

PHOSPHORUS REMOVAL SCIENCE & TECHNOLOGY

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CLEAN WATER OPS.COMTM

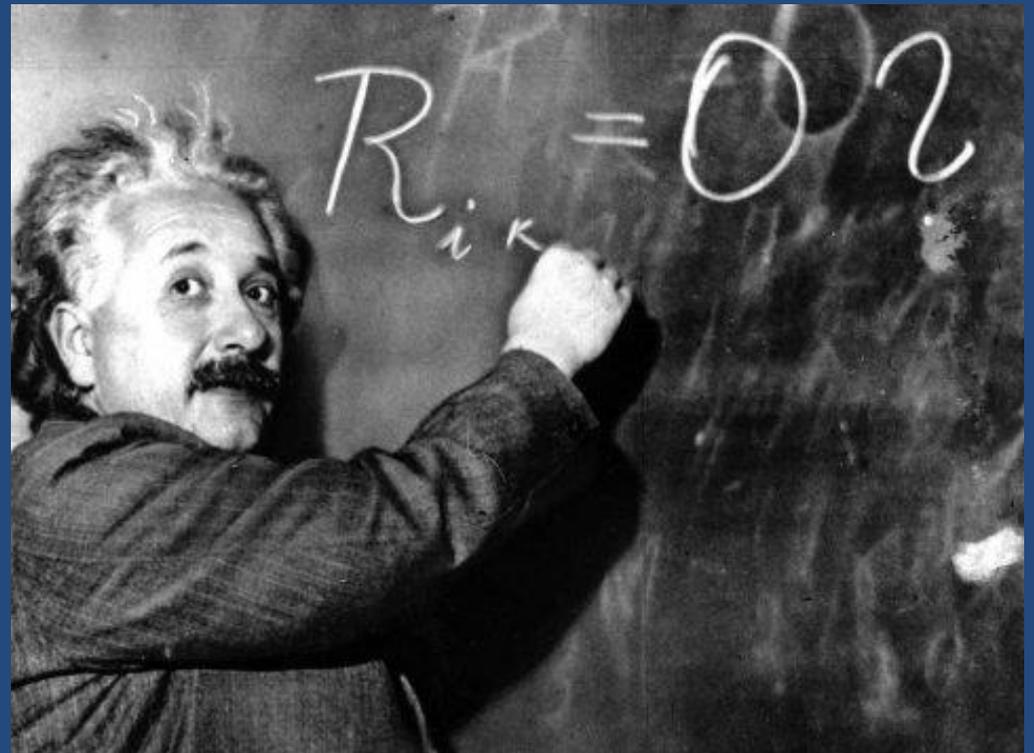


Phosphorus Removal

Part 1: Science & Technology

Part 2: Case Studies

Part 3: Class Exercise



Creating Optimal Habitats



THE SCIENTIFIC METHOD

? **PURPOSE** ?
WHAT DO I WANT TO LEARN?

Research 
Find out as much about your topic as you can.

 **HYPOTHESIS**
Predict what the answer to the problem is.

EXPERIMENT 
Design a test to confirm or disprove your hypothesis.

Analysis
 Record what happened during the experiment.

Conclusion
Was my hypothesis correct?



Wastewater Science
Alkalinity and pH

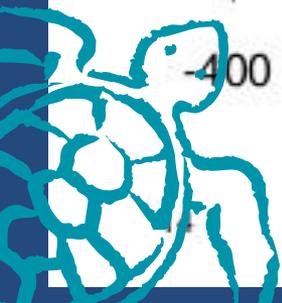
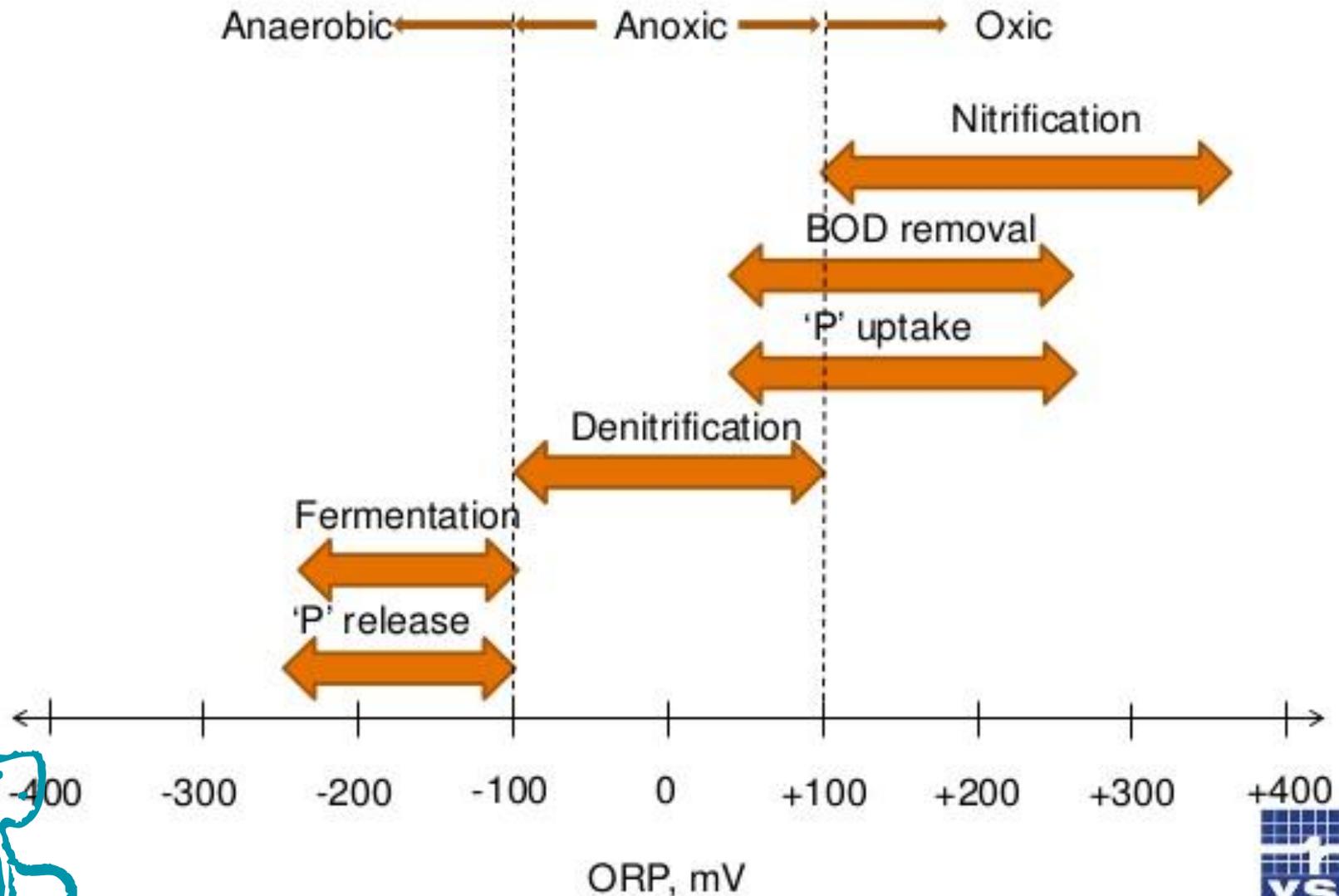


