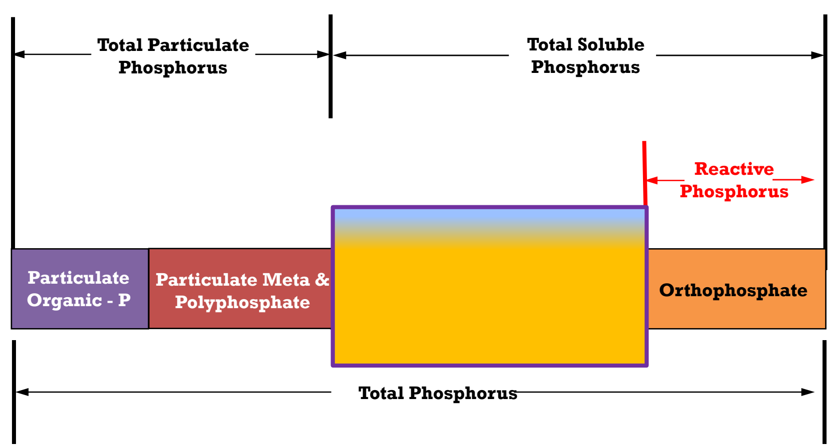
Forms of Phosphorus



Always consider potential for non-reactive, soluble-P, especially when stringent effluent limits are required

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Solids Removal Impacts

- Effluent TSS contains:
  - Secondary Effluent – **2%** as P
  - Chemical P Effluent – **4%** as P
  - Enhanced Bio-P Effluent – **6%+** as P

The treatment technology and effluent TP limits will dictate if Advanced TSS Removal will be required to meet permit.

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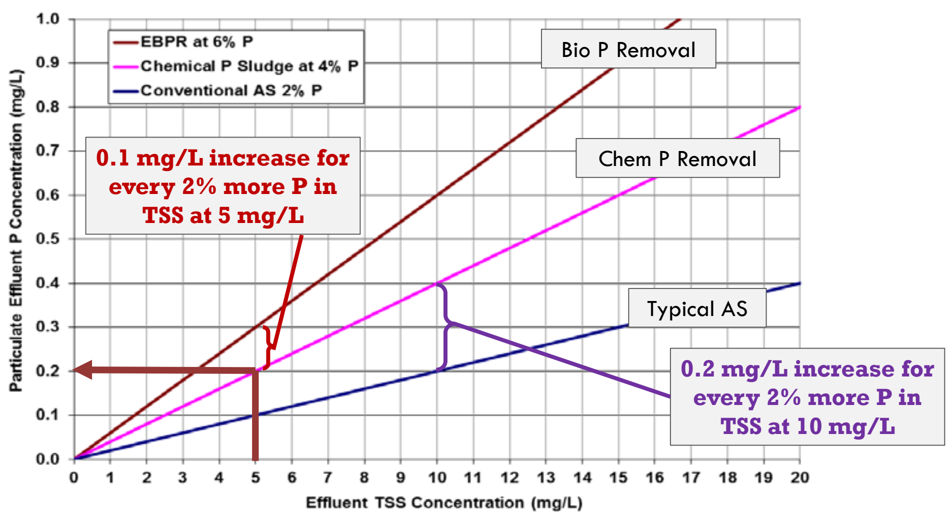
Stringent P Limits require low TSS



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Process Simulators

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Simulator Overview

- Model = Series of equations that defines a process or plant
  - Model based on mass balances and biological conversions of organics (COD), nitrogen, phosphorus and solids
- Simulator = Program that uses a process model to experiment with a plant configuration
- OpTool SimuWorks Overlay = Plant-specific layout that provides graphical interface for plant operational testing and training

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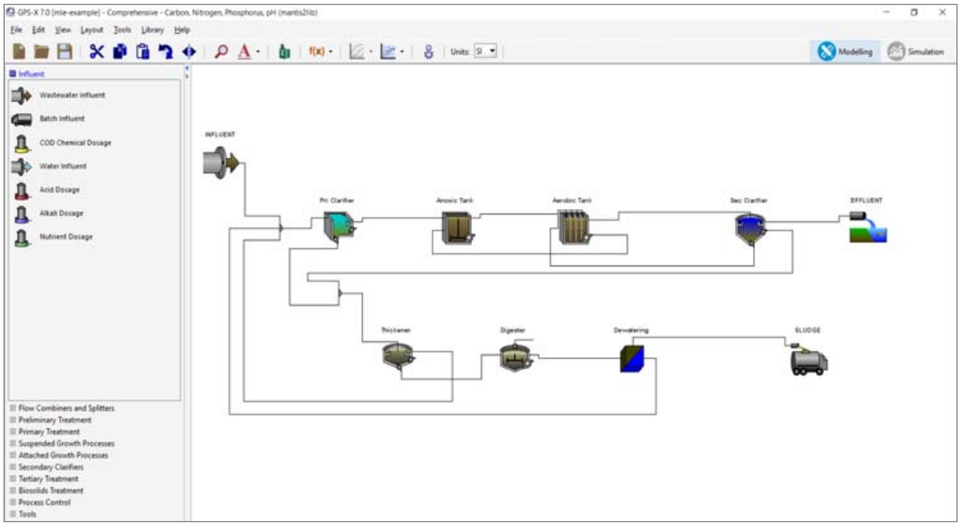
GPS-X Process Simulator



