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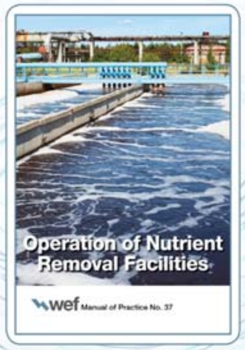

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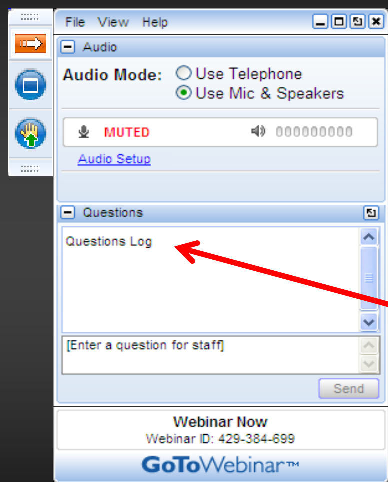

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- **A recording will be available for replay shortly after this webcast.**

Basics of Phosphorus Removal and Operational Lessons Learned

WEF Plant Operations and Maintenance Committee

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Speakers

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Webcast Agenda

Time	Topic	Speakers
1:00-2:00	Operational View of Phosphorus Removal	Sidney Innerebner James Barnard
2:00-2:30	Rock Creek AWWTF - Case Study	Chris Maher
2:30-3:00	F. Wayne Hill Water Resource Campus - Case Study	Joe Rohrbacher

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Operational View of Phosphorus Removal

Sidney Innerebner, PhD, PE, CWP

Indigo Water Group

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Agenda
Operational View Of Phosphorus Removal

- Methods of phosphorus removal
- Chemical removal basics
- Enhanced Biological Phosphorus Removal (EBPR) basics
- *Accumlibacter* and *Tetrasphaera*
- New insights into anaerobic zone operation

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Preventing Eutrophication

- Cells need very little phosphorus
- BOD:N:P ratio for good cell growth is **100:5:1**
- Phosphorus is often the limiting nutrient in natural systems
- When added, creates algae blooms, fish kills, septicity, toxicity and stagnation

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Rule of Thumb

- Influent concentrations between 4 and 12 mg/L as P are typical
- Ratio of P/cBOD$_5$ for domestic wastewater is 0.02 to 0.05
- Flip it and cBOD$_5$/P is 20:1 to 50:1
- Higher ratios may indicate
  - Corrosion control additives
  - Recycle Streams
  - Septic, and/or
  - Industrial Waste

If BOD$_5$ is 250 mg/L, then P should be

(250)•(0.02) = 5.0 mg/L

(250)•(0.05) = 12.5 mg/L

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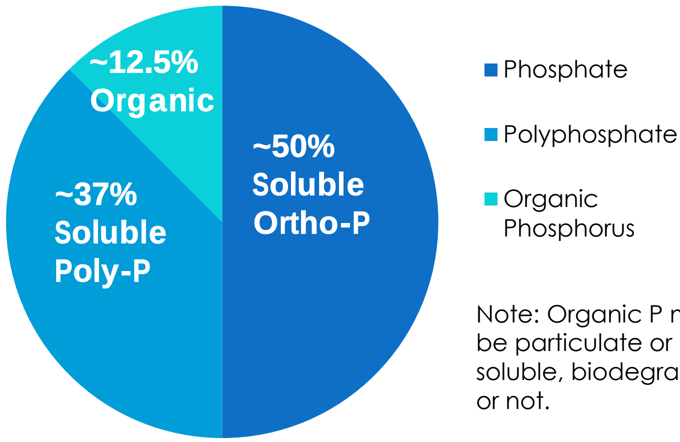
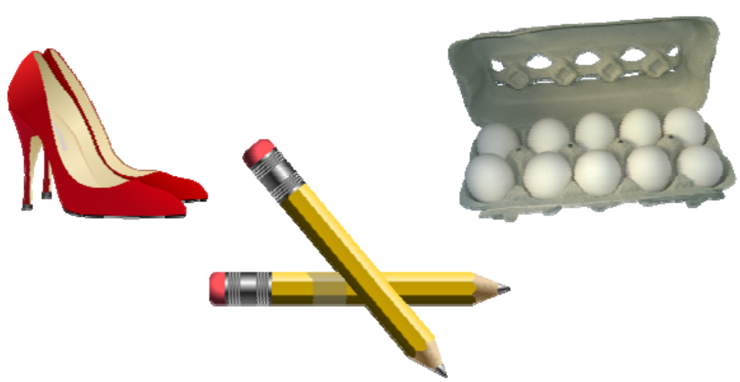
Phosphorus Fractionation



Note: Organic P may be particulate or soluble, biodegradable or not.

What is a Mole?

- 6.022 * 10^{23} atoms (or molecules) in one mole



Images from Pixabay

Phosphate or Phosphorus as P?

Phosphorus is PO_4

One Phosphorus atom	(1)(31 g/mole) = 31 g/mole
Four Oxygen atoms	(4)(16 g/mole) = 64 g/mole
	95 g/mole total

1 g P	1 mole P	1 mole PO_4	95 g PO_4	= **3.07 g PO_4**
	31 g P	1 mole P	1 mole PO_4	

Laboratories are not consistent when reporting phosphorus.

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Practice Problem

A student reported that the analyzed wastewater contains 18 mg/L of orthophosphate. What is the concentration if it is reported as P?

(a) 6

(b) 10

(c) 18

(d) 24

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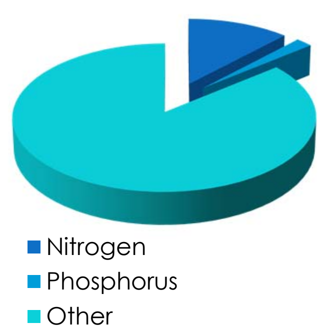
Methods of Phosphorus Removal

- Assimilative Uptake
- Chemical method uses alum or ferric chloride to precipitate phosphorus
  - Levels down to 0.02 mg/L PO_4-P **(as P)**
- EBPR uses PAO's to uptake phosphorus
  - Levels down to 0.07 mg/L orthophosphates (PO_4-P)
  - **Levels down to 0.3 mg/L total PO_4-P without filters**
- Methods often used in combination

Composition of a Cell Results in Assimilative Uptake of N and P

- Cells contain nitrogen and phosphorus
- Between 6 and 12% Nitrogen by weight
- Normally between 1 and 2% Phosphorus by weight
- **PAOs contain up to 40% Phosphorus by weight**



Phosphorus Concentrations Decrease with Treatment

Location	Typical P, mg/L
Raw Sewage	4 – 12
Primary Effluent	2.5 – 8
Secondary Effluent w/o Bio-P	2 – 5
Secondary Effluent with Bio-P	0.7 – 1.0
Tertiary Filter Effluent	0.03 – 0.05

Wasting 1.5 – 2% P sludge reduces P by 10 to 30% in a non-BioP WRRF

Chemical Phosphorus Removal

Chemical Phosphorus Removal

- Precipitate P with a metal salt or lime
- Many chemical choices
- Only ortho-P can be precipitated

- Pros: Extremely low levels achievable, simple to implement
- Cons: Chemical handling, increased operational costs, increased sludge production, consumes alkalinity

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Chemicals used for phosphorus precipitation

Chemical	*Formula*	*Removal mechanism*	*Effect on pH*
Aluminum Sulfate (Alum)	$Al_2(SO4)_3.14.3(H_2O)$ M.W. = 599.4	Metal hydroxides	removes alkalinity
Ferric Chloride	$FeCl_3$ M.W. = 162.3	Metal hydroxides	removes alkalinity
Poly Aluminum Chloride	$Al_nCl_{(3n-m)}(OH)_m$ $Al_{12}Cl_{12}(OH)_{24}$	Metal hydroxides	none
Ferrous sulfate (pickle liquor)	Fe_2SO_4	Metal hydroxides	Removes alkalinity
Lime	CaO, $Ca(OH)_2$	Insoluble precipitate	Raises pH to above 10

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Basic Chemistry

$Al_2(SO_4)_3 \bullet 14H_2O + 2H_3(PO_4) \rightarrow$
$2Al(PO_4)_{(s)}$ $+ 3H_2SO_4 + 18H_2O$

$2FeCl_3 \bullet (6H_2O) + 2H_2PO_4 + 2HCO_3 \rightarrow$
$2FePO_{4(s)}$ $+ 3Cl_2 + 2CO_2 + 9H_2O$

Highest removal efficiency is between pH 5.5 and 7.0
Removal efficiency declines above pH 7

Me_{dose}/P_{ini} Ratio

- Me_{dose} is moles of metal added
- P_{ini} is the moles of soluble P in the influent

Basic Chemistry

One mole

$Al_2(SO_4)_3 \bullet 14H_2O + 2H_3(PO_4) \rightarrow$
$2Al(PO_4)$ $+ 3H_2SO_4 + 18H_2O$

Two moles

$2FeCl_3 \bullet (6H_2O) + 2H_2PO_4 + 2HCO_3 \rightarrow$
$2FePO_4$ $+ 3Cl_2 + 2CO_2 + 9H_2O$

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Let's Simplify for Aluminum

$Al^{+3} + PO_4^{-3} = AlPO_{4(s)}$

27 g/mole 31 g/mole

$$Ratio = \frac{27\ g\ Al/mole}{31\ g\ P/mole} = 0.87\ g\ Al\ per\ g\ P$$

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Let's Simplify for Iron

$$Fe^{+3} + PO_4^{-3} = FePO_{4(s)}$$

55.8 g/mole   31 g/mole

$$Ratio = \frac{55.8\ g\ Fe/mole}{31.0\ g\ P/mole} = 1.8\ g\ Fe\ per\ g\ P$$

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Me_{dose}/P_{ini} Ratio

- Mole ratio holds true when effluent P is greater than 1 mg/L.
- Stoichiometric doses
  - Ferric dose of 1.8 g Fe per g P
  - Alum dose of 0.87 g Al per g P
- Me_{dose}/P_{ini} Ratios of 1.5 to 2.0 are needed to remove 80 – 98% of soluble P
- Me_{dose}/P_{ini} Ratios of 6 to 7 are needed to get below 0.10 mg/L.

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What is Going On?

- Competing reactions
- More competition as P levels decrease

$$FePO_{4(s)} \leftarrow\rightarrow Fe^{3+} + PO_4^{3-}$$

$$Fe(OH)_{3(s)} \leftarrow\rightarrow Fe^{3+} + 3OH^-$$

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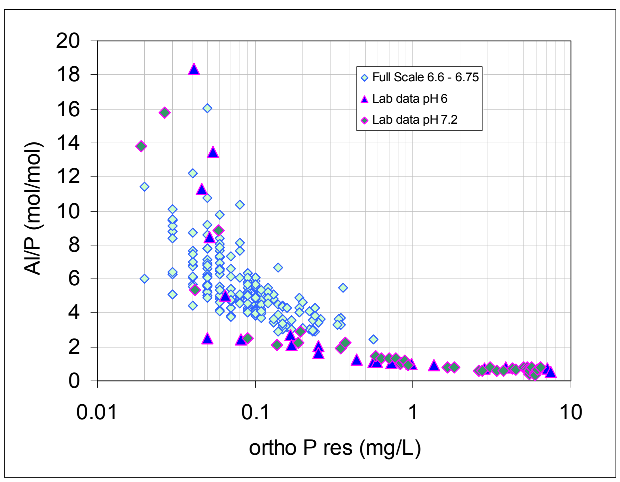
Molar Dose Ratio From Tests



Slav Hermanowicz, Chemical Fundamentals of Phosphorus Precipitation, WERF Boundary Condition Workshop, Washington DC, 2006

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Exact molar ratios versus effluent soluble P will vary

- Ratios are higher with PAC
- Factors that influence ratios
  - pH
  - Mixing method
  - Wastewater characteristics
    - Colloids and solids effect P-metal hydroxide complexations
    - Organic subtrates
    - Iron and aluminum can react with humic substances

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Mixing at the dosing point is important

- Intimate rapid contact to assure that metal and phosphate molecules react
- Rapid mixing make surface sites of hydrous ferric oxides available for P complexation
- Slow mixing gives more time for metal to form metal hydroxides with less available surface reaction
- Mixing G values of 200 to 400 second^{-1} recommended