Wastewater Science

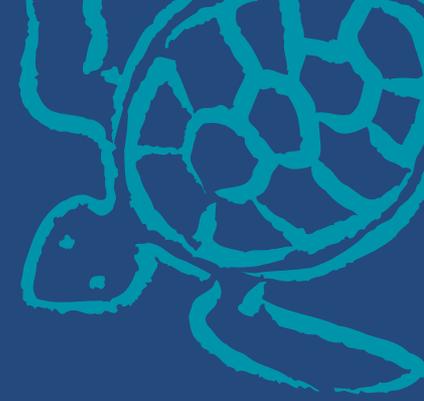
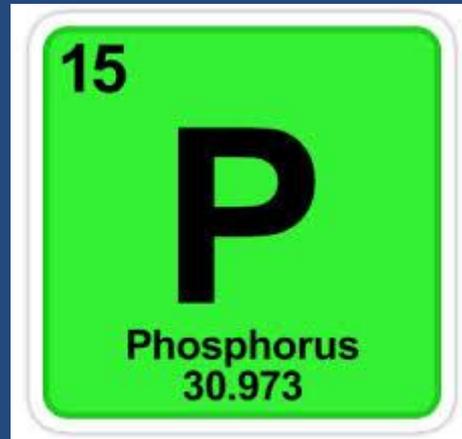
DO (Dissolved Oxygen) and ORP (Oxygen Reduction Potential)



What Does ORP Tell Us About Our Process?



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Phosphorus Removal: What an Operator needs to know

ortho-Phosphate = soluble phosphorus

reactive phosphorus, phosphate, ortho-P, PO_4 , PO_4^- , PO_4^{-2}

total-Phosphorus = soluble + particulate phosphorus

phosphorus, total-P, t-P, tP, P



Phosphorus Removal: What an Operator needs to know, cont'd

ONE. Convert soluble phosphorus to TSS ...

Biologically

Chemically

TWO. Remove TSS



Typical plant

Influent phosphorus: 6 mg/L

Effluent phosphorus: 3 mg/L

Effluent TSS: 15 mg/L

Effluent total-P = particulate P + soluble P

How much effluent phosphorus is soluble and how much is in the TSS?

Approximately 1% of effluent TSS (conventional plant) is phosphorus ...