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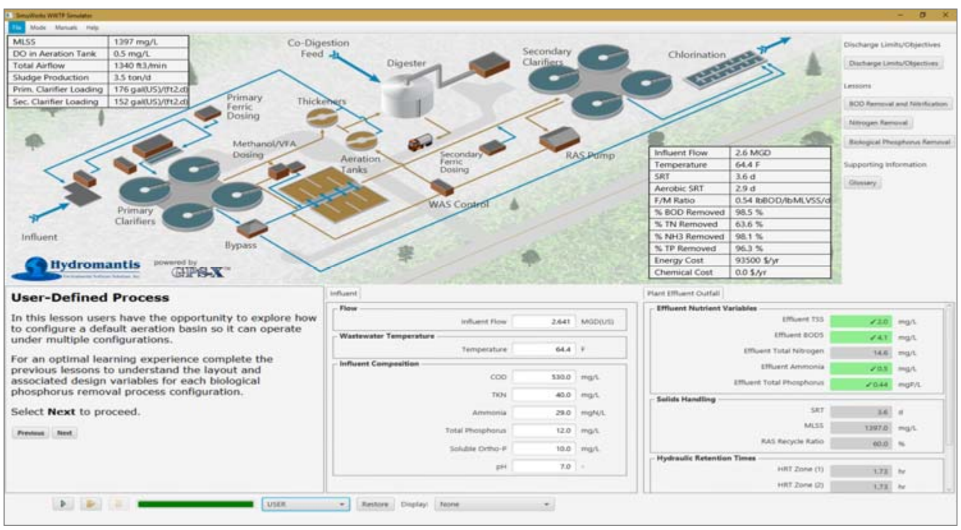
Process Simulator Layout



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Biological Phosphorus Removal

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Conventional Biological P Removal

- Happens with any biological treatment process:
  - As new bacterial cells are formed,
    P is removed as a requirement for cell growth
  - Roughly 1% of the BOD_5 removed
  - 1% - 3% P in sludge

Concord, MA
WWTF CoMag Process

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PAO's vs. GAO's

- Phosphorus Accumulating Organisms (PAO)
  - Can store soluble substrate under anaerobic conditions to accumulate excess phosphorus
- Glycogen Accumulating Organisms (GAO)
  - Can store soluble substrate under anaerobic conditions BUT DO NOT accumulate phosphorus
- Conditions that favor GAO's
  - Low pH
  - Excessive carbon
  - High temperature
  - Longer SRT (5+ days)

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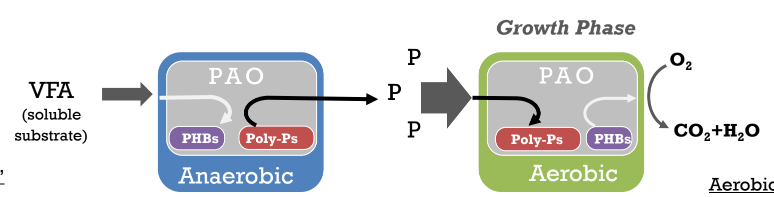
Enhanced Biological Phosphorus Removal (EBPR)

- Requires absence of Oxygen
- Requires absence of Nitrate
- Requires readily degradable carbon in form of short chain volatile fatty acids (VFA)
- Prefers a distinct O_2 gradient for P-uptake
- Removal occurs through waste sludge



Anaerobic Phase "Batteries"
Carbon (PHB) – Charging
Phosphorus- Discharging

Aerobic Phase "Batteries"
Carbon (PHB) – Discharging
Phosphorus- Charging

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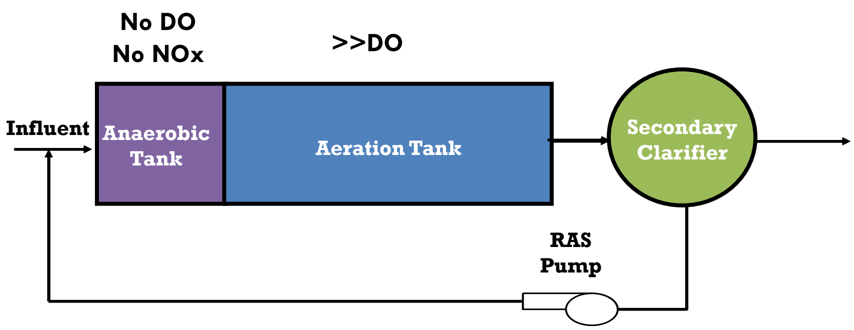
Enhanced Biological P Removal (AO)



BOD Removal & EBPR

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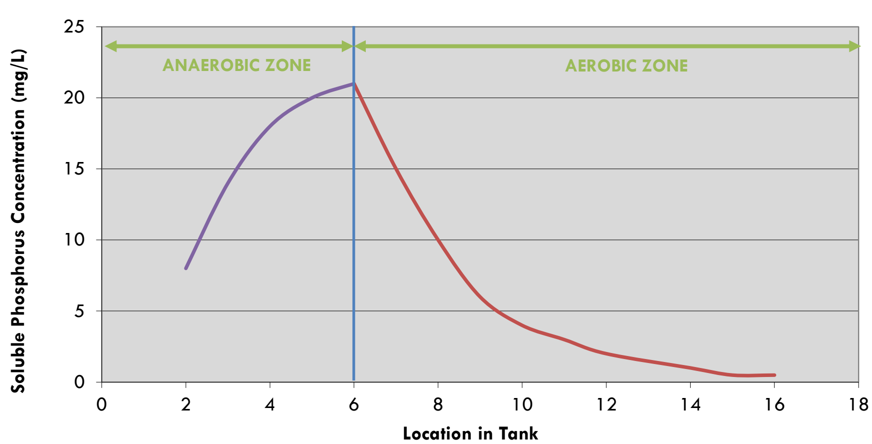
Enhanced Biological P Removal



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Keys to EBPR

- Ratio of Carbon: P (BOD/TP or COD/TP Ratio)
  - COD/TP of >40:1 preferred, rbCOD/TP of >15:1
- Initial Anaerobic Zone
  - BOD available
  - Exclude oxygen, nitrate
- Nature of Carbon Source (soluble, readily biodegradable)
  - Make it yourself – VFA formation in PC, sludge holding
  - Buy it – Chemical addition of VFA's
- Downstream Aerobic & Anoxic Zones
  - Not allowed to go anaerobic again until WAS removed – "secondary release"
- Sludge Handling System