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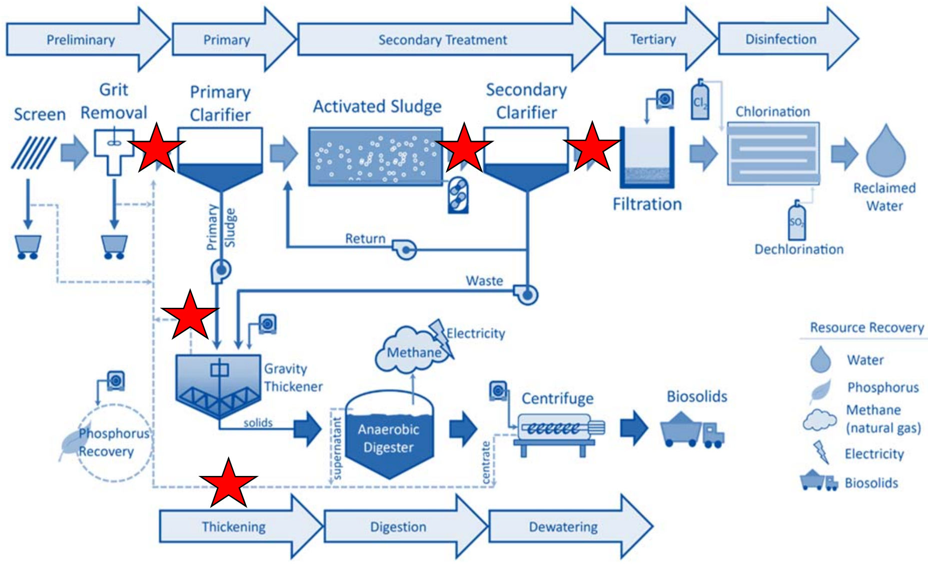
Typical Chemical Treatment Opportunities



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Effect on Sludge Production

Treatment Location	Increase in Sludge Production	
	Process	Total
Metal salts to primary clarifier	50 – 100%	60 – 70%
Metal salts to secondary treatment to achieve effluent P in the range of 0.5 – 1.0 mg/L	35 to 45%	5 – 25%
Tertiary application of metal salts to achieve effluent P less than 0.1 mg/L	45 to 60%	10 to 40%

Lime precipitation produces greater volumes of sludge because of lime's reaction with natural alkalinity.

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Biological Solids are Always Leaving the System

- When solids leave the system, other things leave too
  - BOD
  - TKN
  - Phosphorus
- Remember the ratios? 12% N and 2% P
- So… is it possible to meet a 0.05 mg/L P standard when effluent TSS is 12 mg/L?

(12 mg/L)(0.02) = 0.24 mg/L P

Solids Separation Key to Phosphorus Removal

- Sedimentation in Secondary Clarifier
- Tertiary filtration
  - Achieves effluent P < 0.5 mg/L
  - Traditional media filters
  - Upflow continuous backwash filters
  - Cloth media filters
  - Membranes
  - Other proprietary processes

Operational Impacts

- Added upstream of secondary process
  - May remove too much BOD
  - Increases inert fraction in aeration basin
  - Improves sludge settleability
  - Potential for nutrient limitations downstream
- Added after secondary clarifier
  - Enhances colloidal nitrogen removal
- Filter backwash contains unreacted chemical which is recycled to headworks or aeration basin

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Biological Phosphorus Removal

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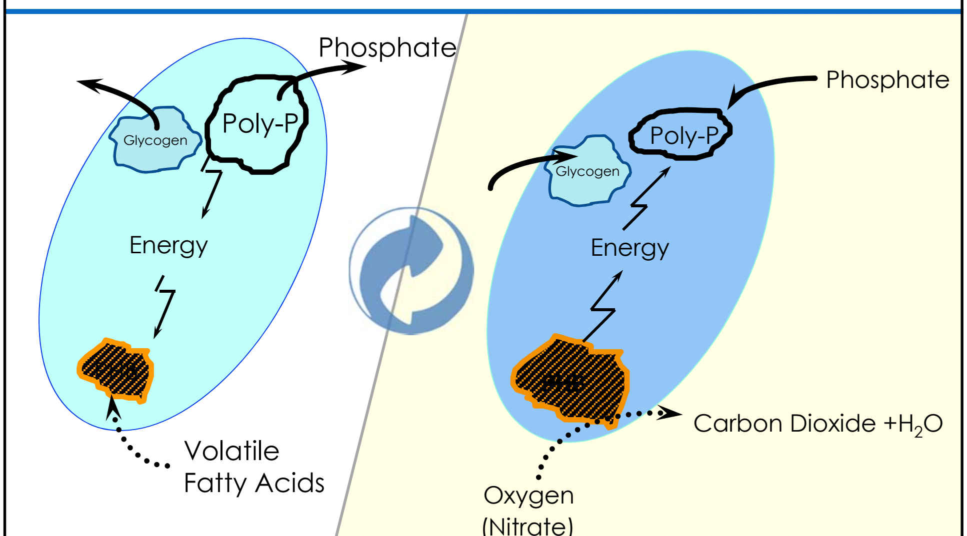
Enhanced Biological Phosphorus Removal (EBPR)

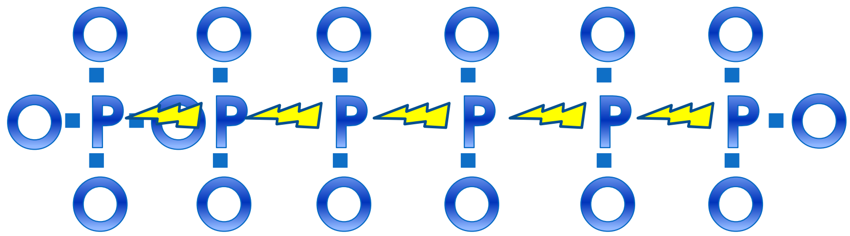
- A two-step process of phosphorus release and uptake under alternating anaerobic and aerobic or anoxic conditions
- Special bacteria call Phosphate Accumulating Organisms or PAOs of which there are many species
- Luxury uptake of phosphorus
- Normal cells have 1-2% P
- **PAOs can have up to 40%**
- **PAOs can make MLVSS between 4 and 8% P**
- WAS removes P from the system

PAOs Must Cycle Between Anaerobic and Aerobic/Anoxic Zones



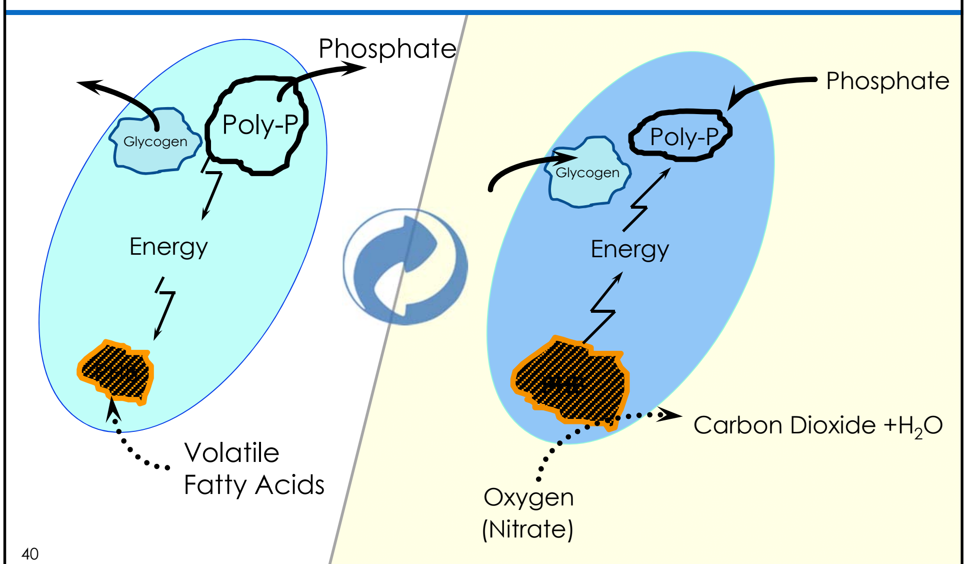
PHB is poly-β-hydroxybutyrate.

Poly-P Acts Like a Battery Storing and Releasing Energy

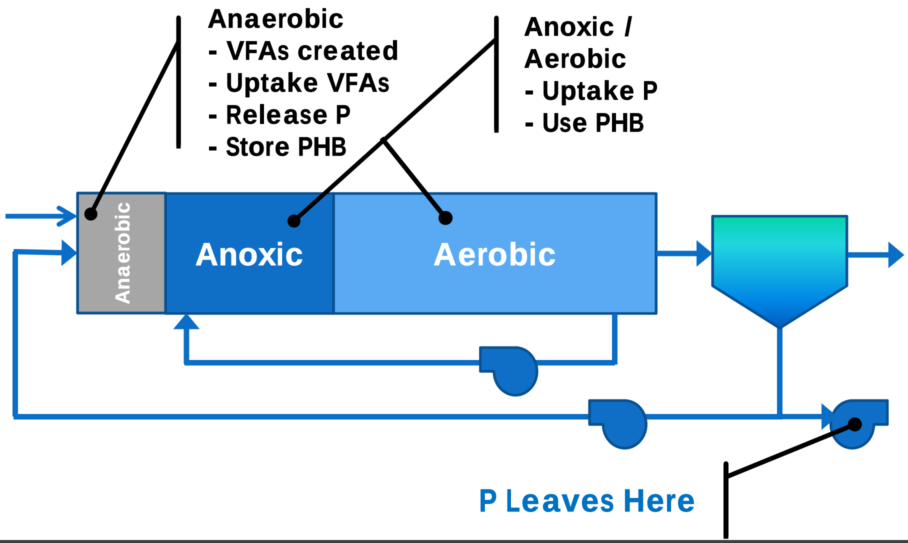


ATP – adenosine triphosphate on steroids!

PAOs Must Cycle Between Anaerobic and Aerobic/Anoxic Zones



Three-Stage BNR



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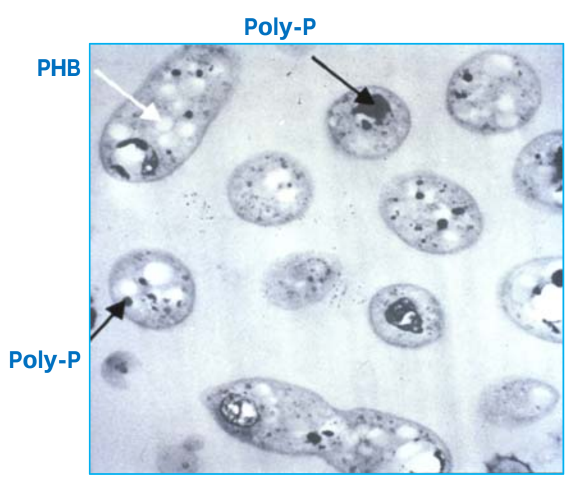
PAO's with Inclusions



Thank you to James Barnard with Black and Veatch for use of these images.

In the Anaerobic Zone.

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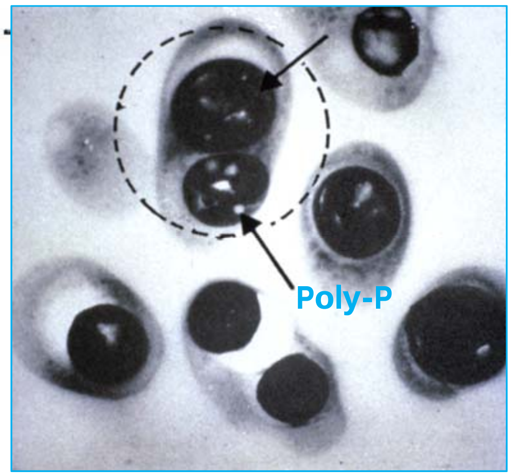
Tons of Poly-P per PAO



In the Aerobic Zone.

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Operational Considerations

- **Influent COD:P Ratio Critical (or is it?)**
- **Dissolved oxygen**
- pH and Temperature
- Solids Retention Time (SRT)
- Hydraulic Retention Time (HRT)
- Most common PAOs *Accumulibacter* and *Tetrasphaera*
- Competing Organisms – GAOs and Denitrifiers

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Additional information and case studies may be found in MOP 37 – Operation of Nutrient Removal Facilities.