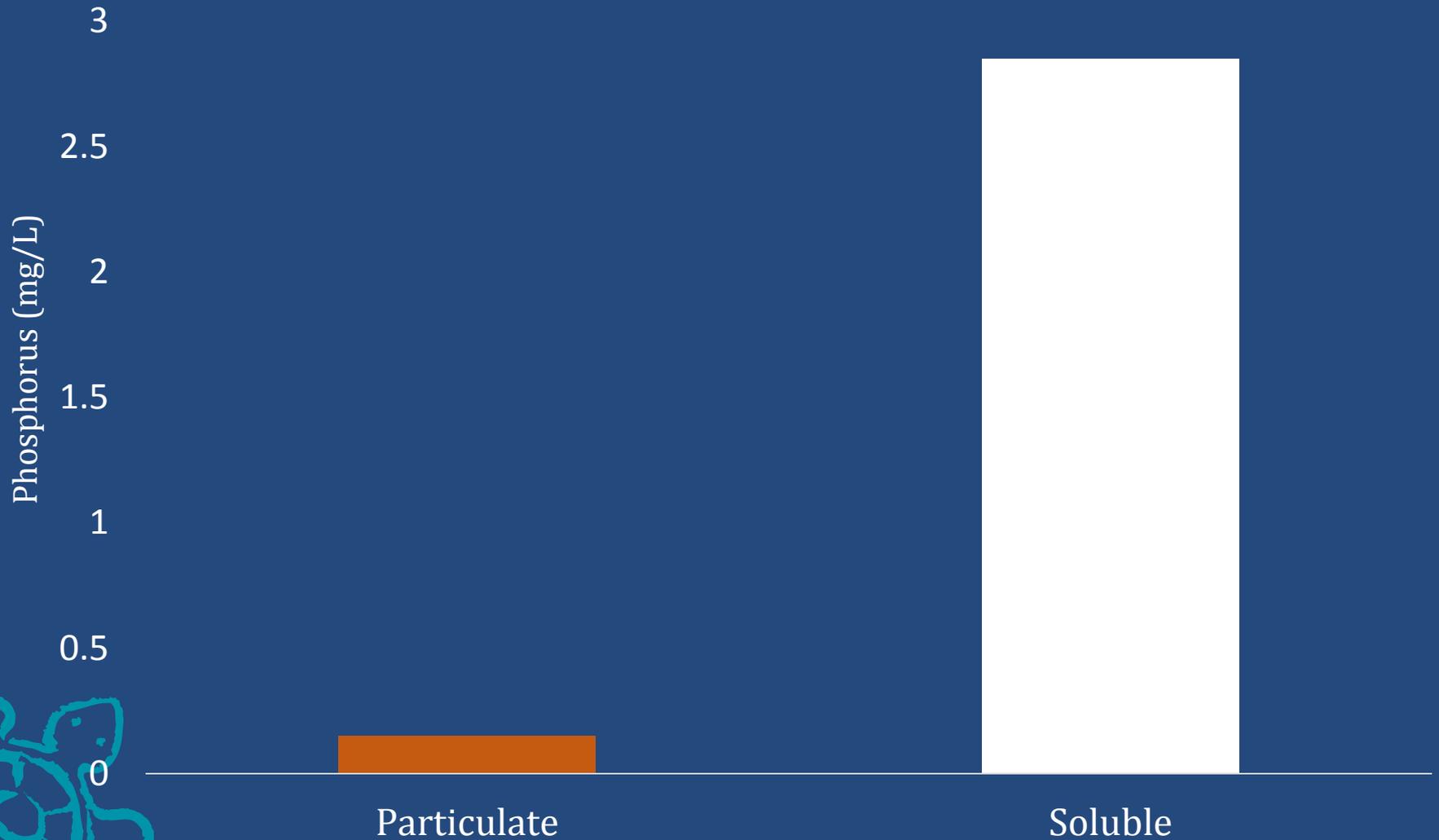
Effluent P = particulate P + soluble P

Particulate (P in the TSS): 15 mg/L TSS x 0.01 = **0.15** mg/L

Soluble = 3 mg/L – 0.15 mg/L with TSS = **2.85** mg/L



Example: effluent phosphorus (mg/L) Before Phosphorus Removal (Biological or Chemical)



Converting SOLUBLE phosphorus to PARTICULATE phosphorus

Biological Phosphorus removal, when fully optimized, will remove all but 0.05 mg/L of the soluble Phosphorus

and

Chemical Phosphorus removal, the same, all but 0.05 mg/L

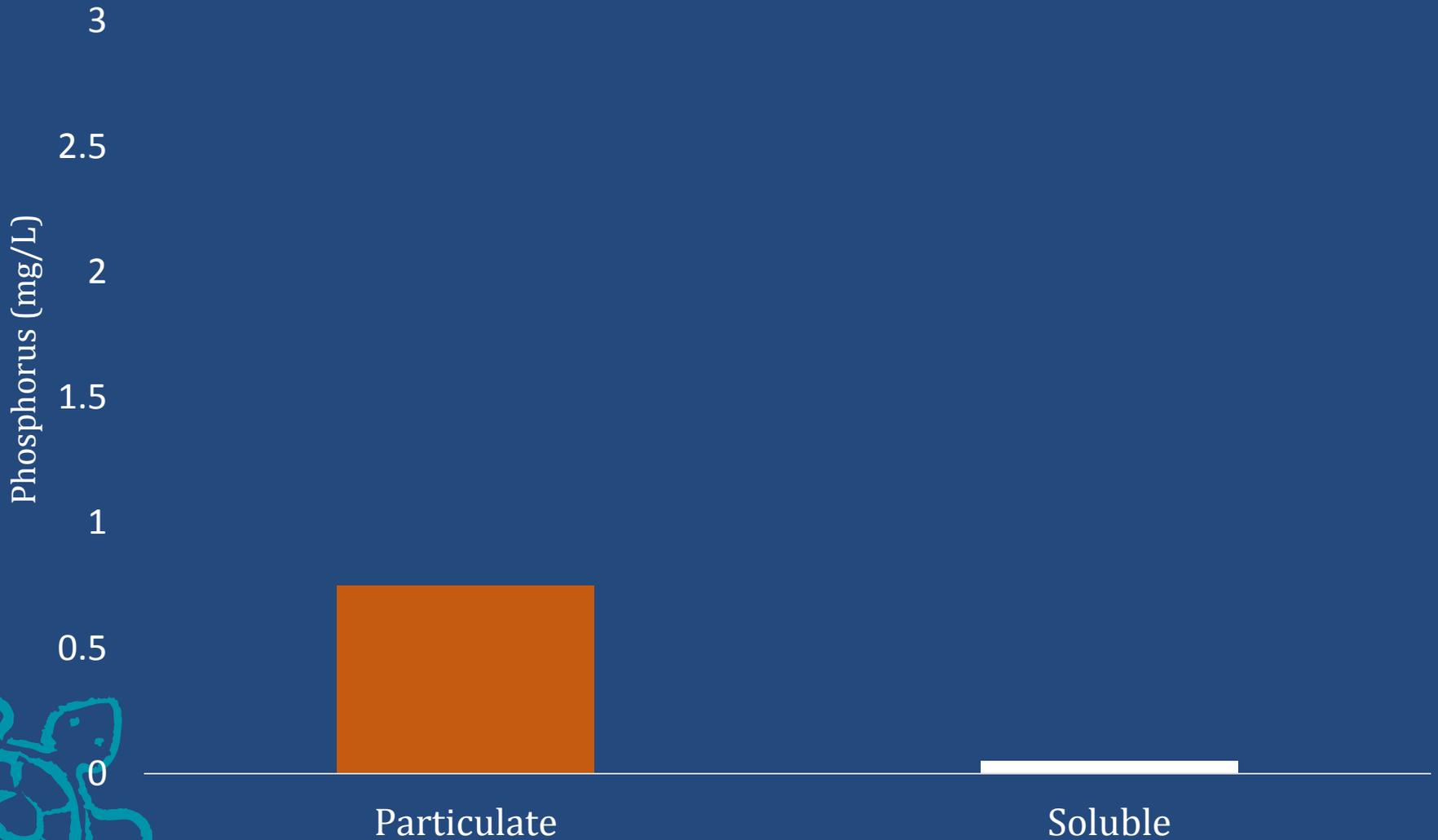
Either way, only 0.05 mg/L of soluble Phosphorus remains; most all of it is particulate Phosphorus ... that is, effluent TSS