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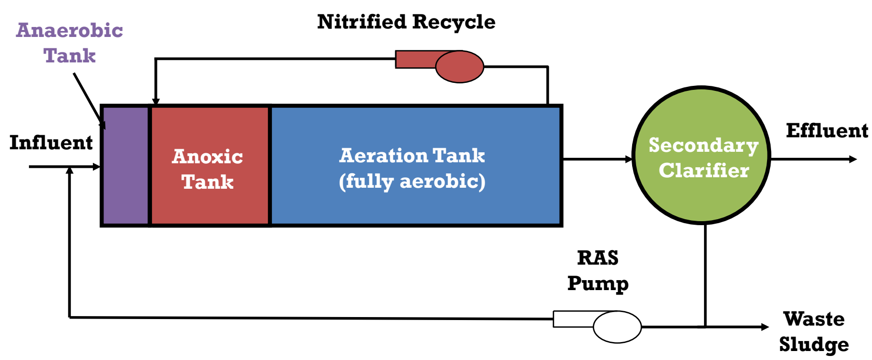
A2O Process



BOD Removal, Nitrification, Denitrification & Phosphorus

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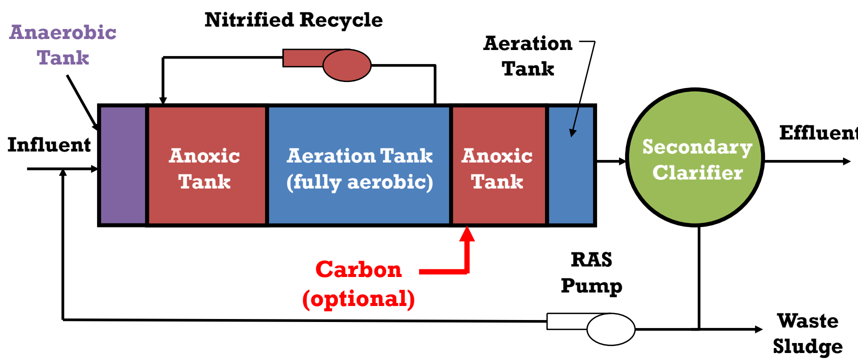
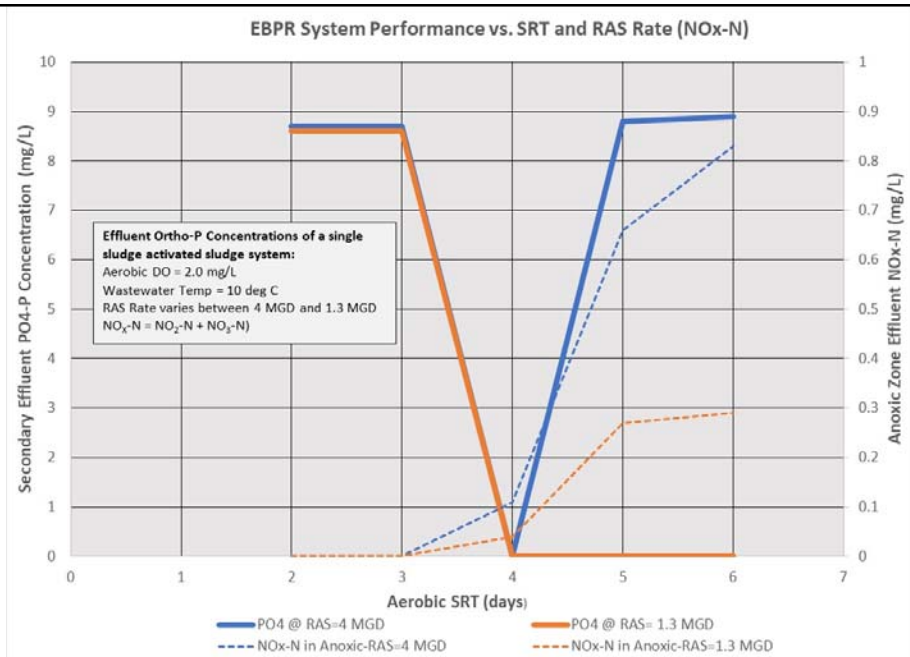
5-Stage Bardenpho Process



BOD Removal, Nitrification, Denitrification & Phosphorus

Process Simulator – EBPR Examples



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Limitations of Conventional EBPR

- Reliant on influent conditions
- Changes in influent conditions or operation can result in inconsistent performance
- Minimal process control options
- Potential competition of GAOs with PAOs

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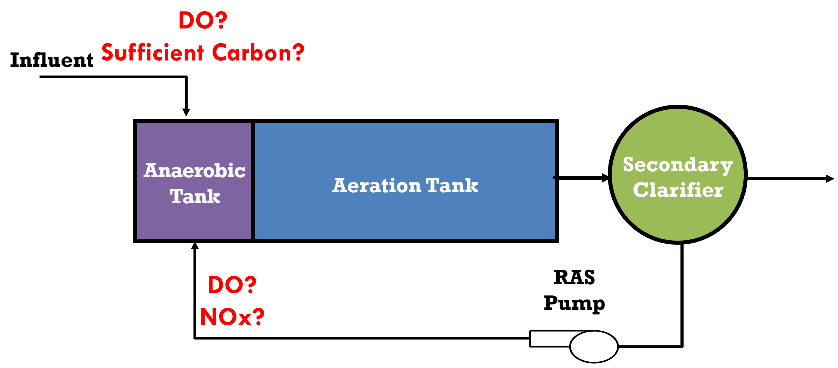
Conventional EBPR



BOD Removal & EBPR

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Sidestream EBPR is the next wave…

- S2EBPR is a fairly recent development in nutrient removal
  - Europe: in use for more than 10 years
  - USA: in use at a few facilities in recent years
- S2EBPR conditions a portion of the RAS or MLSS to grow PAOs
- S2EBPR requires:

  Holding the solids under "deep" anaerobic conditions
  to ferment the activated sludge solids to make VFA's,
  allowing release and then P uptake in downstream anoxic and aerobic zones.