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Conventional Wisdom Says….
Minimum COD:TP Ratios

Parameters	Recommended Minimum Ratio
COD:TP	40 – 45
cBOD:TP	20
rbCOD:TP [1, 2]	**10 – 16**
VFA:TP	4 - 16

[1] Most Accurate Predictor
[2] May vary considerably by season in temperate climates

COD = Chemical Oxygen Demand, TP = Total Phosphorus, BOD = Biochemical Oxygen Demand, rbCOD = readily biodegradable COD, VFA = Volatile Fatty Acid
Source: EPA/600/R-10/100 (August 2010)

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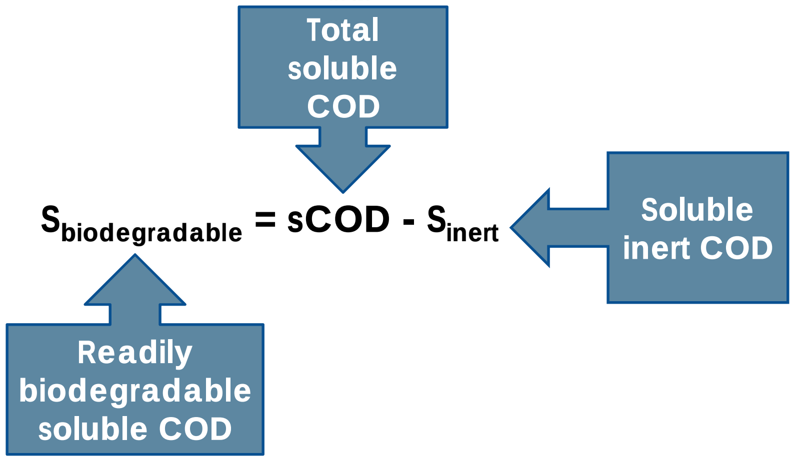
Estimating Available rbCOD

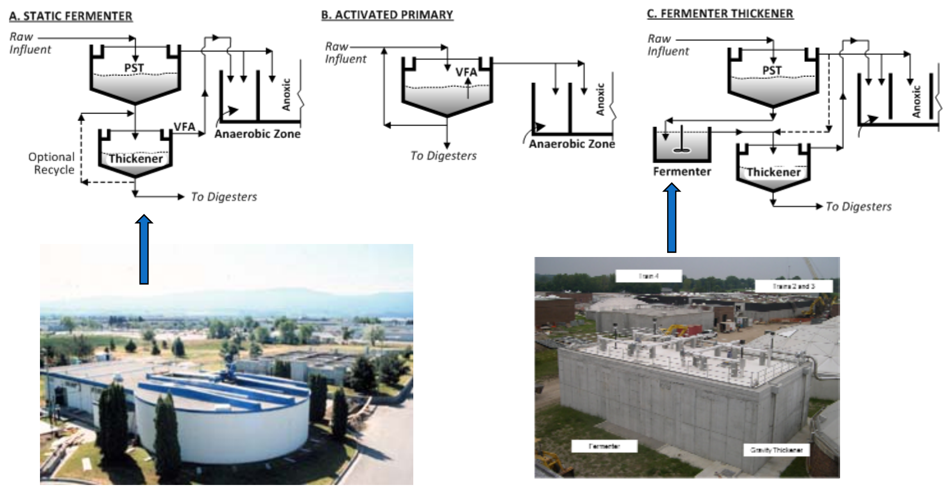


Analytical Procedure

- Add 1 mL of 100 g/L zinc sulfate to a 100 mL wastewater sample.
- Mix with magnetic stirrer for 1 minute.
- Adjust pH to 10.5 with 6-M sodium hydroxide (NaOH)
- Settle for a few minutes
- Withdraw clear supernatant
- **Filter through acid-washed 0.45 um filter***
- Measure COD by normal method

Source: MOP29 (2005), page 447

VFA from Fermenters



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Oxygen in Anaerobic Zone

- DO and nitrate will be used by
  - Heterotrophs
  - Glycogen Accumulating Organisms (GAOs)
  - PAOs
- Reduces VFAs available for EBPR
- Inhibits fermentation so fewer VFAs are produced
- Nothing good!

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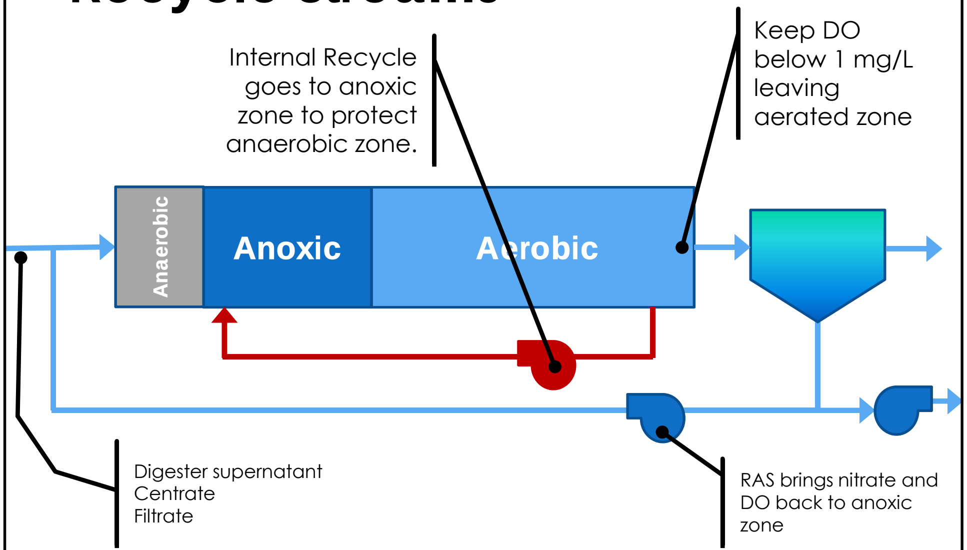
Recycle Streams



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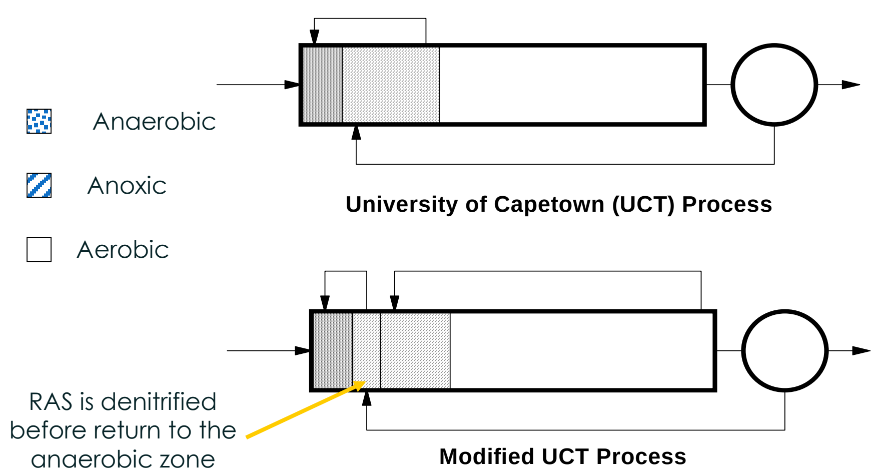
For Ammonia and Phosphorus Removal



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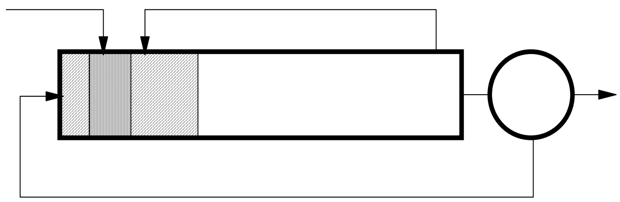
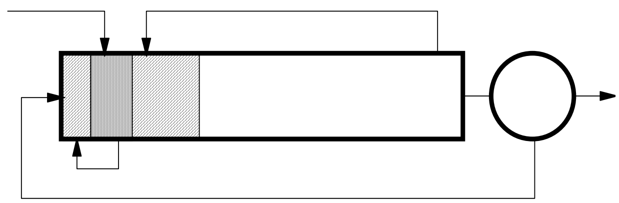
JHB and MJHB



Johannesburg (JHB) Process

RAS is denitrified by endogenous respiration before passing to the anaerobic zone



Modified JHB Process

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Operational View of Phosphorus Removal

James Barnard, Ph.D.,D.Ing.h.c.,Pr.Eng.
BCEE, WEF Fellow, Dist. MASCE

BLACK & VEATCH

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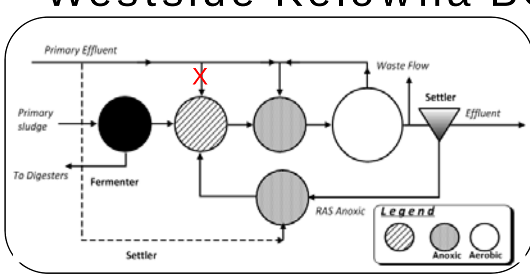
Later studies identified *Accumulibacter* as the dominant PAO

- "…it was incorrectly considered that PAOs were of the genus *Acinetobacter* (Fuhs & Chen)…. or *Tetrasphaera* (Maszenan et al) …" *
- "More recently, culture-independent methods have shown *Accummulibacter* … is a PAO which can be grown in enriched cultures …"*
- "For the purpose of design it will be considered that anoxic P uptake is not significant"*

*IWA – Biological Wastewater Treatment - Principles, Modeling, and Design Henze *et al*

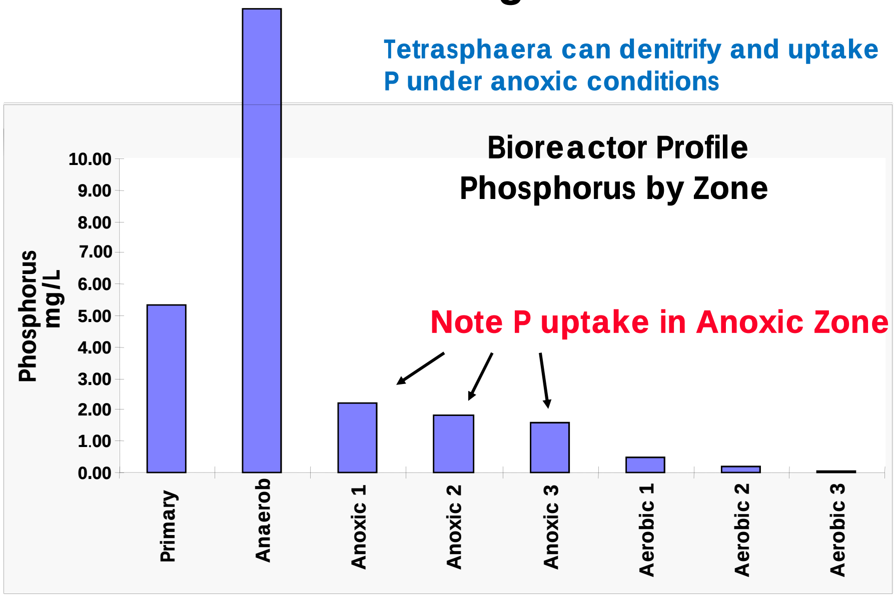
Westside Kelowna BC (Westbank)



TN	< 6 mg/ℓ
BOD	< 5 mg/ℓ
TSS	< 2 mg/ℓ
TP	< 0.15 mg/ℓ

Westside Reg. WWTP

Tetrasphaera can denitrify and uptake P under anoxic conditions



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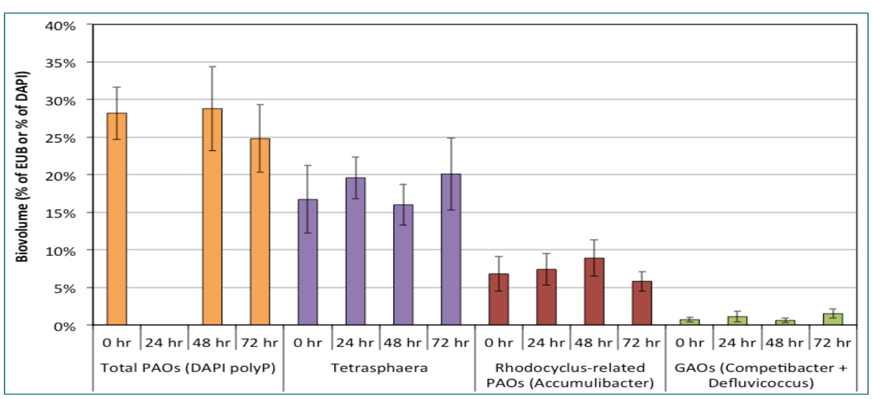
PJD1

Key Microbial Populations Abundance



Tooker et al.