Meanwhile ...

The vast majority of the soluble phosphorus is converted to particulate phosphorus; increasing the percentage of the MLSS and TSS that is P from ~1% to ~5%



Example: effluent phosphorus (mg/L)
After Phosphorus Removal (Biological or Chemical)



TSS Removal Requirements

Since all but 0.05 mg/L of the soluble Phosphorus can be converted to TSS Phosphorus (Biologically and/or Chemically)

And, because approximately 5% of Effluent TSS is Phosphorus

... To meet a total-P limit, the effluent TSS needs to be kept to the max TSS number shown in the table.

P Limit	max TSS
0.1	1
0.2	3
0.3	5
0.4	7
0.5	9
0.6	11
0.7	13
0.8	15
0.9	17
1.0	19
1.1	21
1.2	23
1.3	25
1.4	27
1.5	29



Intro: Biological Phosphorus Removal

Step 1: prepare “dinner”

VFA (volatile fatty acids) production in anaerobic/fermentive conditions

Step 2: “eat”

Bio-P bugs (PAOs) eat VFAs in anaerobic/fermentive conditions ... temporarily releasing more P into the water

Step 3: breathe and grow

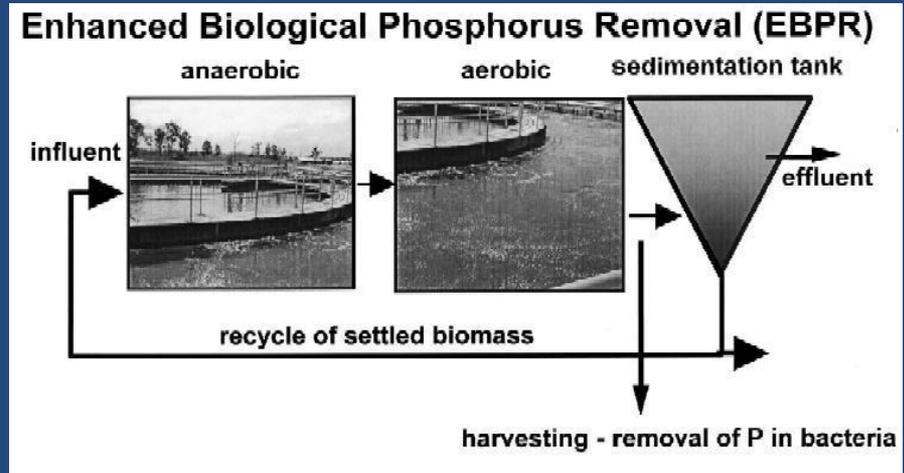
Bio-P bugs (PAOs) take in almost all of the soluble P in aerobic conditions as they grow and reproduce



Biological Phosphorus Removal: Converting LIQUID phosphorus to SOLID phosphorus

Zero Oxygen Habitat (Fermentation)

Bacteria break down BOD to create volatile fatty acids (VFAs)
Other bacteria (PAOs: phosphate accumulating organisms) take in the VFAs as an energy source and temporarily release more ortho-P into solution