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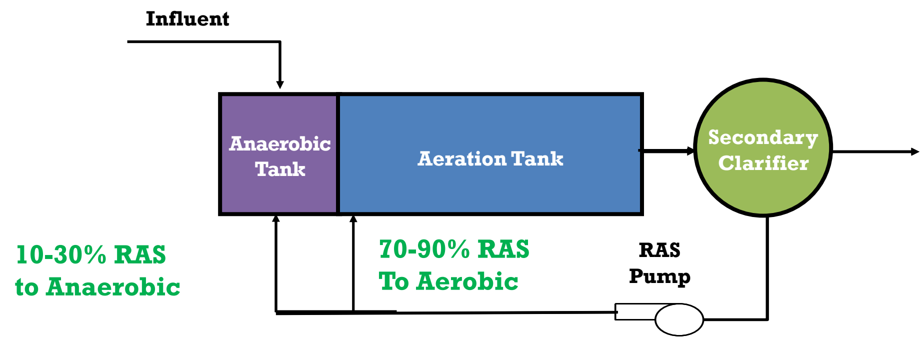
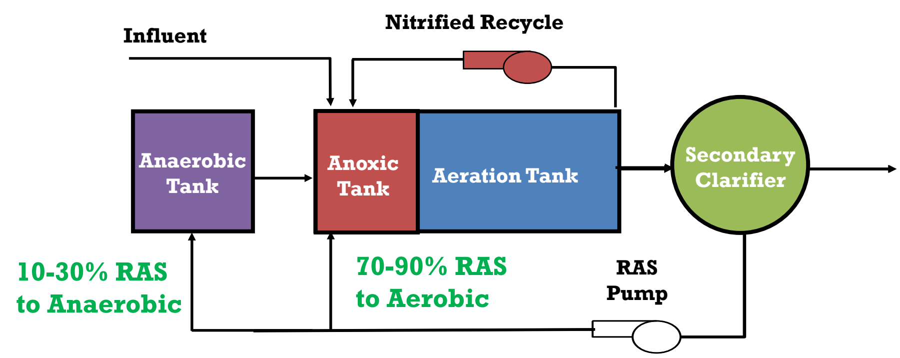
Conventional EBPR



BOD Removal & EBPR

Sidestream EBPR (S2EBPR) with Anoxic Zone



BOD Removal, TN Removal & EBPR

Why Use S2EBPR?

- More reliable than conventional EBPR
- Less sensitive to influent carbon quantity and quality
- Less impacted by DO and NO_3-N recycles
- Selects against GAO's
- Uses similar or less tank volume as standard EBPR
- Can be readily incorporated into existing tanks
- Allows more influent C for denitrification

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Biological Phosphorus Removal Case Study

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Biological Phosphorus Removal Case Study

- **South Mesquite Regional WWTP,** Mesquite, TX
- 33 MGD Capacity
  - BOD, Nitrogen and Phosphorus Removal
- Biological Nutrient Removal
  - A2O System
  - anaer/anox/aer zones

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Biological Phosphorus Removal Case Study

- **South Mesquite Regional WWTP,** Mesquite, TX

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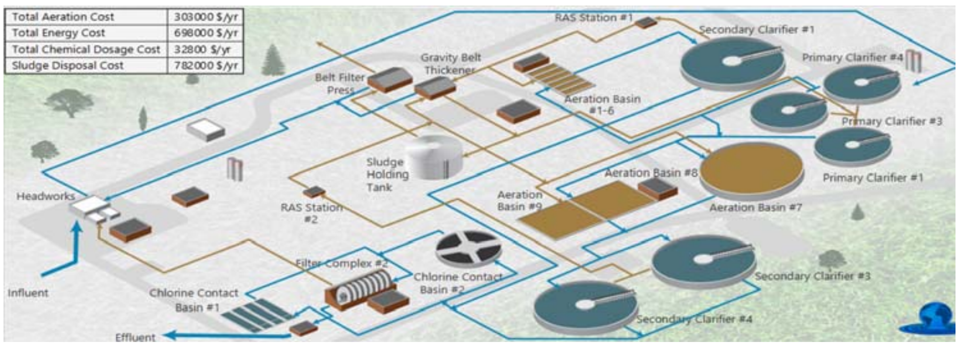
Biological Phosphorus Removal Case Study

- **South Mesquite Regional WWTP,** Mesquite, TX



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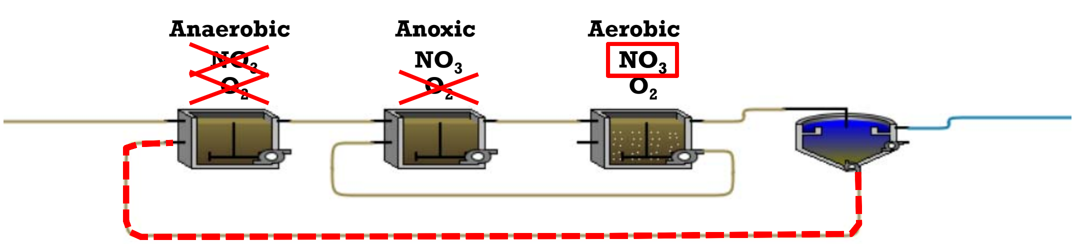
Biological Phosphorus Removal Case Study

