

PHOSPHORUS REMOVAL

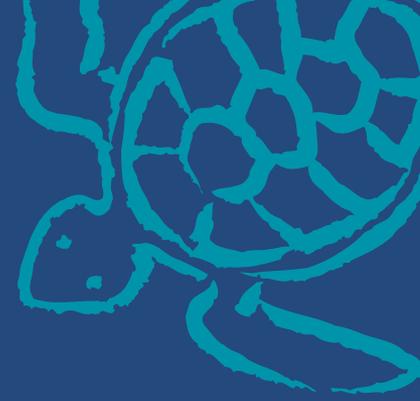
GRANT WEAVER, PE & WWTP OPERATOR
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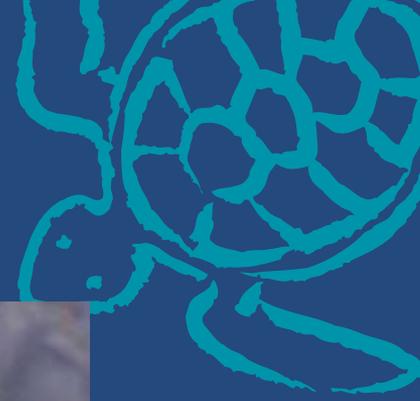
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Creating Optimal Habitats



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.

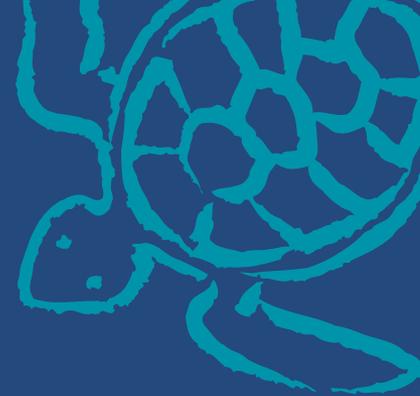


Analysis

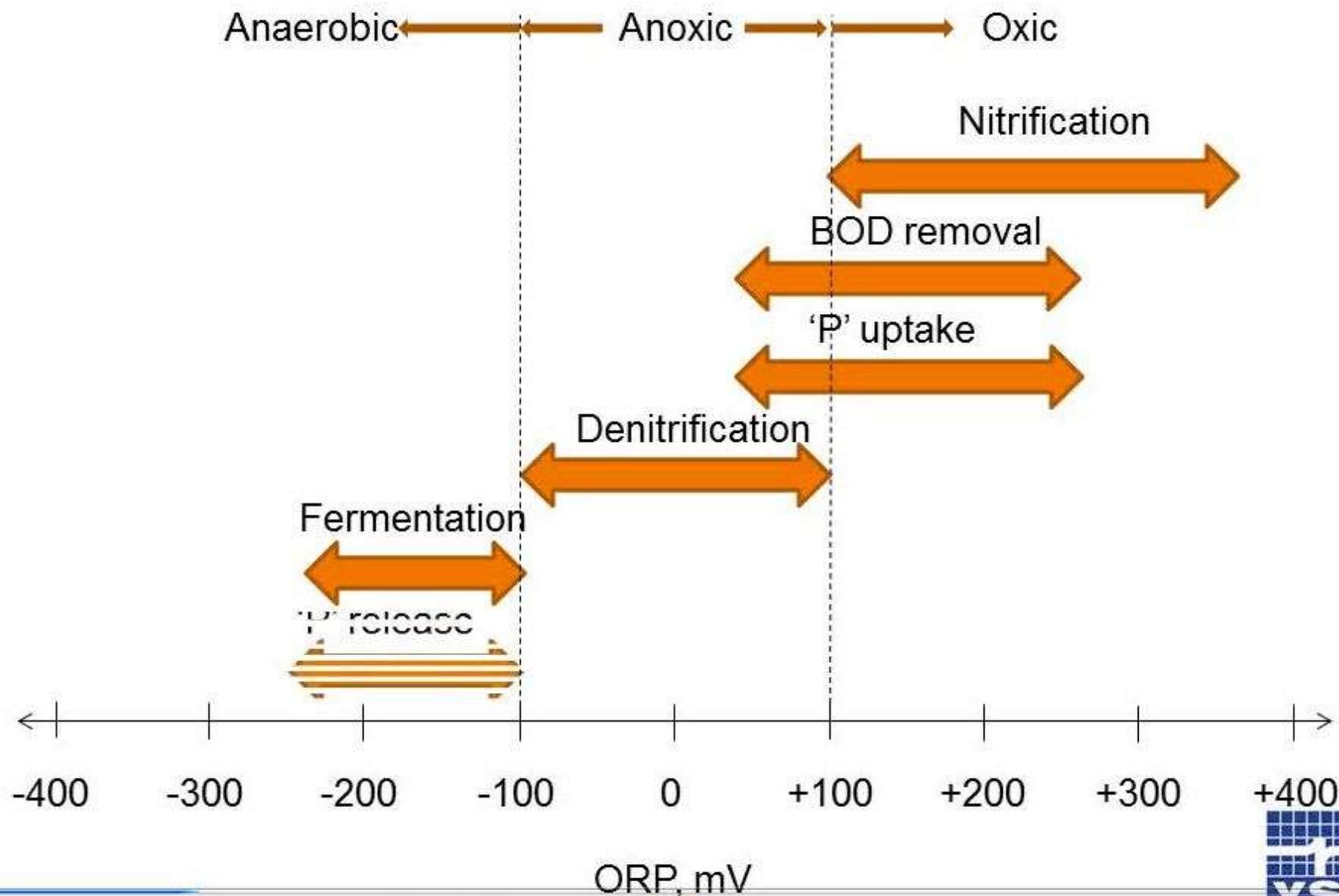
Record what happened during the experiment.