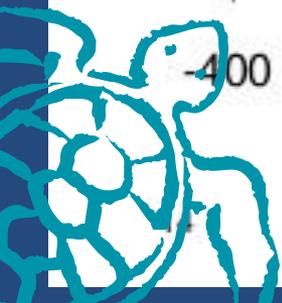
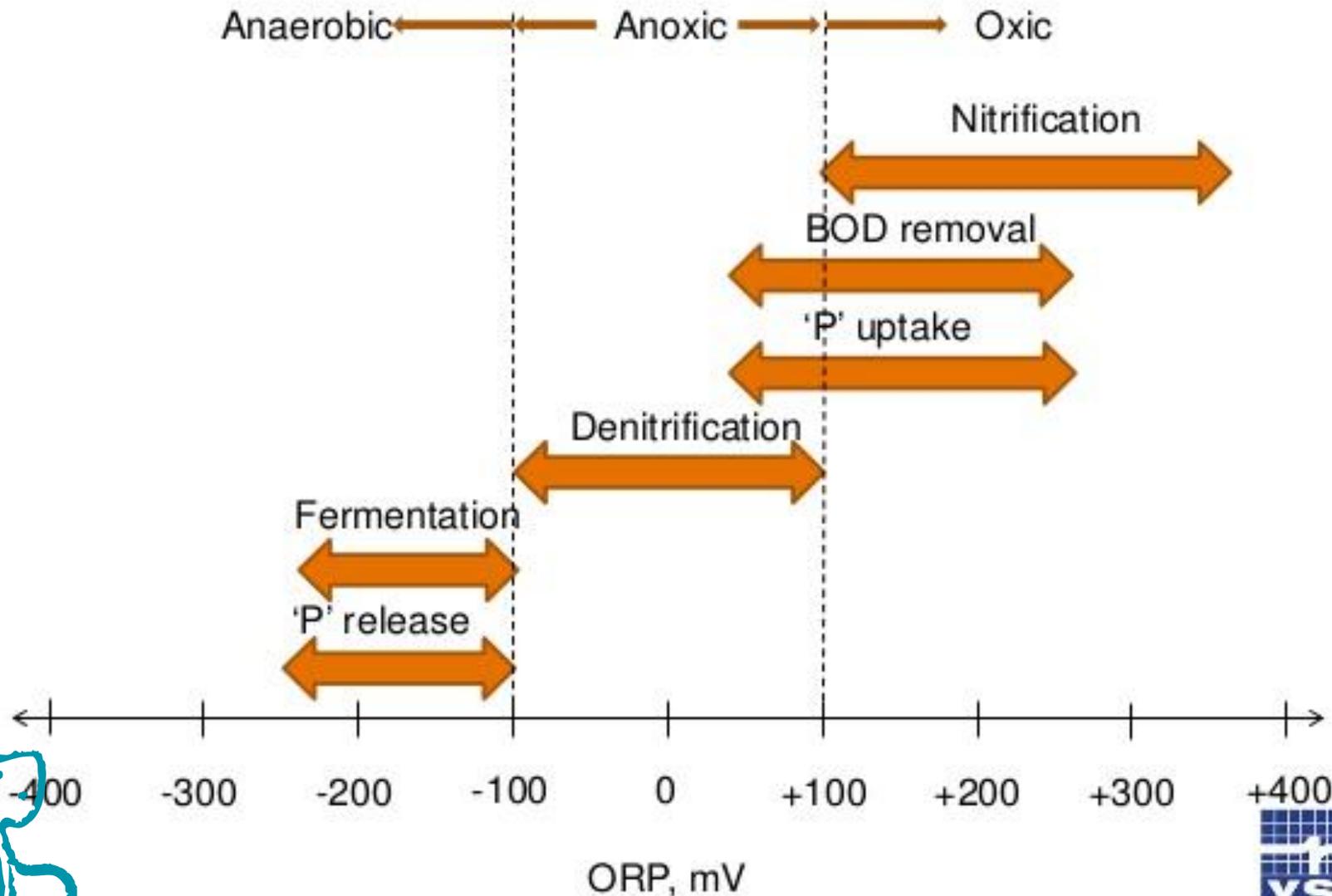


Oxygen Rich Habitat (Aeration Tank)

PAO bacteria use the stored energy to “bulk up” on ortho-P

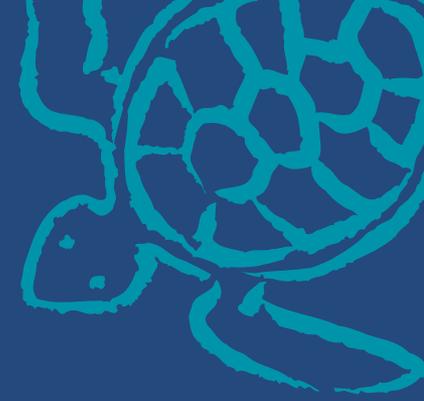


What Does ORP Tell Us About Our Process?