- **A2O Biological Phosphorus Removal**



Recycle (RAS) flow rate impacts BioP performance

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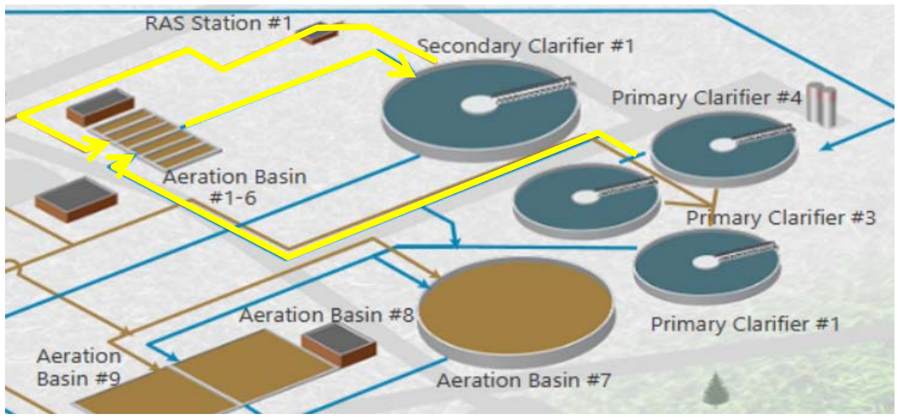
Biological Phosphorus Removal Case Study

- **Aeration Basin 1-6 BNR:**



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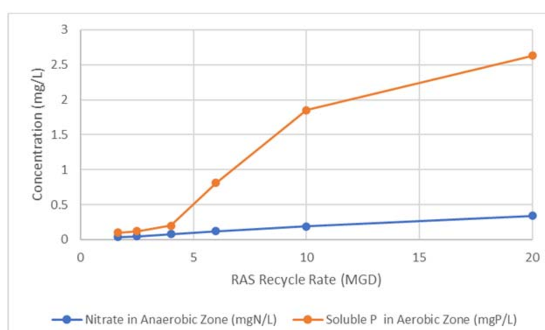
Biological Phosphorus Removal Case Study

- **Aeration Basin 1-6 BNR:**

Recycle Rate (MGD)	Nitrate in Anaerobic Zone (mgN/L)	Soluble P in Aerobic Zone (mgP/L)
1.66	0.04	0.10
2.5	0.05	0.12
4	0.08	0.20
6	0.12	0.81
10	0.19	1.85
20	0.34	2.63



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Case Study Summary

- Bio-P systems (like A2O) are sensitive to the loss of anaerobic zone volume
- Makeup of biomass population can shift (decrease in PAO population)
- Recycle (RAS) rates can bring NO_3 back to the anaerobic zone and reduce Bio-P removal performance

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Chemical Phosphorus Removal

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Chemical P Removal

- Form an insoluble precipitate
  - Aluminum (Alum, PAC, others)
  - Iron (Ferric or Ferrous)
- Flocculation key step
- Physical separation process
  - Clarifiers
  - Filters
  - Membranes




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Keys to Chemical P Removal

- Proper chemical dose
- Optimized pH control
- Multi-point dosing
- Excellent flocculation
- Efficient solids removal
- **Once you make the metal-phosphate particle handle with care until it's removed**

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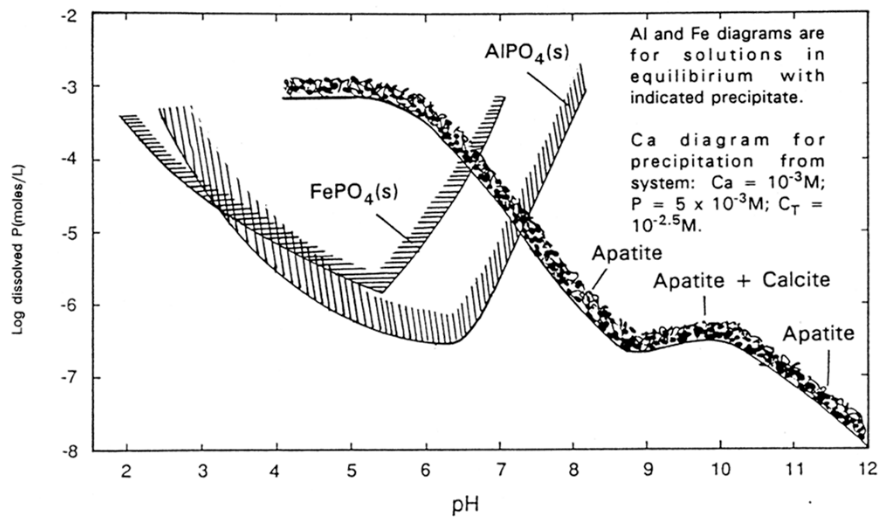
pH impacts on Metal Salt Solubility



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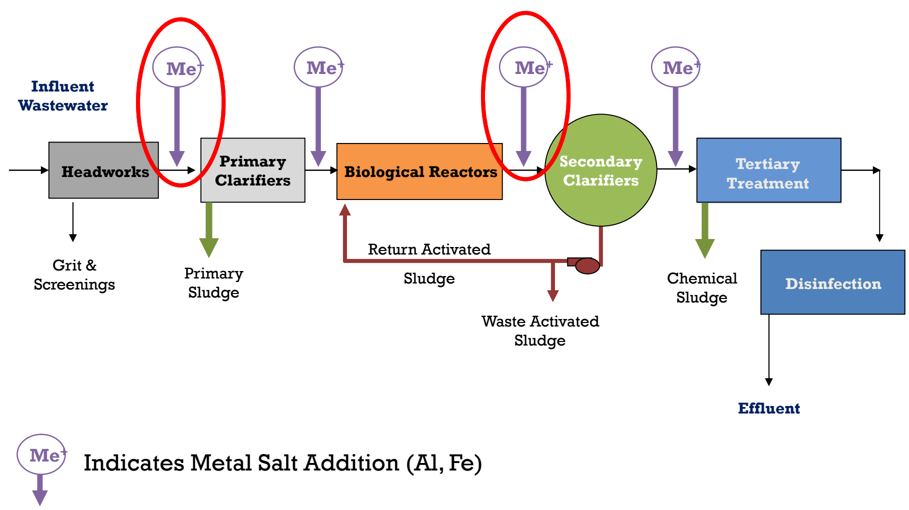
Multi-Point Chemical Addition