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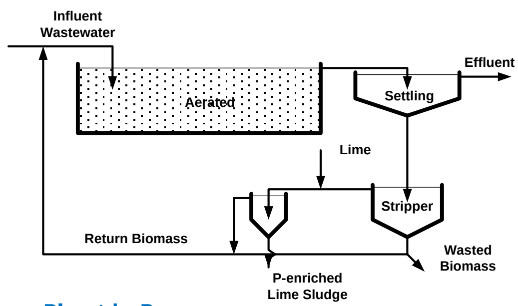
Slide 58

PJD1 Check with Nick/April?
Patrick J Dunlap, 7/4/2016

RAS fermentation

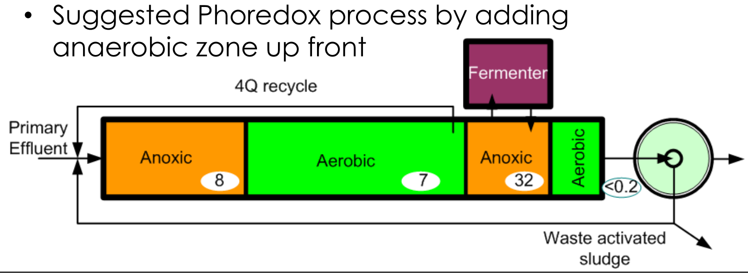
- Hi-rate no nitrification
- 30 to 40 h in Stripper
- Supernatant high in P treated with lime
- All primary effluent to aeration basin
- RAS thru deep anaerobic conditions



Phostrip Process
Levin et al (1975)

Mixed Liquor Fermenter (MLF)

- Fermenter resulted from basin configuration and not deemed important
- Excellent phosphorus removal resulted
- Note orthophosphates profile through plant
- Performance could not be replicated in laboratory
- Barnard suggested organisms (PAO) should pass through anaerobic phase with low ORP which triggered EBPR
- Suggested Phoredox process by adding anaerobic zone up front



Barnard 100 m^3/d pilot 1972

Alternative EBPR configurations promote growth of Fermenting PAO's

- Advantages of PAOs like Tetrasphaera that can ferment :
  - Ferment glucose and amino acids and other higher carbon forms and store phosphorus
  - Produce VFA that allow a population of Accumulibacter to grow alongside them, and
  - can denitrify and uptake P under anoxic conditions

Alternative EBPR configurations promote growth of Fermenting PAO's

- It would appear an ORP of less than < -250 mV is needed to cultivate for Fermenting PAOs
  - Longer AN SRT (1.5 to 2.0 days)
  - Use PS fermentate when available which would reduce needed anaerobic SRT
  - Reduce dilution (PE and RAS)

Potential Limitations of Conventional EBPR

- Perhaps they cultivate for Accumulibacter species that need acetic & propionic acid?
  - Short anaerobic residence time
  - Relatively weak anaerobic conditions (ORP > -150 mV)
  - due to high nitrate and DO concentrations
- Too much primary effluent low in VFA and high in DO going to AN zone, thus reducing AN SRT

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Potential Limitations of Conventional EBPR

- Many AN zones are over-mixed:
  - surface agitation and DO entrainment prevents deeper anaerobic conditions
  - Standard mixing energy 0.3 to 0.6 hp/kcf
  - When 0.08 hp/kcf is adequate (huge saving in energy)

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What is significant about these unconventional plants?

- Only a portion of the RAS or mixed liquor was used
- Primary effluent went to anoxic zone
- Using only 10% to 20% of RAS reduces the nitrate load on the anaerobic zone to that same percentages
- Low mixing energy resulted in less oxygen entrainment
- Longer and deeper anaerobic zones
- Plug-flow conditions allow more anaerobic conditions further down the tank.
- Presence of *Tetrasphaera* which can ferment higher carbon

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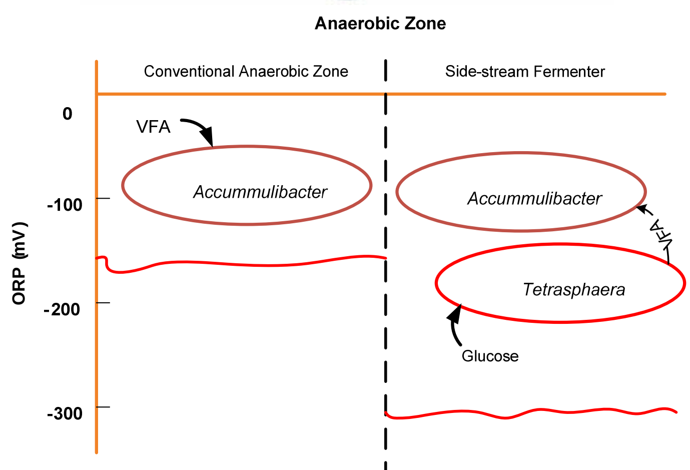
Conventional vs. Sidestream EBPR



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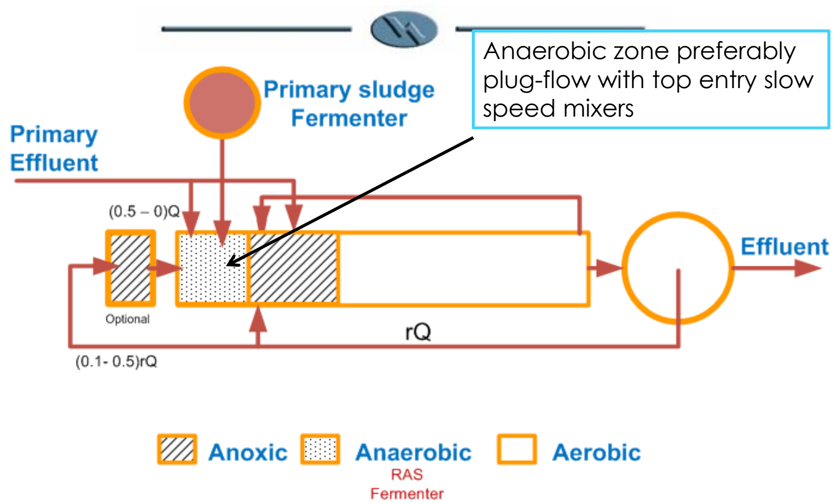
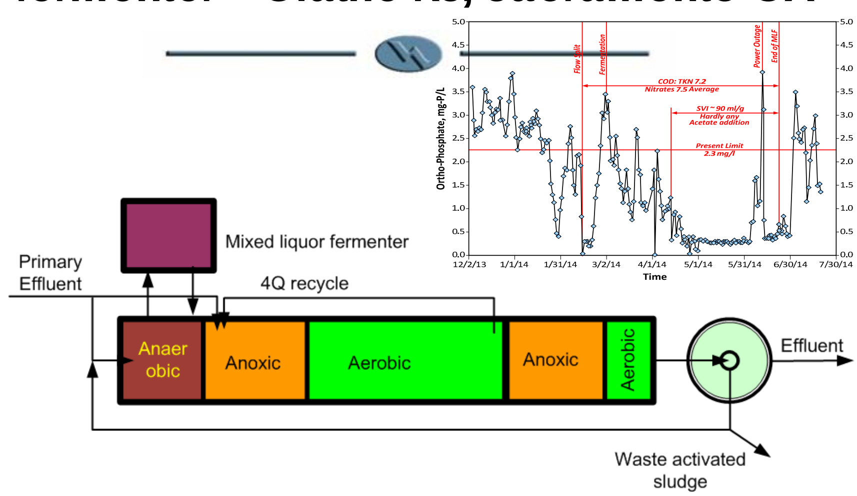
Modified Westbank Process



When no primaries use MIXED LIQUOR fermenter – Olathe KS, Sacramento CA



Guideline SRT of MLF approximately 2 days

What happened to secondary release of phosphorus?

- Secondary release of phosphorus happens when only Accumulibacter are present and "anaerobic" conditions are too long
- Together with other factors such as primary effluent with little rbCOD or VFA and over-mixing (higher ORP), even longer anaerobic zones will not produce more VFA
- Secondary release still possible in second anoxic zone when running out of nitrates or in final clarifiers
- With Tetrasphaera present longer and deeper anaerobic conditions will encourage more fermentation

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Models Under-Predict Performance of Sidestream EBPR Processes

- Potential Sources of Discrepancy
  - Variation in hydrolysis rate and fermentation yield
  - Impact of microbial ecology on apparent PAO stoichiometry
- How does this apply to
  - Westside Regional and Denver Metro Plants?
  - RAS Fermentation and Mixed Liquor Fermentation Plants

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Lessons learned for optimizing conventional plants

- With minimum temperature above 20°C conventional EBPR may still perform well, but there may be a benefit in reducing mixing energy
- With lower temperatures and poor performance
  - Reduce mixing energy
  - Partition anaerobic zones if possible
  - By-pass storm flows if possible
  - Pump mixed liquor from anaerobic zone to unused basin for fermentation and back again

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Reducing Mixing Energy

- If possible replace mixers with slow speed top entry and save a lot of energy. Will need less than 0.1 hp/kcf as opposed to 0.6 which we still find in Manuals
- Put mixers on timers
- Switch mixers off for long period and on for short periods
- Put mixers on VFD to reduce surface agitation

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Examples of Manipulating Existing Plants for EBPR

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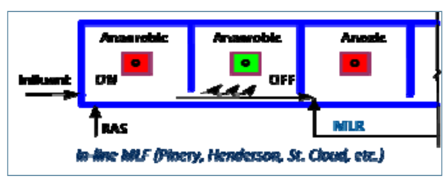
REDUCING MIXING ENERGY

- **Pinery Water CO**
  - Switching off mixer in anaerobic zone
- **Henderson NV**
  - Switching off mixer in anaerobic zone
- **St Cloud MN**
  - Switching off air in first pass of plug-flow aeration basin to allow sludge to settle and ferment
- **Stickney MWRDGC**
  - Switching off air in half of first of four pass aeration basin

Stickney treats 800 mgd



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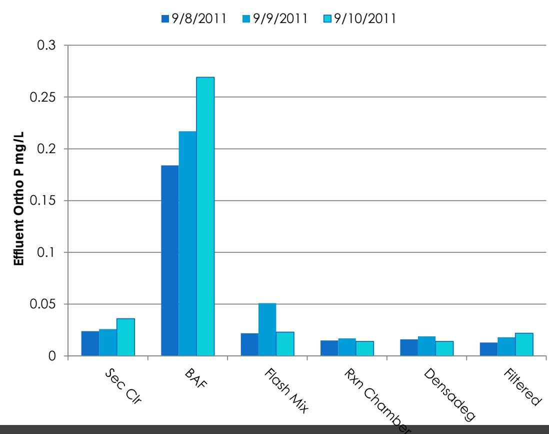
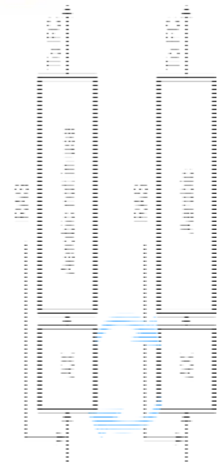
Phosphorus removal with Side-stream fermentation

Iowa Hill CO plant – From Chris Maher





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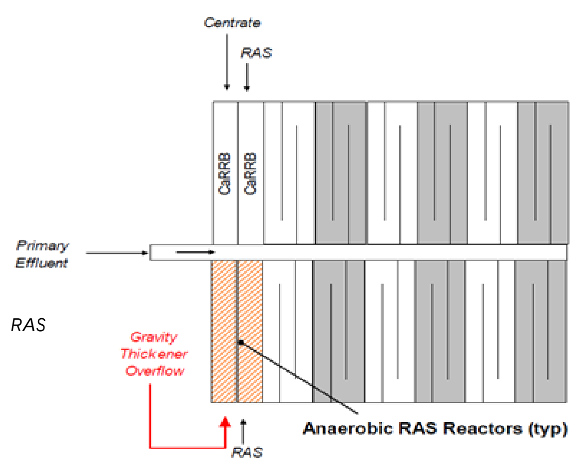
EXPERIMENT AT METRO DENVER



Cavanaugh, L., Carson, K., Lynch, C., Phillips, H., Barnard, J. and McQuarrie, J. (2012) A Small Footprint Approach for Enhanced Biological Phosphorus Removal: Results from a 106 mgd Full-Scale Demonstration. *Proceedings of the 85th Annual Water Environment Federation Technical Exhibition and Conference*, New Orleans, LA, October 2012.