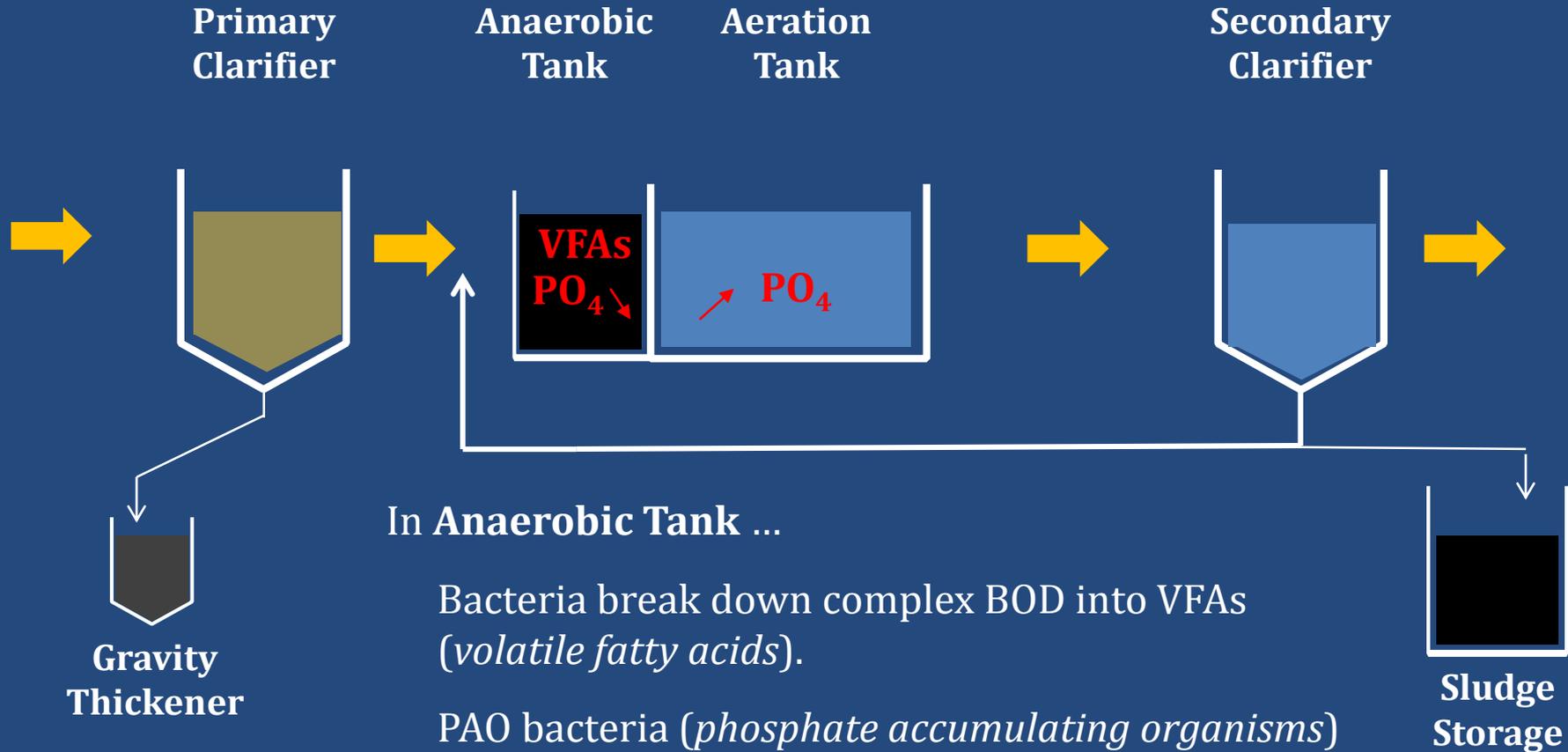


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*Biological Phosphorus Removal:
Mainstream Flow Fermentation Processes*



Bio-P Removal: Mainstream Fermentation Process



In Anaerobic Tank ...

Bacteria break down complex BOD into VFAs (*volatile fatty acids*).

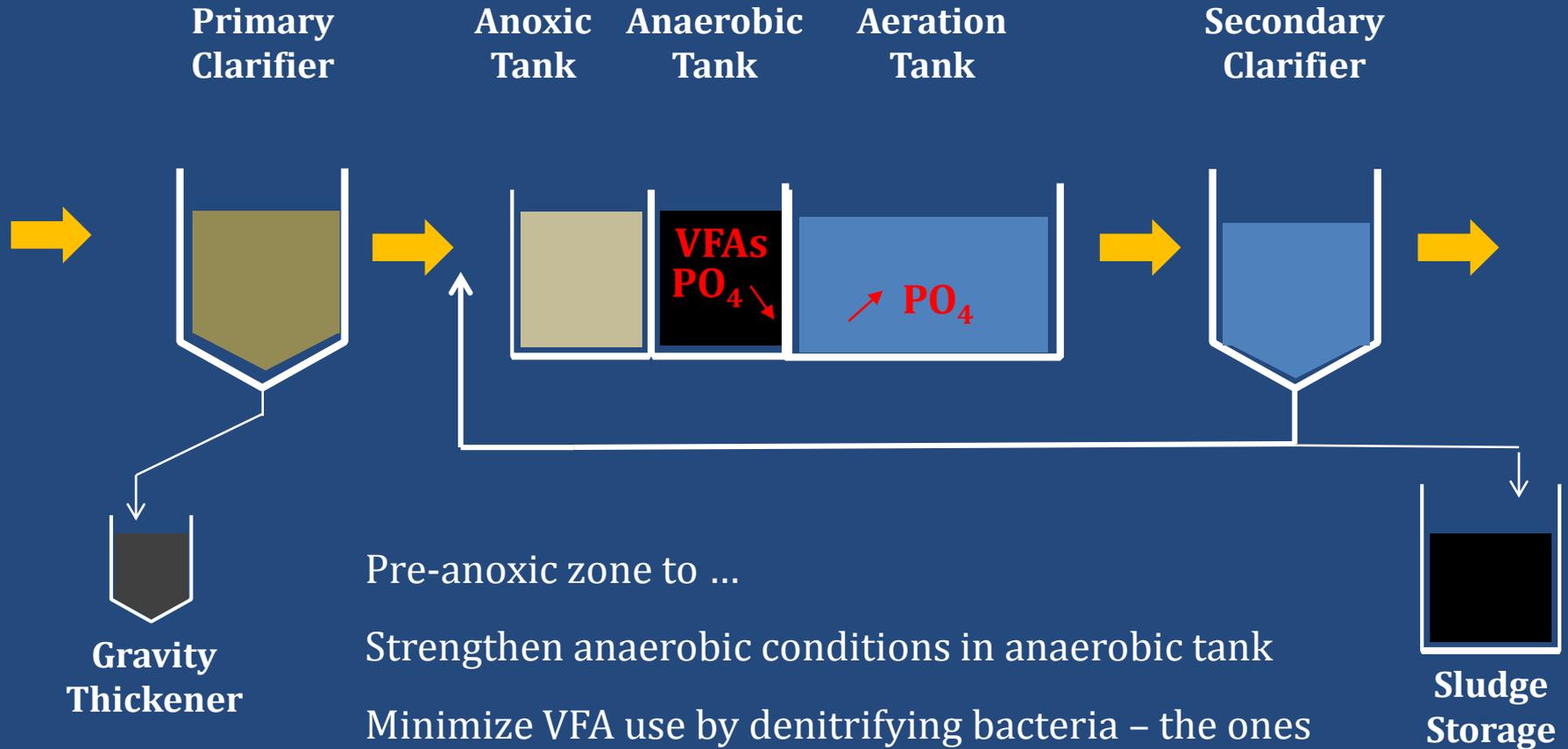
PAO bacteria (*phosphate accumulating organisms*) take in VFAs as energy source & temporarily release PO₄ (*phosphate*) into solution.