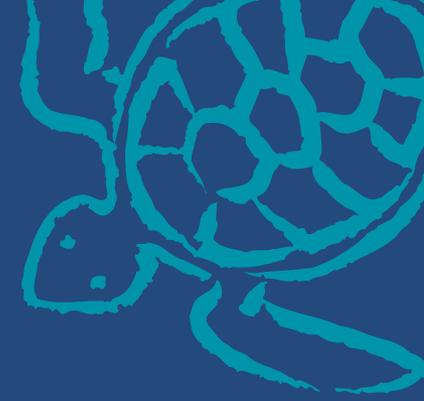
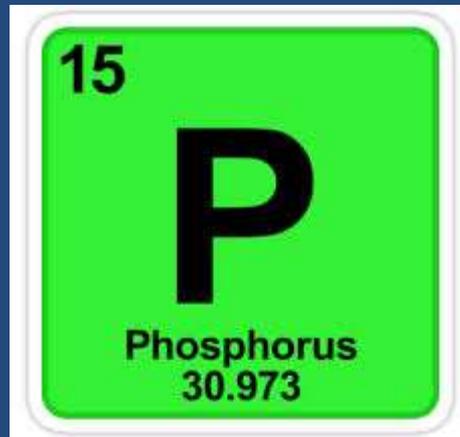
Conclusion

Was my hypothesis correct?



What does ORP tell us about our process?





Phosphorus Removal: What an Operator needs to know, Part 1

ortho-Phosphorus = soluble 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, Part 2

ONE. Convert soluble phosphorus to TSS ...

Biologically

Chemically

TWO. Remove TSS



Rules of Thumb:

0.05 mg/L of soluble phosphorus (PO_4 , ortho-P) remains after treatment

Each 1 mg/L TSS contains up to 0.05 mg/L total-P



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



Biological Phosphorus Removal: Converting liquid phosphorus to solid phosphorus

Zero Oxygen Habitat (Fermentation)

Bacteria break down BOD to create volatile fatty acids (VFAs)

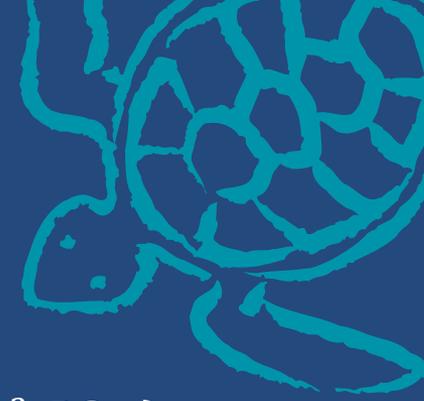
Other bacteria (PAOs: phosphate accumulating organisms) take in the VFAs as an energy source and temporarily release more ortho-P into solution

Oxygen Rich Habitat (Aeration Tank)