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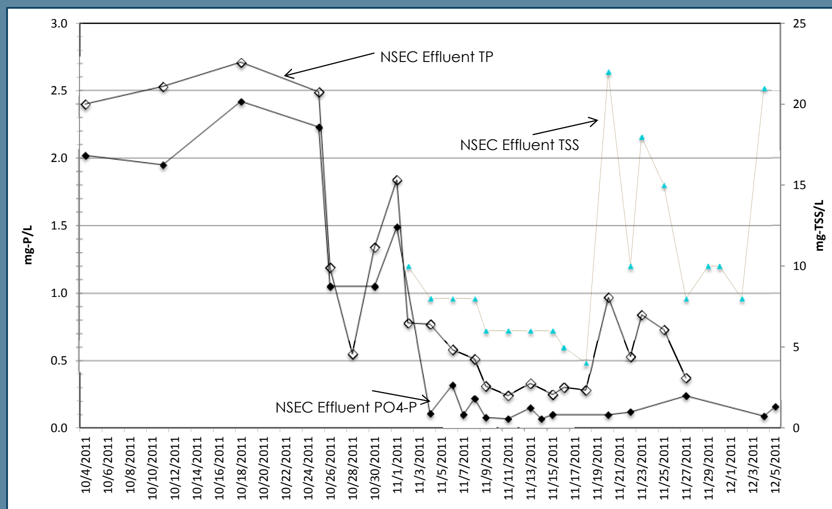
Phosphorus Removal by RAS Fermentation – Metro Denver



Cavanaugh, L., Carson, K., Lynch, C., Phillips, H., Barnard, J. and McQuarrie, J. (2012) A Small Footprint Approach for Enhanced Biological Phosphorus Removal: Results from a 106 mgd Full-Scale Demonstration. *Proceedings of the 85th Annual Water Environment Federation Technical Exhibition and Conference*, New Orleans, LA, October 2012.

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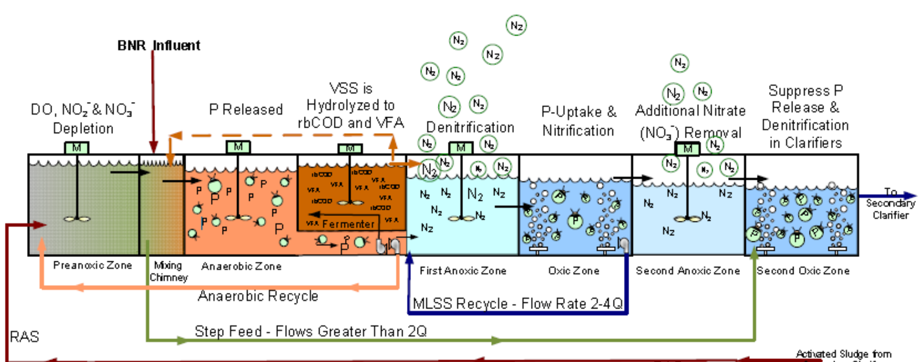
Olathe KS - MLF



Definitions

- DO – Dissolved Oxygen
- N_2 – Nitrogen (gas)
- NO_2^- – Nitrite
- NO_3^- – Nitrate
- P – Phosphorus
- Q – Annual Average Influent Flow
- rbCOD – readily biodegradable Carbonaceous Oxygen Demand (used for Phosphorus Removal)
- VFA – Volatile Fatty Acids (used for Phosphorus Removal)
- VSS – Volatile Suspended Solids
- Denitrification – Nitrate Removal
- Hydrolyze – Water is used to breakdown complex compounds into rbCOD and VFAs
- Nitrification – Converting Ammonia to Nitrate
- (symbol) – Phosphorus Accumulating Organism

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Olathe – Cedar Creek

- 5-stage Bardenpho no primaries
- Very unfavorable wastewater characteristics
- Designed with side-stream fermenter
- Pump 10% of flow as mixed liquor to fermenter then to first anoxic zone
- Mixing in fermenter once per day for 15 minutes
- Sludge concentration around 1.5% by controlled pumping
- Operate for close to 2 days SRT
- Very reliable performance
- Effluent orthophosphates LT 0.1 mg/L, TN LT 5 mg/L

Operator Innovations to Improve Performance

- Determine rbCOD/P ratio must exceed 14 to 16
- Consider passing primary sludge thickener to anaerobic zone or consider primary sludge fermenter
- Carry higher sludge blankets in the PST to ferment – Activated Primaries
- Reduce mixing energy – replace mixers
- Timers on mixers to switch off for prolonged periods - If problem is winter only then adjust for seasons

Operator Innovation- continued

- By-pass storm flows if possible
- Reduce RAS rates to lowest possible without carrying high sludge blanket in final clarifiers
- Consider using existing spare structure for mixed liquor fermentation
  - Pump 10% of flow from anaerobic zone to side-stream mixed liquor fermenter
- Partition tanks to form plug-flow

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Operator Control

For SSEBPR

- Need 30 to 40 hours for RAS or mixed liquor fermentation
- Need as little as 5% of RAS or MLQ
- Better with 4 basins in series of which some may be mixed or un-mixed
- Need only 10 to 12 hours when passing primary sludge fermenter fermentate to RAS fermenter
- For continuous mixing use slow speed mixers
- For intermittent mixing - not important

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Reliability and Consistency

- Note that the pilot plant operating with only sidestream fermentation had no effluent P concentrations above 0.2 mg/L
- Full-scale plants running with RAS or mixed liquor fermentation consistently have effluent Ortho-PO_4 below 0.1 mg/L as P.
- Independent of influent wastewater characteristics
- Not influenced by rain or high flows
- Used in plants with combined sewers

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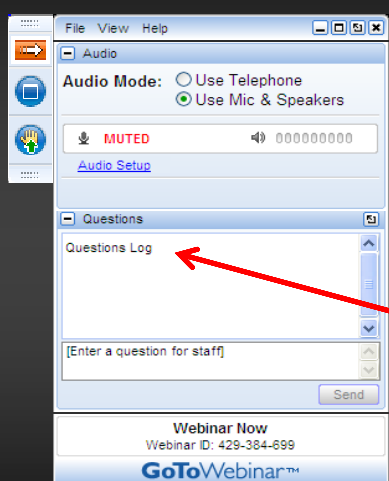
Questions?



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Rock Creek AWWTF
Case Study
Chris Maher
Clean Water Services
Clean Water Services
Water Environment
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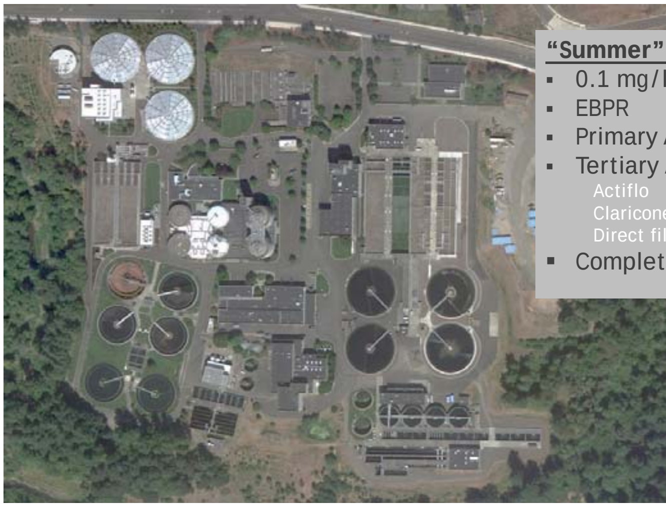
Rock Creek AWWTF



"Summer" Limits

- 0.1 mg/l TP Monthly Median
- EBPR
- Primary Alum
- Tertiary Alum
  - Actiflo
  - Claricone
  - Direct filtration
- Complete Nitrification

Bio-P optimization through:

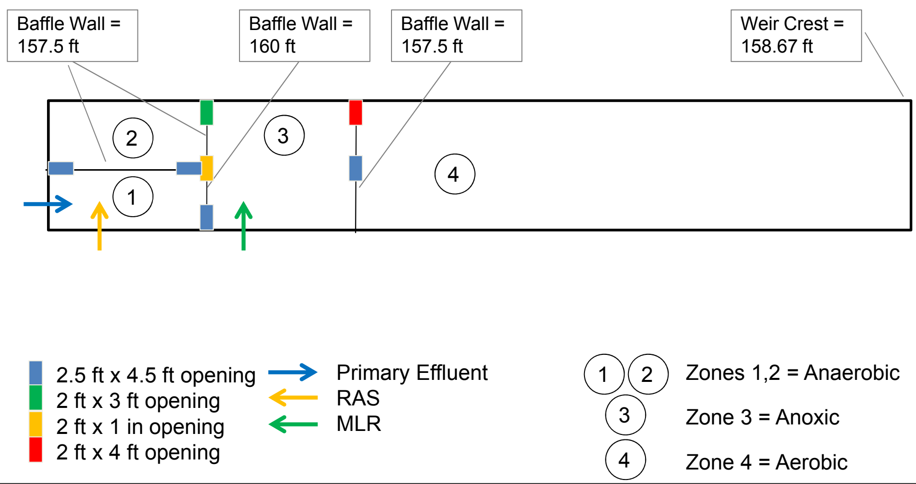
- Environmental Controls
  - Reactor modification
  - e^- acceptor control (DO and NO_3)
  - Anaerobicity control
- Substrate Control
  - VFA Production

3 pairs of A-basins, all A2O, not all equal

Basin performance differs

Aeration Basin	Operating Modes	Anaerobic Volume	Anoxic Volume	Aerobic Volume	Average 2011 Effluent OP, mg/L
AB 1-2	AO, A2O	14%	14%	72%	**0.60**
AB 4-5	AO, A2O	10%	10%	80%	**0.62**
AB 6-7	AO, A2O, Step Feed, Johannesburg	11%	10%	79%	0.33

Aeration Basin 4-5 Hydraulic Evaluation



Hydraulic Evaluation Identifies Potential Issues

- Back mixing
- Anaerobic zone short-circuiting
- Anoxic zone short-circuiting
- MLR short-circuiting
- MLR into anaerobic zones?

Hydraulic modifications completed using short lead-time materials

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Modifications Improved Conditions In Anaerobic and Anoxic Zones

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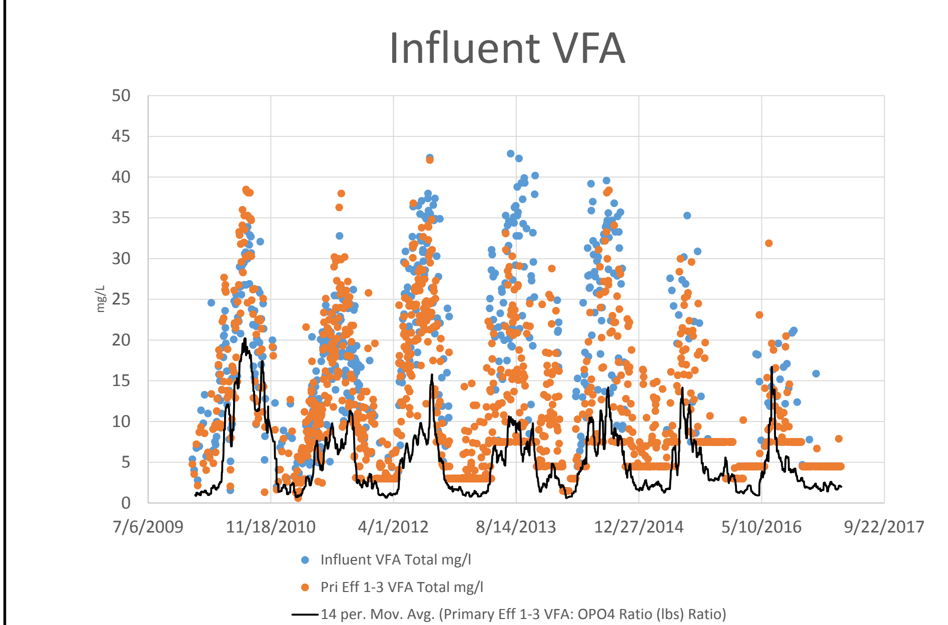
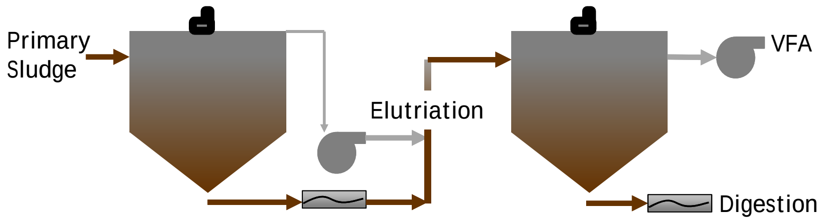
VFA Limitation