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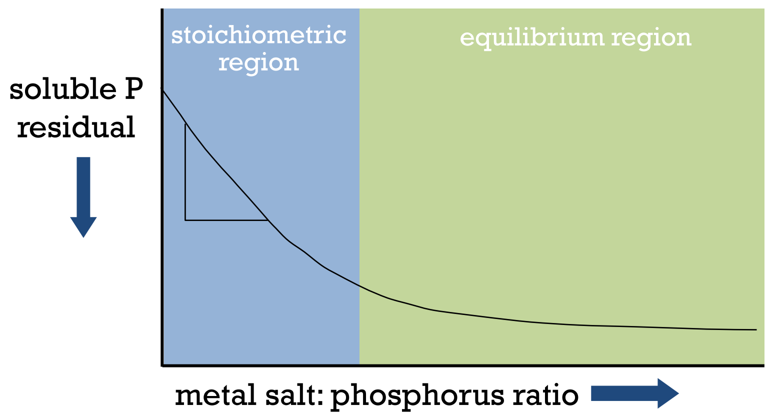
Chemical P Removal



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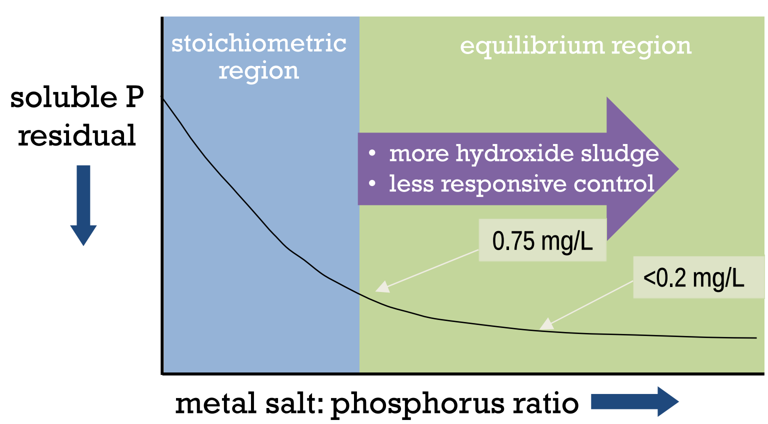
Chemical P Removal



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Chemical Sludge Considerations

- Sludge production is a function of coagulant dose
  - Alum generates ~ 0.33 lb sludge/lb added
  - Ferric generates ~ 0.6 lb sludge/lb added
  - Sludge production per unit P removed depends on limit, lower limit increases sludge produced
  - More alkalinity may be required
  - Extra care required to limit impact on nitrogen removal

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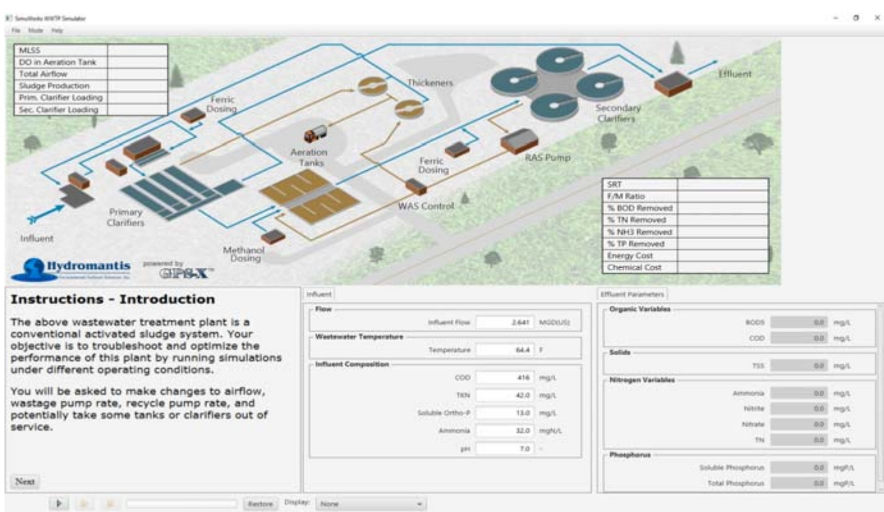
Process Simulator – Chem P Example