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



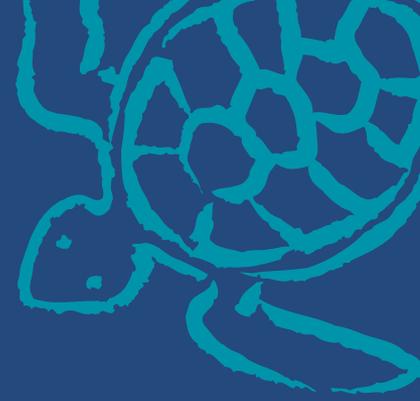
Phosphorus Terms for Operators



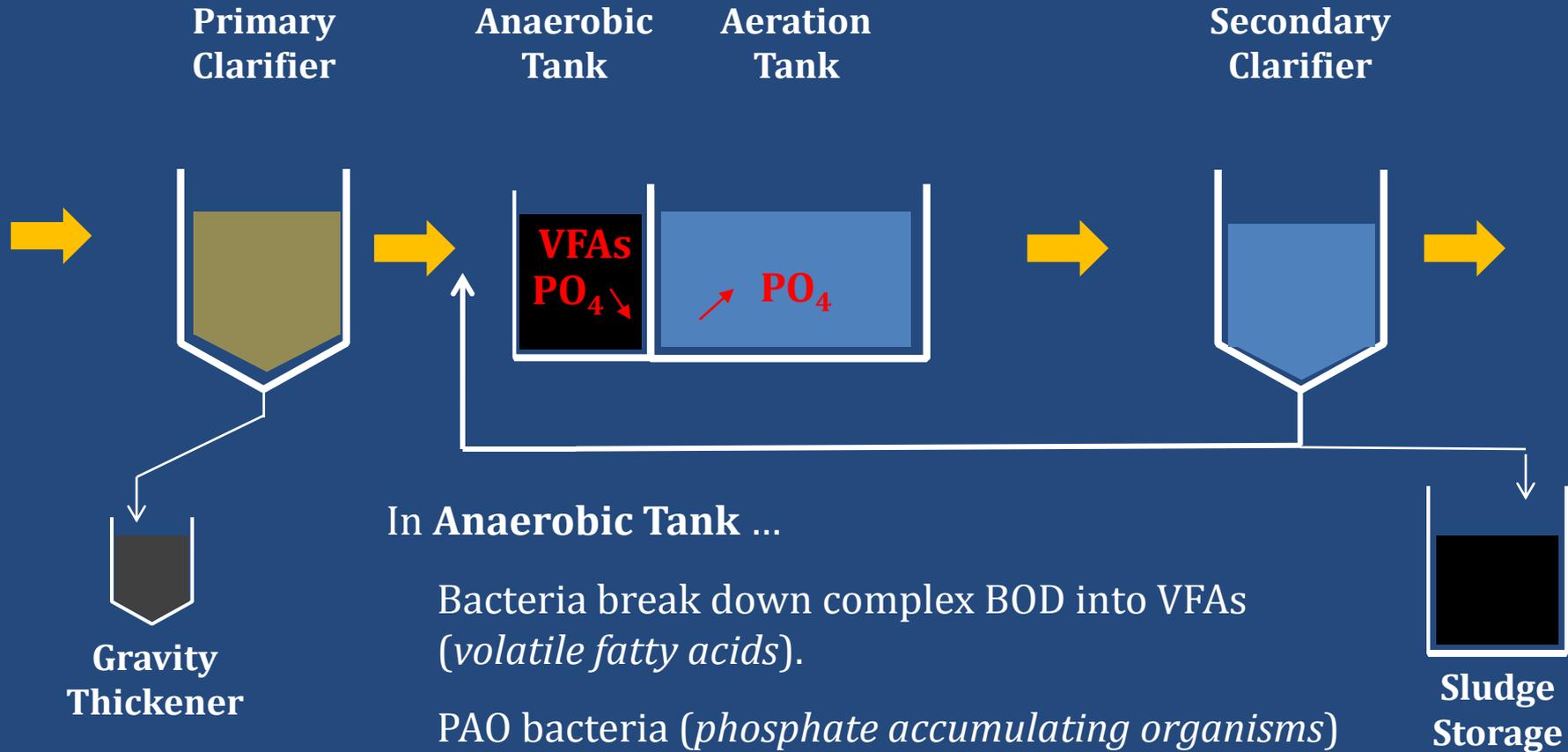
orthophosphate (ortho-phosphate, ortho-P, P_{ortho} , PO_4 , $\text{PO}_4\text{-P}$, PO_4^{-2} , PO_4^{-})
= soluble form of phosphorus

total Phosphorus (total-P, P, TP, tP, or P_{total})
= ortho-P + the P contained in TSS (total suspended solids)

*Biological Phosphorus Removal:
Mainstream Flow Fermentation Processes*



Bio-P Removal: Mainstream Fermentation Process



In Anaerobic Tank ...