- Control the VFA, control the Bio-P
- Install primary sludge fermentation

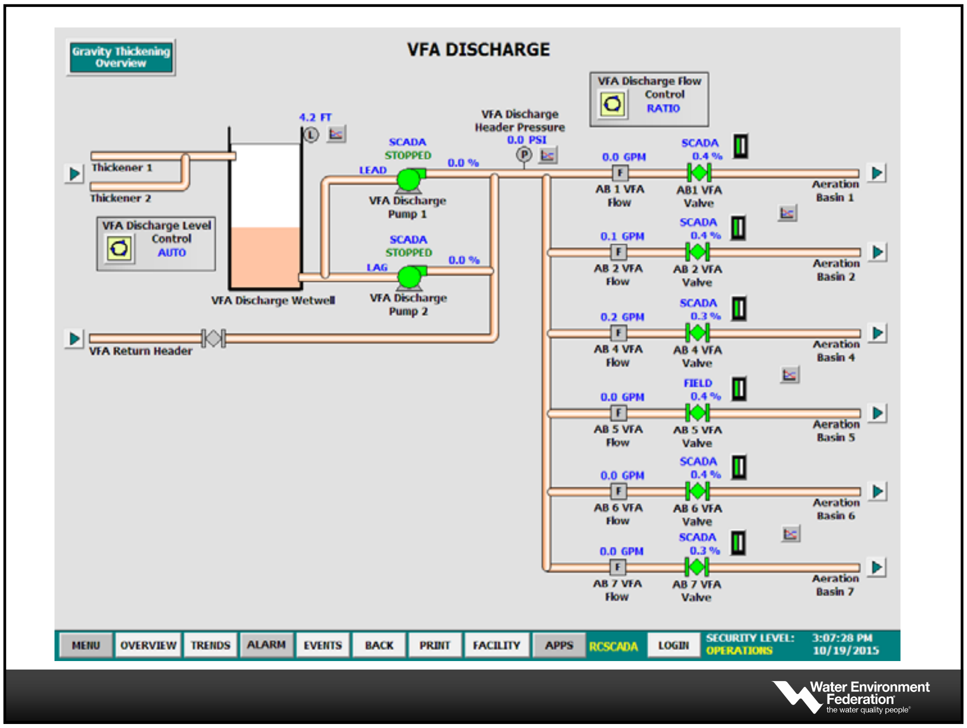


Unified Fermentation and Thickening (UFAT) Process Schematic



VFA Dosing

- Are we just dumping VFA into the system, or is this controlled chemical dosing?
  - Three different biological basin designs
  - Step feed configurations
  - Potential RAS fermentation configurations
- Dose VFA where you need VFA
  - Each RAS line just ahead of anaerobic zone
  - Utilize a percentage setpoint and MOV control


Gravity Thickening Overview
VFA DISCHARGE
VFA Discharge Flow Control
RATIO
4.2 FT
VFA Discharge Header Pressure
0.0 PSI
Thickener 1
Thickener 2
VFA Discharge Level Control
AUTO
SCADA
STOPPED
LEAD
0.0 %
VFA Discharge Pump 1
LAG
VFA Discharge Pump 2
VFA Discharge Wetwell
VFA Return Header
AB 1 VFA Flow
AB1 VFA Valve
AB 2 VFA Flow
AB 2 VFA Valve
AB 4 VFA Flow
AB 4 VFA Valve
AB 5 VFA Flow
AB 5 VFA Valve
AB 6 VFA Flow
AB 6 VFA Valve
AB 7 VFA Flow
AB 7 VFA Valve
Aeration Basin 1
Aeration Basin 2
Aeration Basin 4
Aeration Basin 5
Aeration Basin 6
Aeration Basin 7
FIELD
MENU
OVERVIEW
TRENDS
ALARM
EVENTS
BACK
PRINT
FACILITY
APPS
RCSCADA
LOGIN
SECURITY LEVEL: OPERATIONS
3:07:28 PM 10/19/2015
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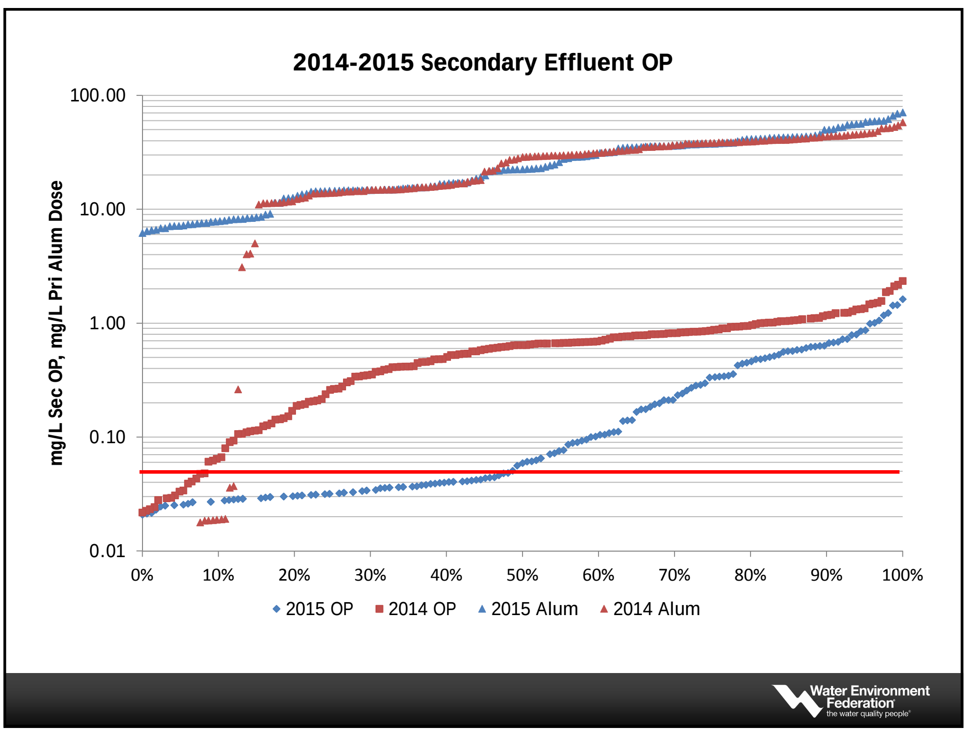
2014-2015 Secondary Effluent OP
mg/L Sec OP, mg/L Pri Alum Dose
100.00
10.00
1.00
0.10
0.01
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
2015 OP
2014 OP
2015 Alum
2014 Alum
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What do you put in your anaerobic zone?

- Influent, Primary Effluent?
  - What's in your influent? DO or NO_3?
- RAS
  - What's in your RAS? PAOs, Denitrifiers, NO_3, COD, VFA?
- VFA?
  - What's in your VFA? VFA, P, Fermenters?

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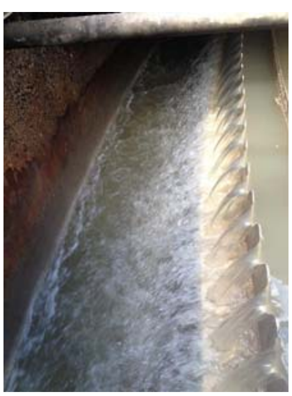
DO entrainment issues

Primary Weir Drop



Primary-Secondary Headloss

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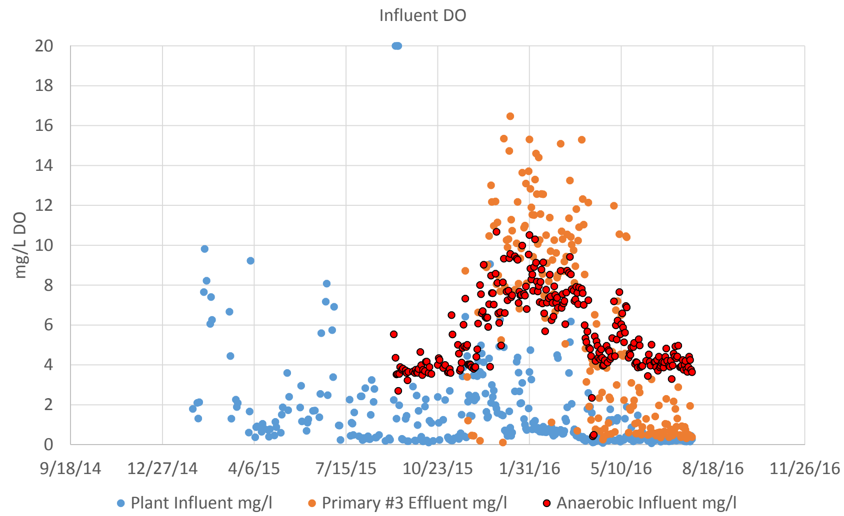
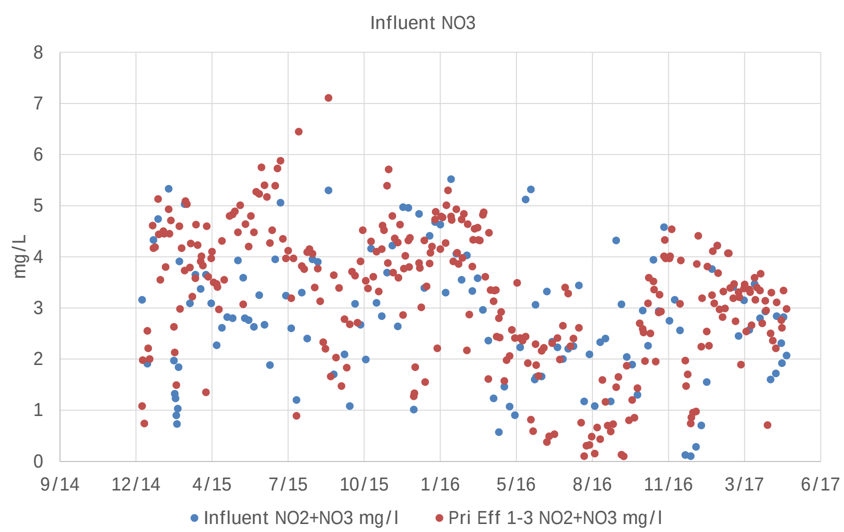
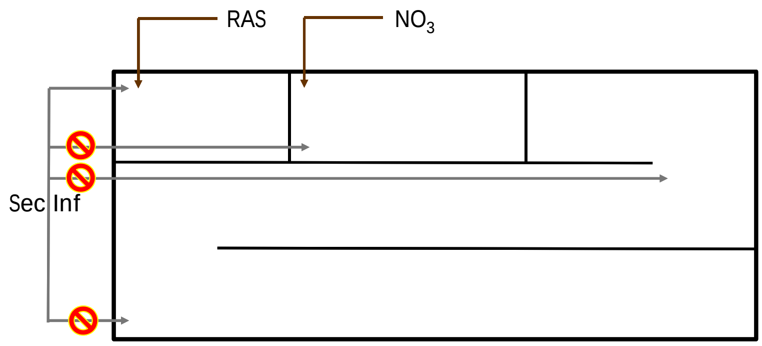
Dissolved Oxygen



Double check the nitrate



Step feed mods - Standard Plug Flow



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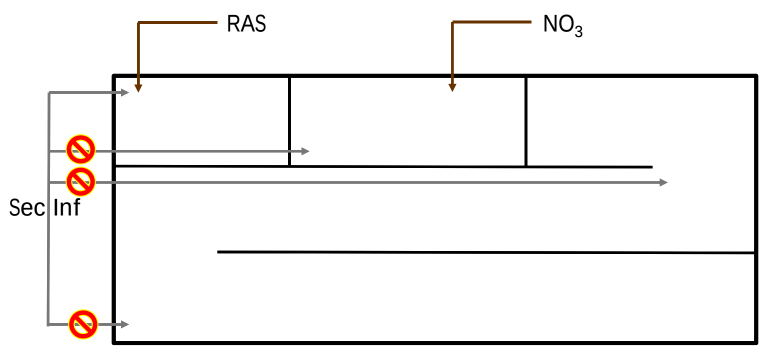
Step feed mods - Extend the anaerobic zone (decreases the anoxic zone)