In Aeration Tank ...

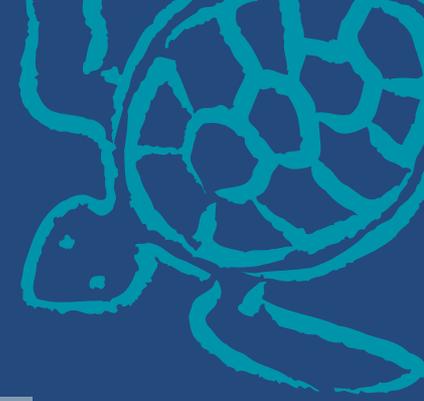
Energized PAO bacteria take PO₄ out of solution.



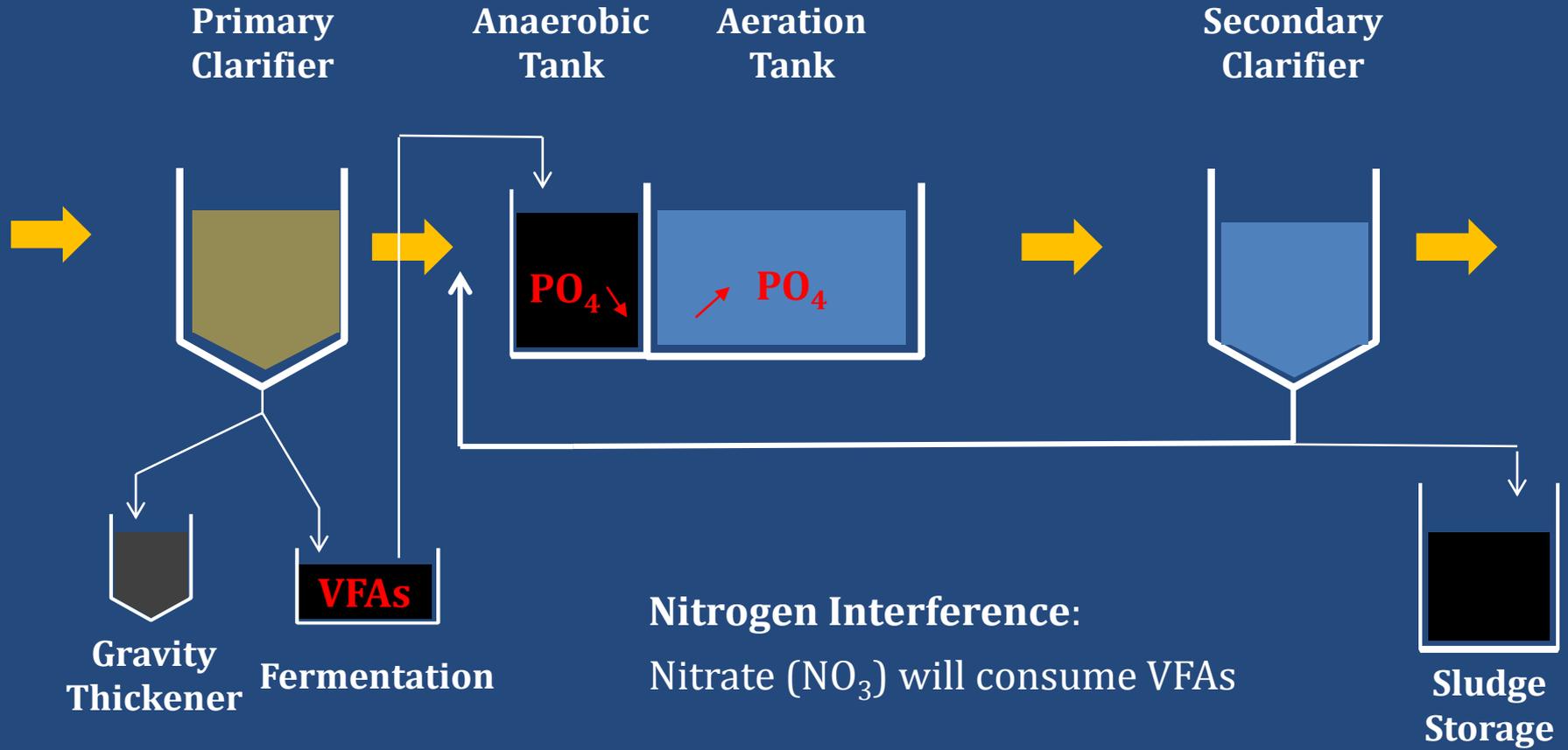
Bio-P Removal: Mainstream Fermentation Process