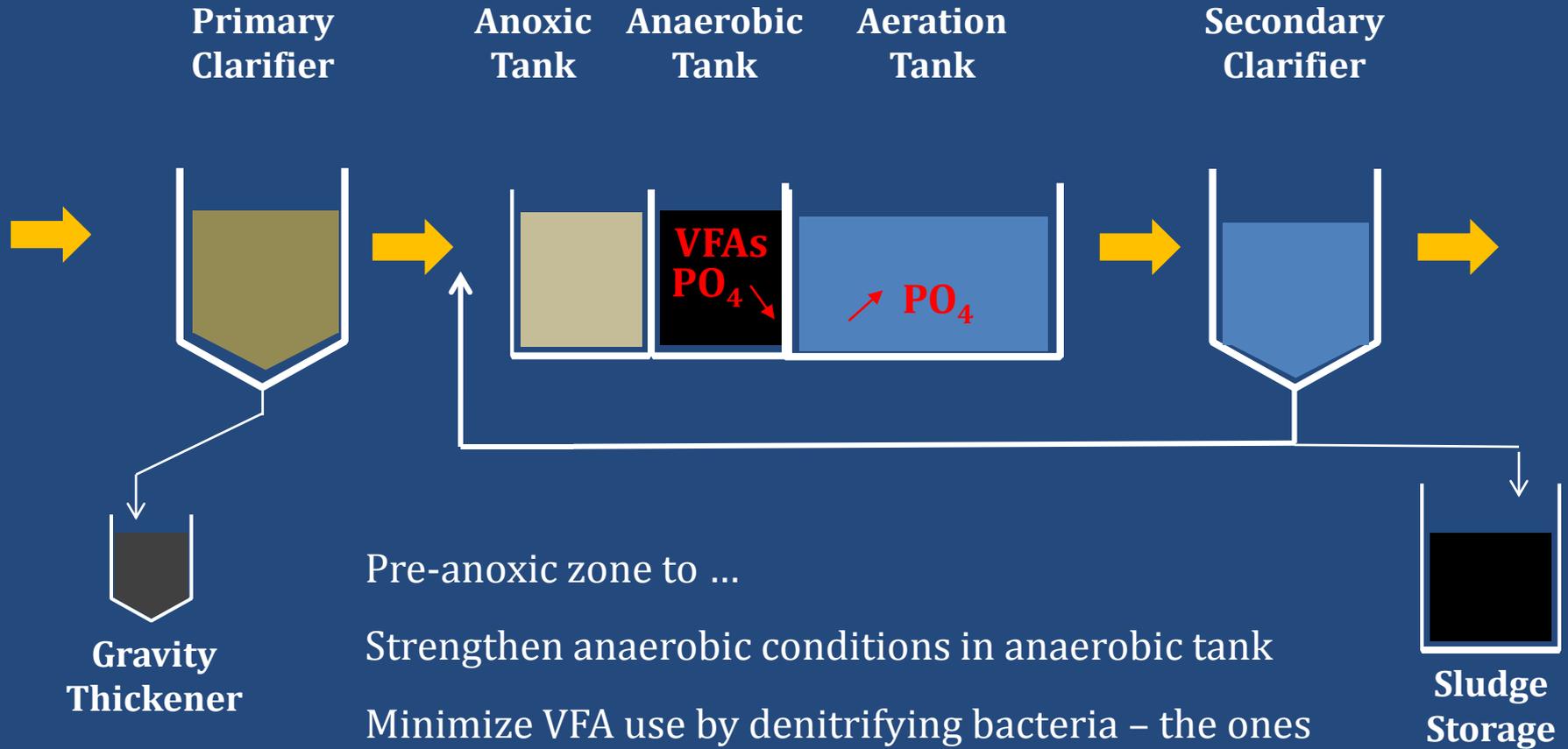
Bacteria break down complex BOD into VFAs (*volatile fatty acids*).