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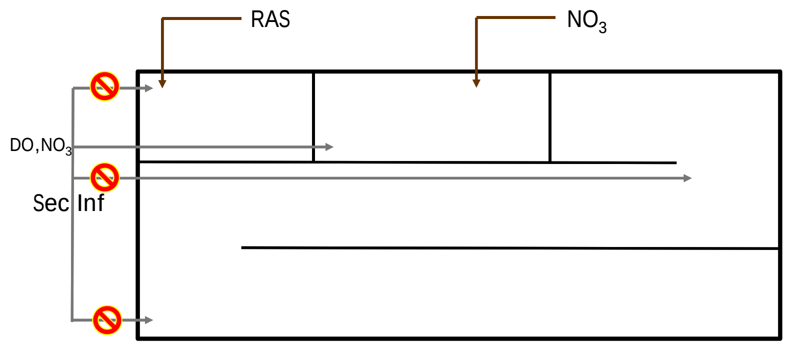
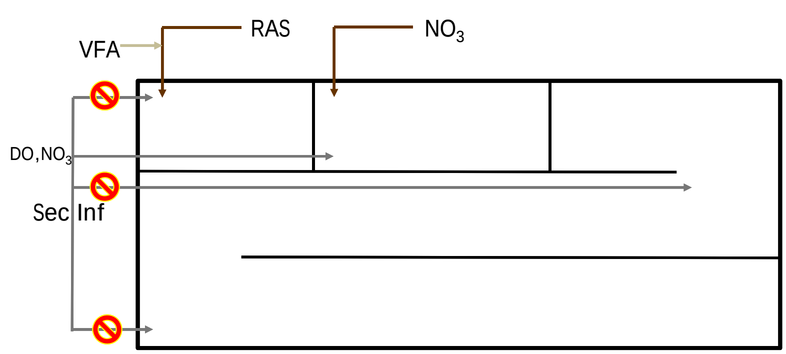
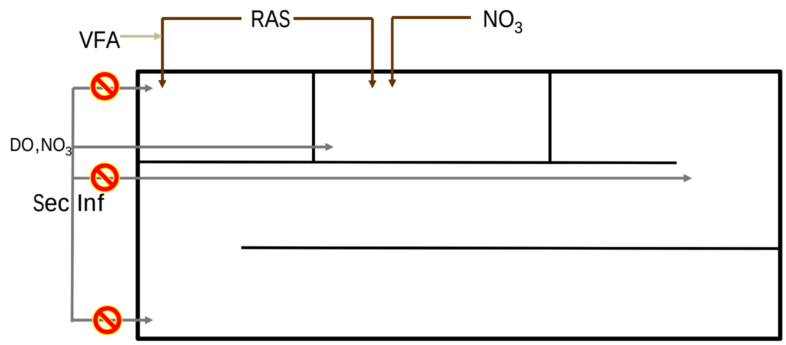
Step feed mods - Protect the anaerobic zone



Step feed mods - Enhance PHA formation with VFA source Optimize denitrification



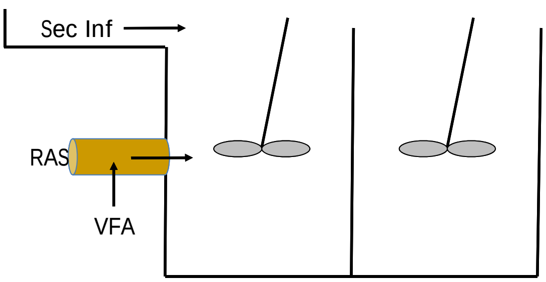
Step feed mods -
Extend the anaerobic zone by controlling RAS flow



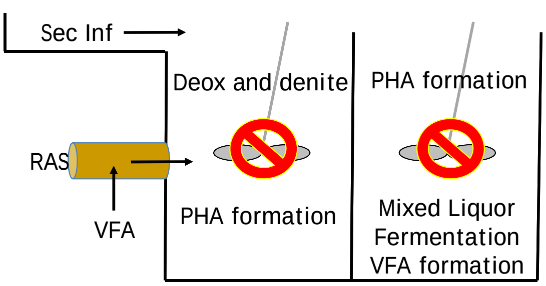
Mixing

- Why mix?
- Why not mix?
- Why not not mix?
- If mixing provides a uniform environment, stratification affords the opportunity for multiple environments.

Protecting the anaerobic zone without the ability to step feed



Protect the anaerobic zone without the ability to step feed



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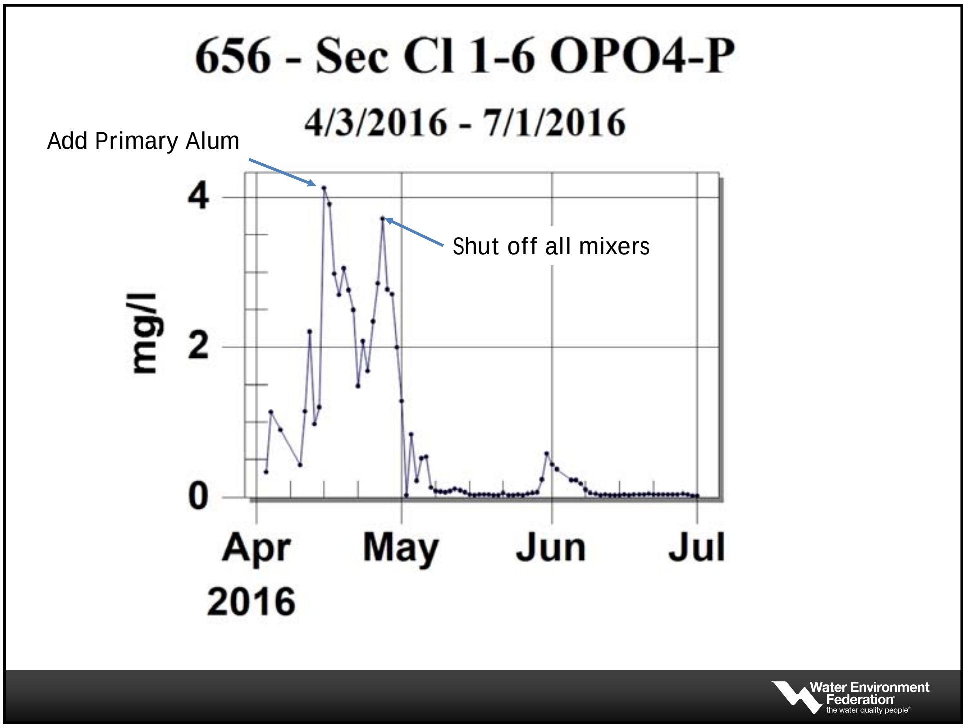

Summary

- Lock down every source of DO and NO_3 that can poison the anaerobic zone
  - Influents, Back-mixing, mixing
- Control VFA
  - Production, dosing, fate (PHA)

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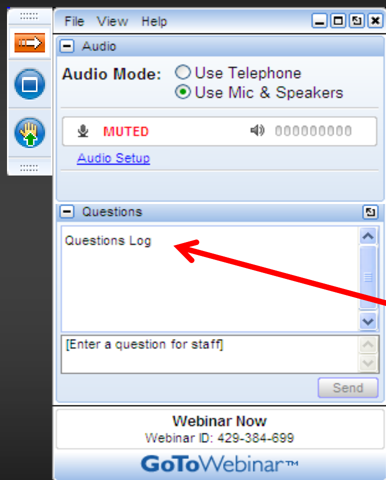
Questions?



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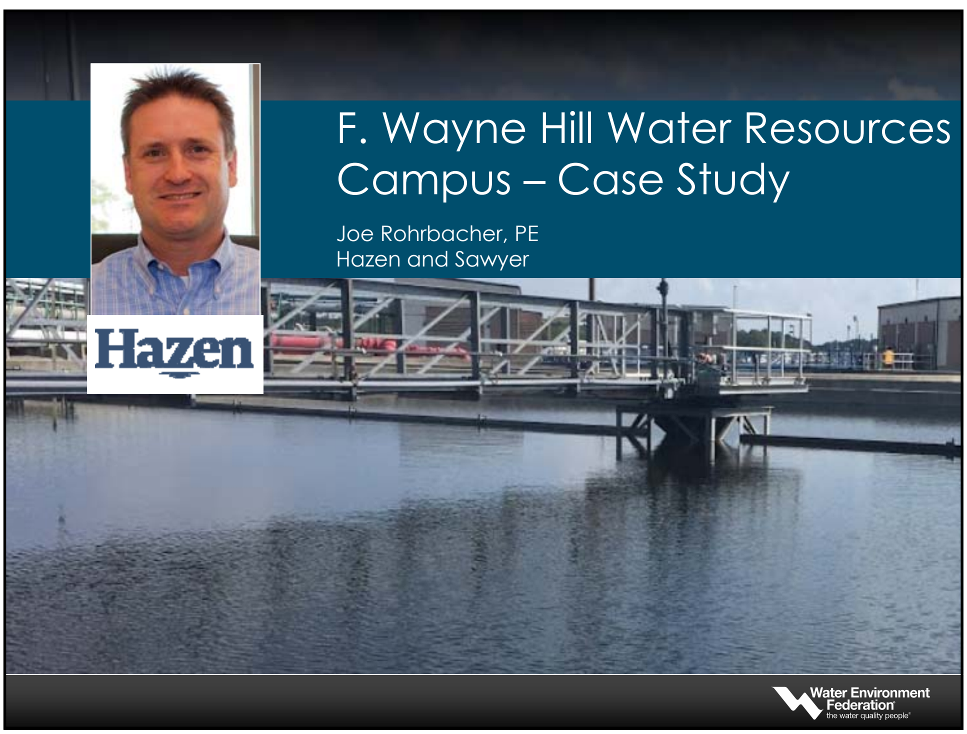
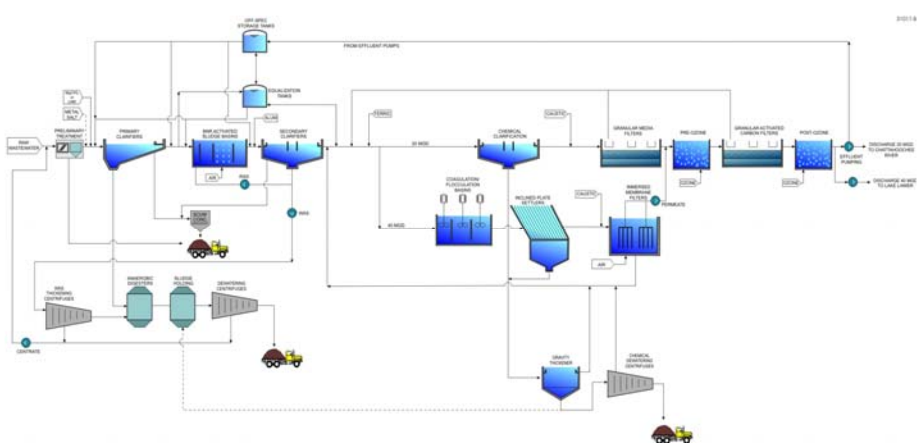


F. Wayne Hill WRC

- Gwinnett County, GA
- 60 mgd advanced WWTP
  - 30-35 mgd current flow
- 0.08 mg/L TP effluent limit
- IPR, Nutrient Recovery, Energy Recovery (CHP/FOG/HSW)

FWHWRC Process Flow Diagram



Treated Effluent Discharged to Indirect Potable Reuse

- BNR activated sludge
- Tertiary clarification
- Tertiary UF membrane filtration
- O_3/BAC/O_3

Lake Lanier

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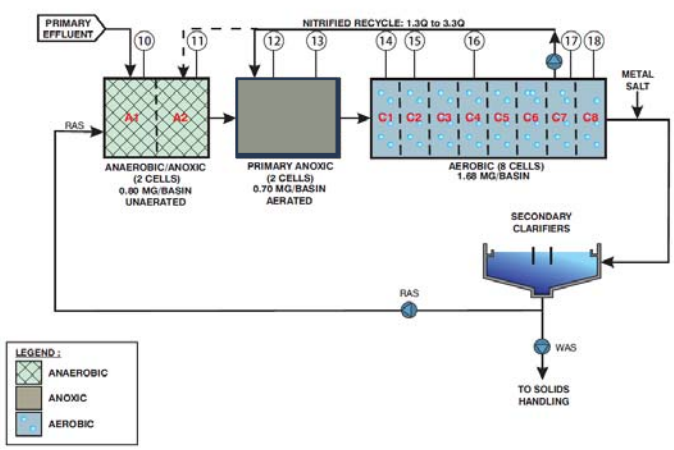
FWHWRC BNR Process Configuration