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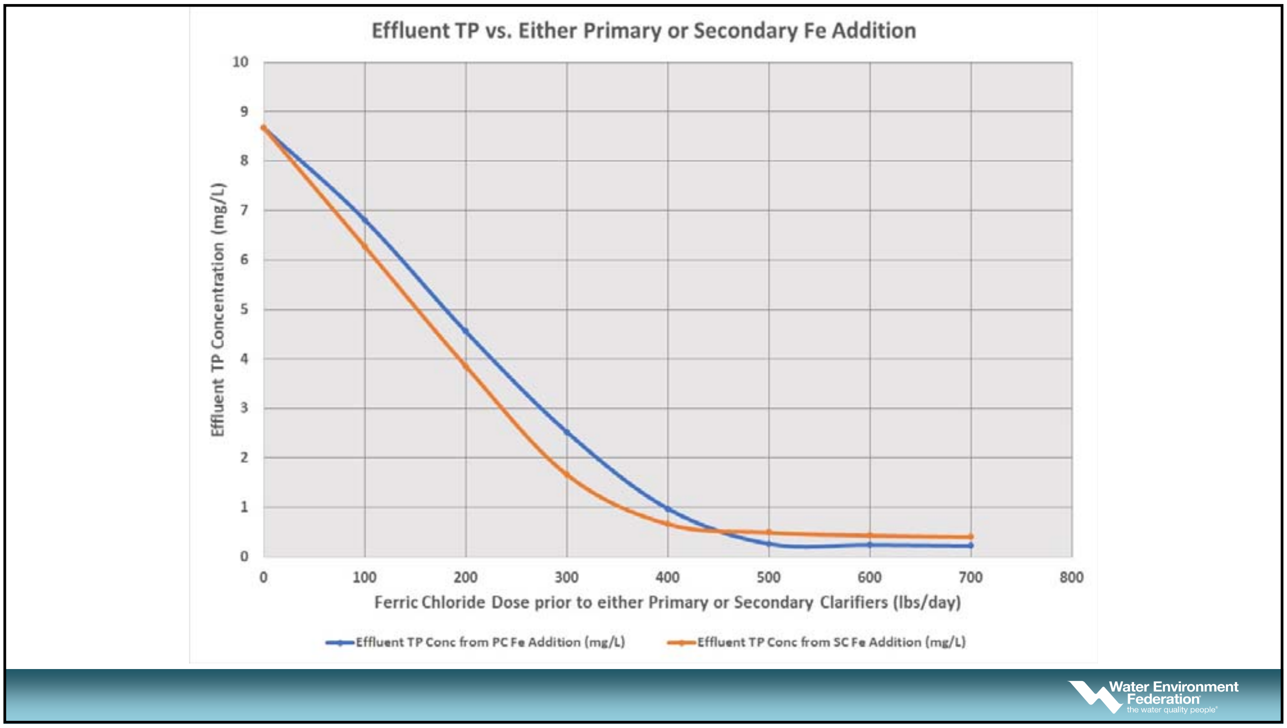
Effluent TP vs. Either Primary or Secondary Fe Addition
Effluent TP Concentration (mg/L)
Ferric Chloride Dose prior to either Primary or Secondary Clarifiers (lbs/day)
Effluent TP Conc from PC Fe Addition (mg/L)
Effluent TP Conc from SC Fe Addition (mg/L)
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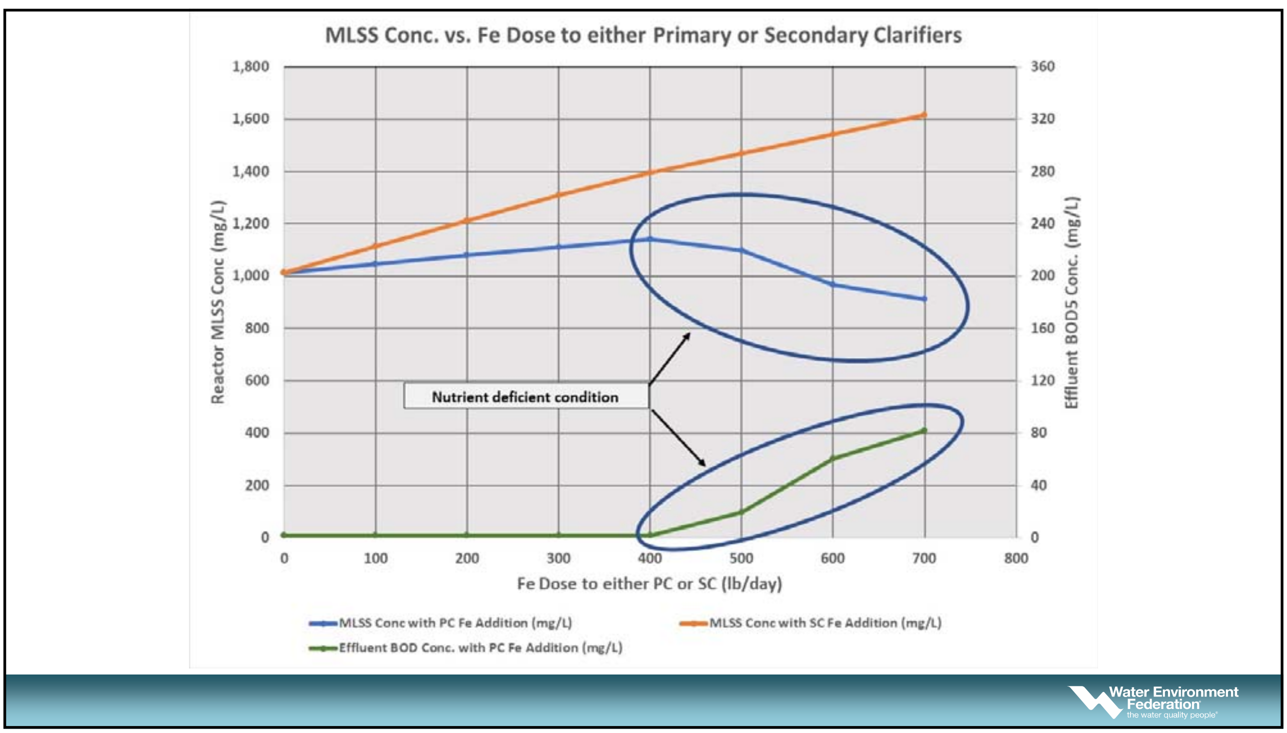
MLSS Conc. vs. Fe Dose to either Primary or Secondary Clarifiers
Reactor MLSS Conc (mg/L)
Effluent BOD5 Conc. (mg/L)
Nutrient deficient condition
Fe Dose to either PC or SC (lb/day)
MLSS Conc with PC Fe Addition (mg/L)
MLSS Conc with SC Fe Addition (mg/L)
Effluent BOD Conc. with PC Fe Addition (mg/L)
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Conventional wisdom on P removal technology

Effluent TP Target	Conventional Approach
<1.0 mg/L	EBPR or chemical addition + good clarification + chem addition (backup for EBPR)
<0.5 mg/L	EBPR or chemical addition + filtration + chem addition (backup for EBPR)
<0.1 mg/L	EBPR + chem addition to clarifiers + filtration (or tertiary process)
< 0.05 mg/L	EBPR + chem addition + high-level filtration
< 0.01 mg/L	EBPR + chem addition + membrane filtration

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Chemical Phosphorus Removal Case Study