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

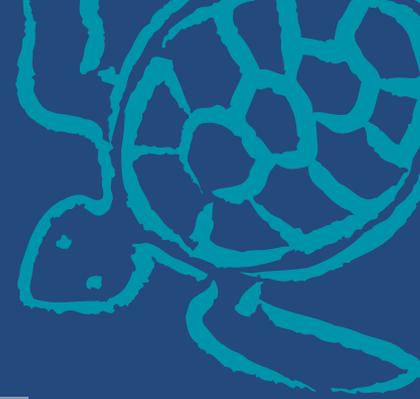
In Aeration Tank ...

Energized PAO bacteria take PO₄ out of solution.

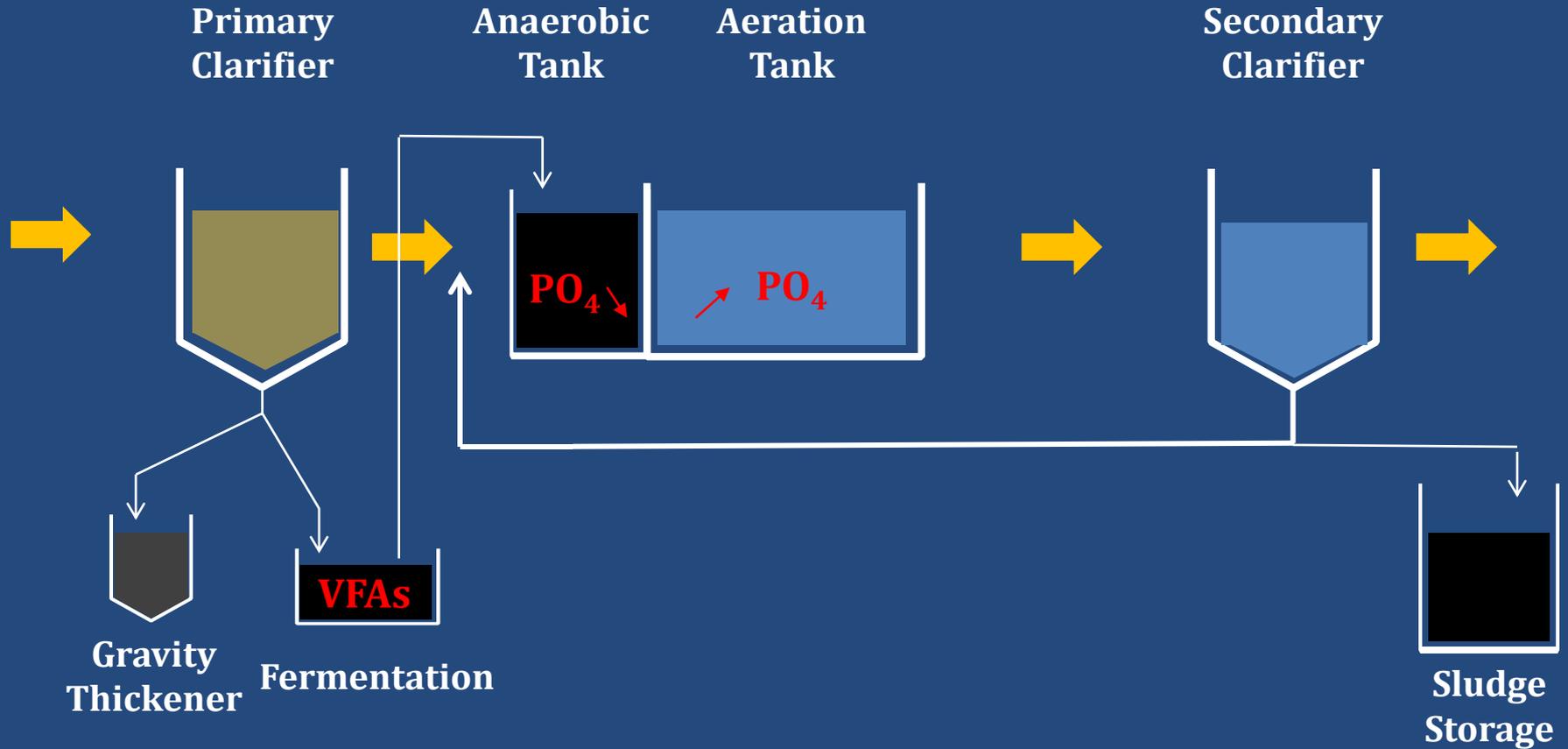
Bio-P Removal: Mainstream Fermentation Process