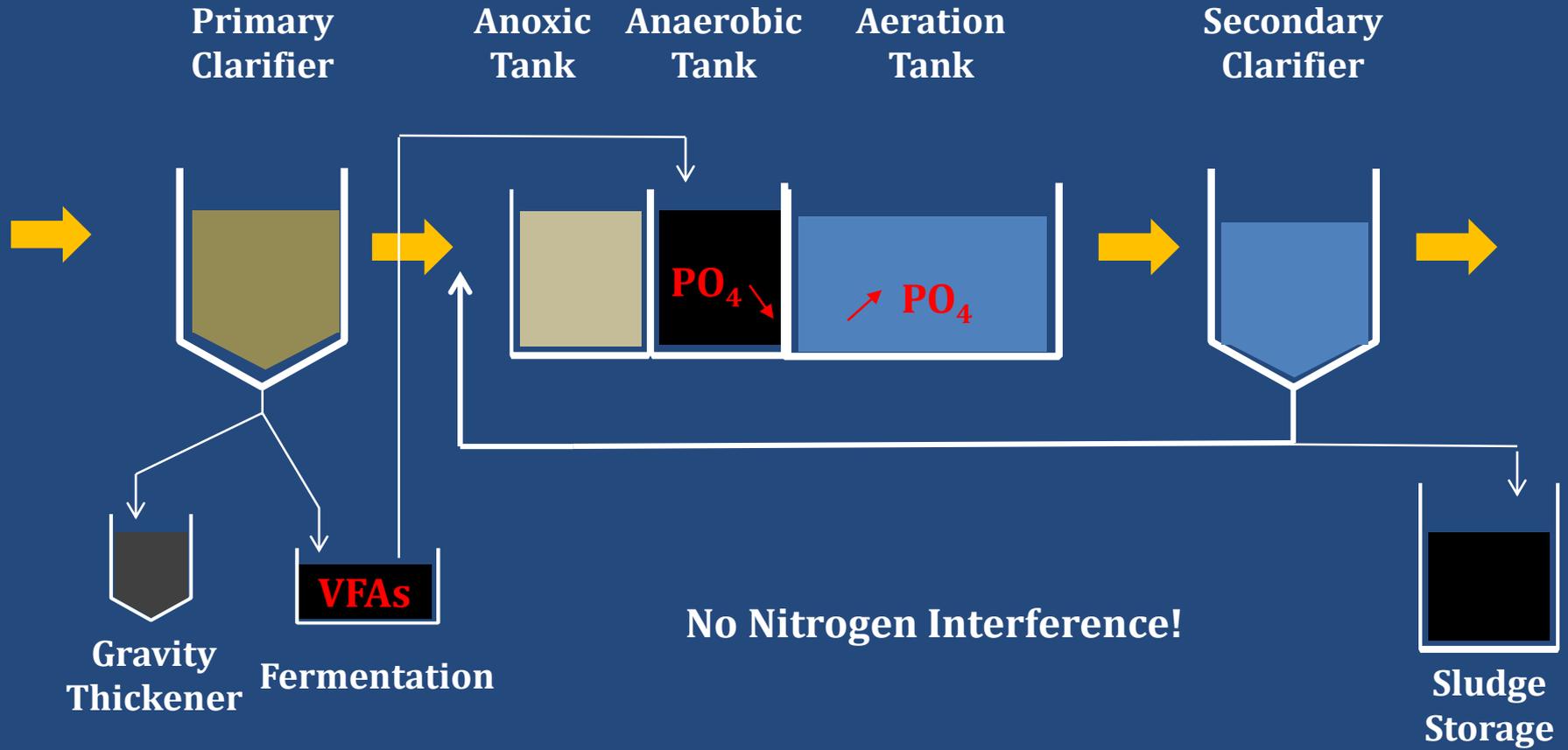
*Biological Phosphorus Removal: Combined
Sidestream & Mainstream Fermentation*



Bio-P Removal: Sidestream Fermentation Process



Bio-P Removal: Sidestream Fermentation Process



Optimizing Bio-P Removal: Mainstream or Sidestream Fermentation

Anaerobic Tank

~1 hour HRT*

ORP of -200 mV*

25 times as much BOD as influent ortho-P*

Ortho-P release (3 times influent ortho-P)*

Aeration Tank

High DO / High ORP

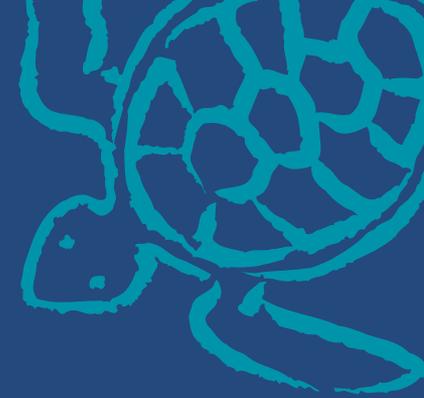
pH of 6.8+*

Ortho-P concentration of 0.05 mg/L*

*Approximate: Every Plant is Different



**BACKGROUND
INFORMATION**



	total-Phosphorus (mg/L)		
	before	after	
Conrad, Montana	2.1	0.15	
Keene, New Hampshire	1.0	0.20	50% less chemicals
Chinook, Montana	2.8	0.30	
East Haddam, Connecticut (2 month trial)	3.5	0.35	
Palmer, Massachusetts	0.5	0.50	25% less chemicals
Westfield, Massachusetts	0.5-2.5	0.50	50% less chemicals
Athens, Tennessee: Oostanaula	0.5	0.50	100% less chemicals
Plainfield, Connecticut: Village Plant	2.5	0.70	
Suffield, Connecticut	3.0	0.70	
Cookeville, Tennessee	2.0	1.4	
Helena, Montana	2.9	0.5-2.0	
Athens, Tennessee: North Mouse Creek	2.8	0.3-3.0	



Discussion

High expectations are the
key to everything.

~Sam Walton
From: RaiseYourMind.com



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