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Chemical Phosphorus Removal Case Study

- **Nobleton WRF**
  Nobleton, Ontario, Canada
- Extended Aeration System
  - BOD, Nitrogen and Phosphorus Removal
- 0.75 MGD (2.9 MLD) Capacity
  - Extended Aeration
  - Chemical Phosphorus Removal
  - pH Control
  - Filtration/UV Disinfection

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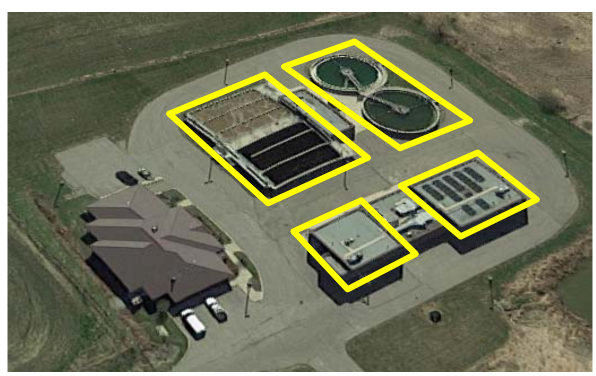
Chemical Phosphorus Removal Case Study

- Small facility – receiving relatively small load
- Only one half of the plant in service
- Influent from pump station



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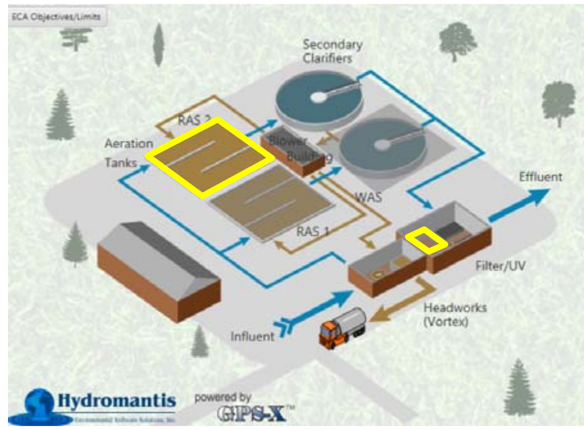
Chemical Phosphorus Removal Case Study

- Low influent Phosphorus:
  - Total P ≈ 4 mgP/L
  - Soluble P ≈ 1.8 mgP/L
- Effluent objective:
  - Total P < 0.15 mgP/L
- Dual-point chemical dosage (alum) in bioreactor, and prior to filters



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Case Study – Alum Dosage

- **Influent:**
  - BOD_5 = 107 mg/L
  - TSS = 120 mg/L
  - TKN = 32 mgN/L
  - Total P = 4 mgP/L
  - Soluble P = 3 mgP/L
  - pH = 6.5
- **Effluent – no alum dosage:**
  - BOD_5 = 1 mg/L
  - TSS = 1.3 mg/L
  - TKN = 2.7 mgN/L
  - Total P = 3.5 mgP/L
  - Soluble P = 3.4 mgP/L
  - pH = 6.9

Target: < 0.15 mgP/L

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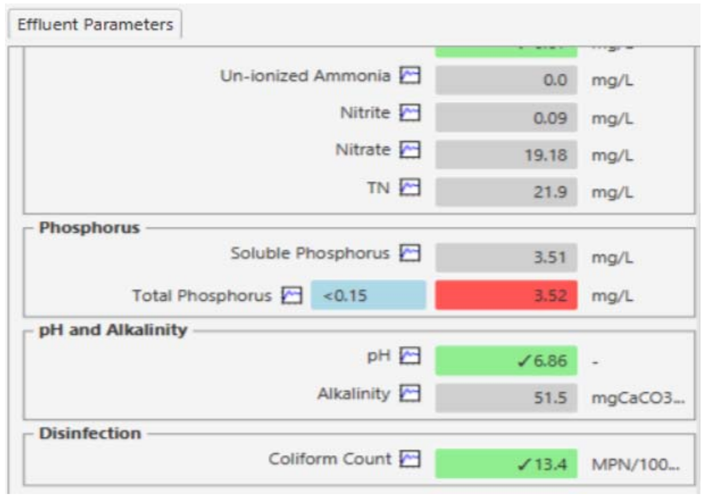
Case Study – Alum Dosage

- No Alum Dosage:
- Increase dosage in bioreactor



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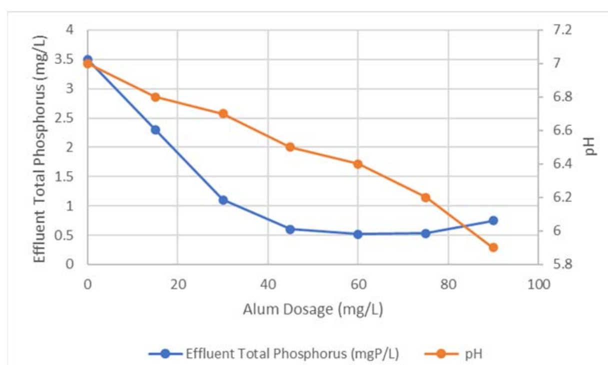
Case Study – Alum Dosage

Primary Alum Dosage (mg/L)	Effluent Total Phosphorus (mgP/L)	pH
0	3.5	7.0
15	2.3	6.8
30	1.1	6.7
45	0.6	6.5
60	0.52	6.4
75	0.53	6.2
90	0.75	5.9



MLSS increases from 1640 to 2290 mg/L

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Case Study – Alum Dosage

- Efficiency of alum dosage is dependent on pH
- Bring up pH with NaOH dosage
- Chemical dosing can have significant effect on MLSS
- Secondary alum dosage to polish effluent

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Case Study Summary

- Nobleton, Ontario achieves their phosphorus limit through alum dosage
- It can sometimes be a challenge to manage both effluent TP and effluent pH in systems with chemical dosage

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Questions?

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