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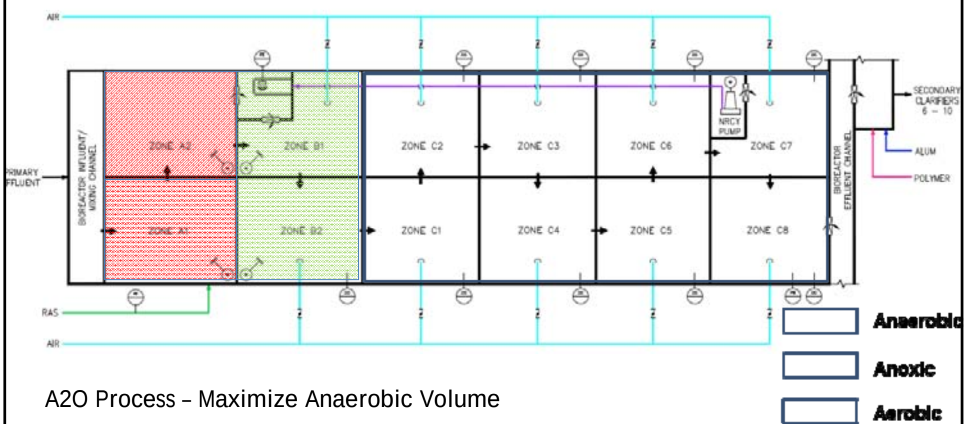
FWRWRC Basins Configuration



A2O Process – Maximize Anaerobic Volume

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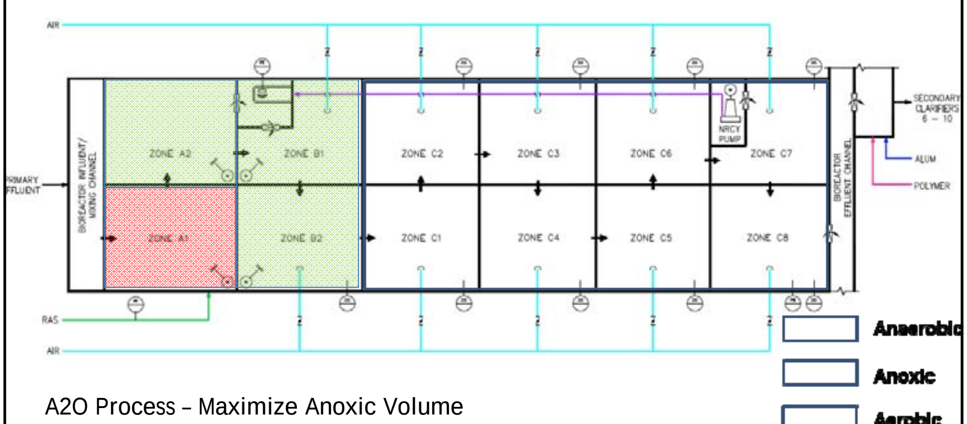
FWRWRC Basins Configuration



A2O Process – Maximize Anoxic Volume

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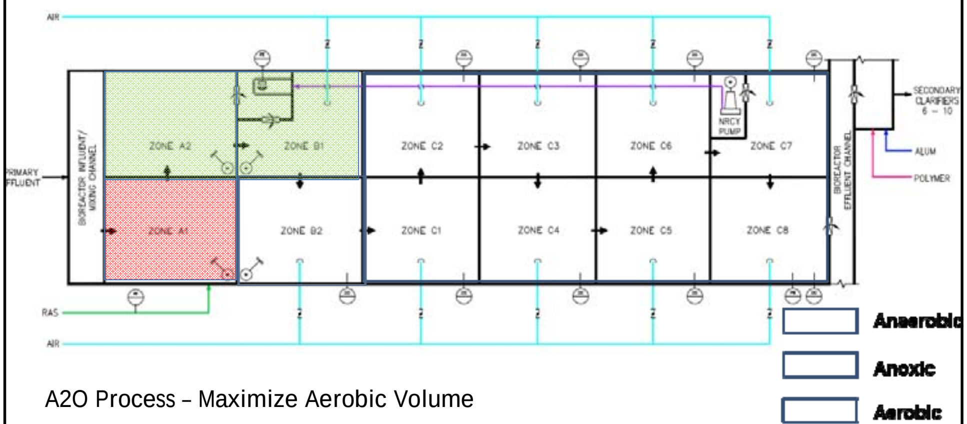
FWRWRC Basins Configuration



A2O Process – Maximize Aerobic Volume

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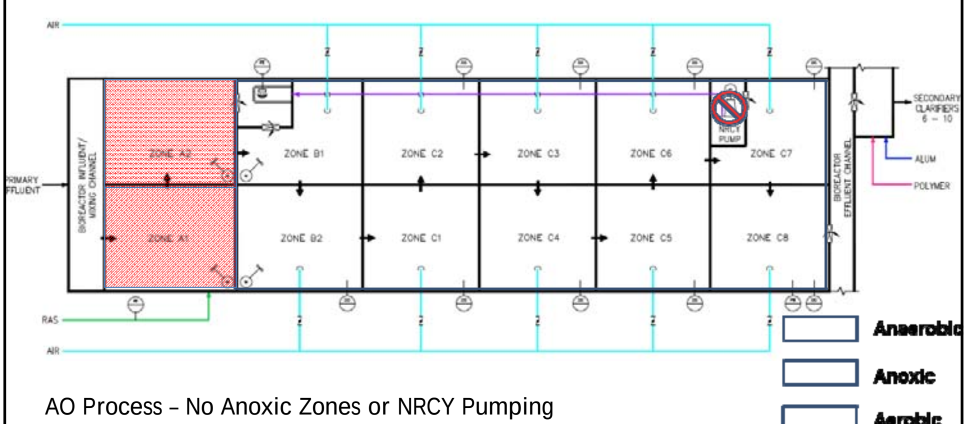
FWRWRC Basins Configuration



AO Process – No Anoxic Zones or NRCY Pumping

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Nutrient Recovery Facility was put Online in Summer 2015

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Economic Evaluation of Struvite Control: Nutrient Recovery vs. Ferric Addition

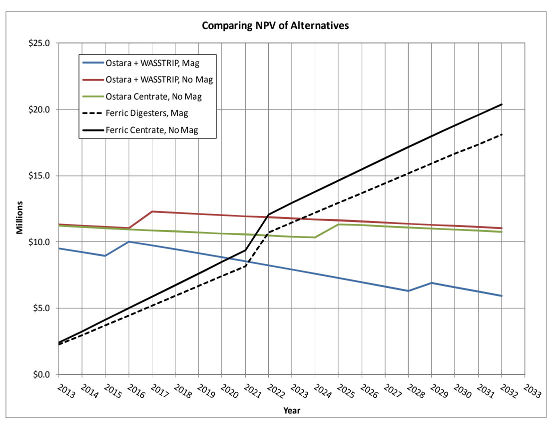
20 YR NPV showed payback over ferric

< 10 years

Sensitivity analyses

- Price of ferric
- Energy cost
- Fertilizer price
- Inflation rate

All affected NPC but did not change rank.



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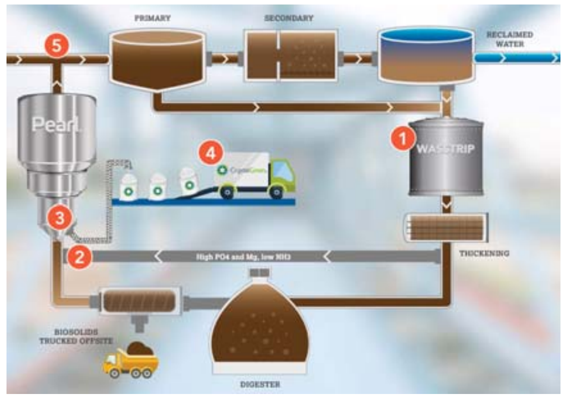
Nutrient Recovery – Recovering Phosphorus and Nitrogen Fertilizer

25 to 30 bags per month



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Nutrient Recovery Equipment and Product

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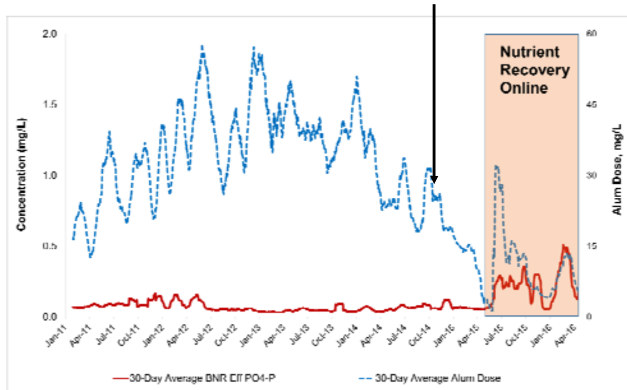
Alum Dose has Trended Downwards over past Few Years

Operator Training Reduced Alum Feed



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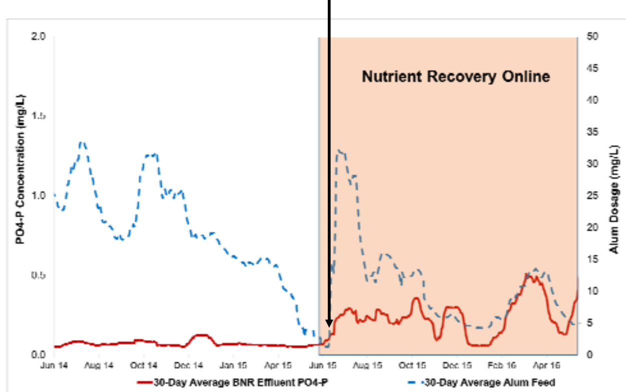
SCE PO4-P Concentration Setpoint was Increased

SCE PO_4-P setpoint changed from 0.1 to 0.3 mg/L



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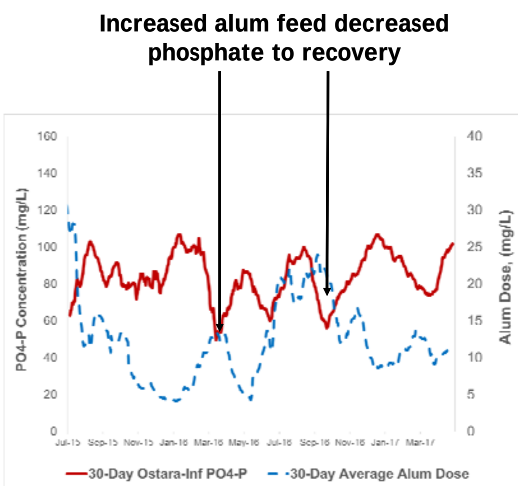
Ostara Influent TP vs Alum Dose



Alum Dose has Decreased 64% since Nutrient Recovery Online

	2011	2012	2013	2014	2015	2016
Inf. TP, mg/L	8.3	9.7	9.4	8.8	9.2	9.1
PCE TP, mg/L	7.7	9.4	6.3	7.0	6.1	6.5
SCE TP, mg/L	0.22	0.23	0.21	0.23	0.39	0.72
TCE TP, mg/L	0.16	0.14	0.13	0.15	0.12	0.17
Final Eff. TP, mg/L	0.04	0.05	0.05	0.04	0.03	0.05
Alum Dose, mg/L	26	41	41	27	12	13

Alum Dose has been reduced from 32 mg/L to 12 mg/L average since nutrient removal online

Implementing Nutrient Recovery - Lessons Learned

- Operator training reduces operational costs, improves performance
- Transition chemical feed to tertiary processes to optimize biological P and nutrient recovery
- Careful control of chemical feed needed to optimize nutrient recovery

F. Wayne Hill Nutrient Recovery Advantages

- Eliminated nuisance struvite issues
- Significant reduction in alum use for P limit
- Benefit to dewatering

Year	Avg Dewatering Polymer Dose Rate (lb/DT)
2013	51
2014	44
2015	**32**
2016	**28**

Year	Avg Dewatering Cake Solids %TS Concentration (%TS)
2013	21.8
2014	22.2
2015	**23.4**
2016	**23.9**

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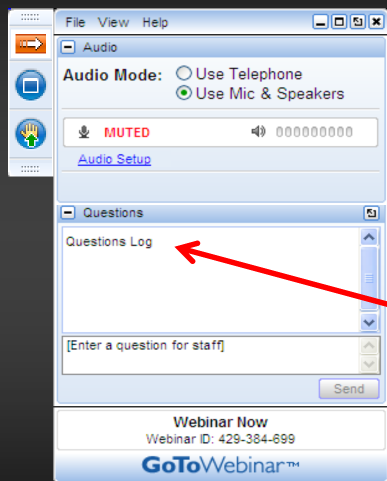
Questions?



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