*Biological Phosphorus Removal: Combined
Sidestream & Mainstream Fermentation*

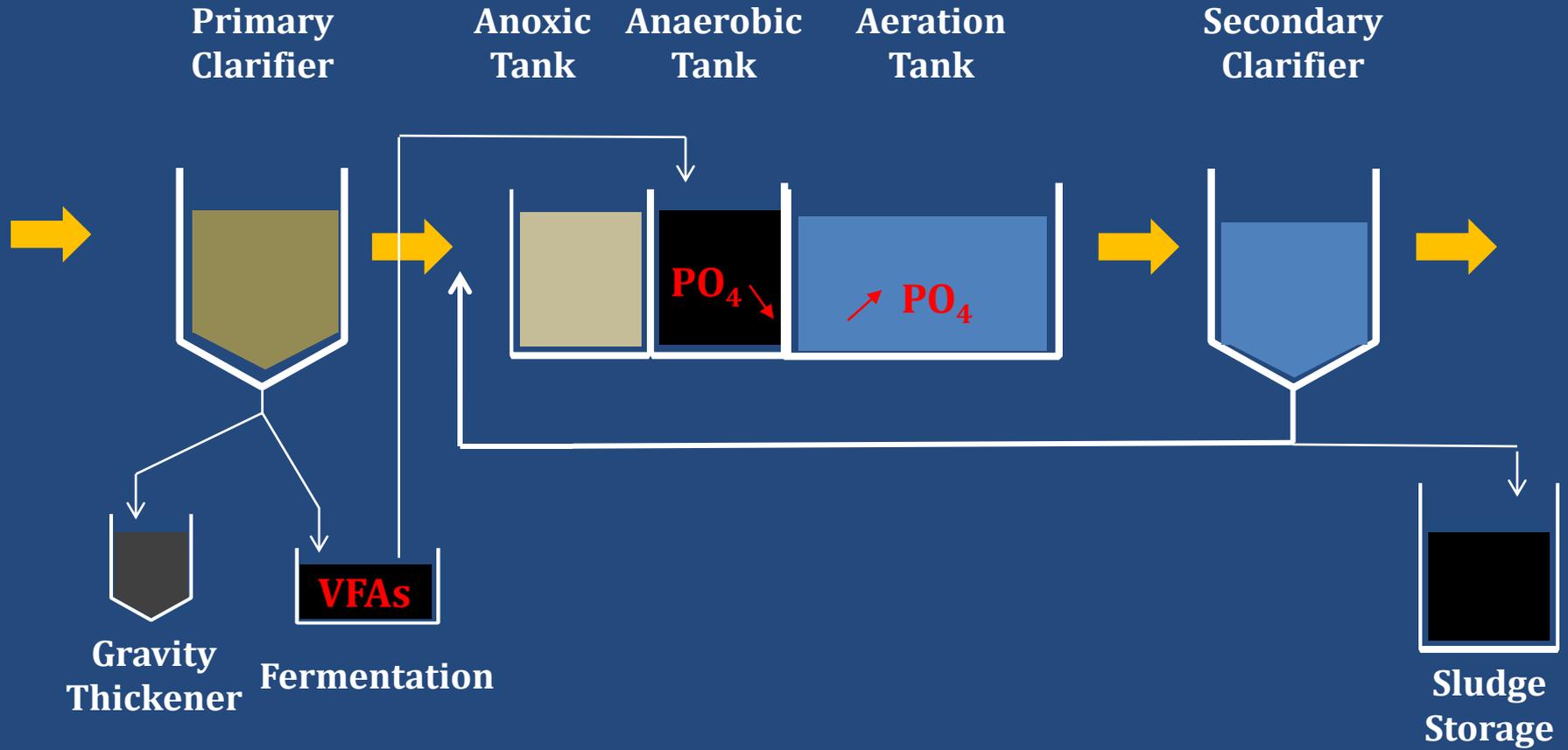


Bio-P Removal: Sidestream Fermentation Process



Nitrogen Interference: Nitrate (NO_3) will consume VFAs

Bio-P Removal: Sidestream Fermentation Process



No Nitrogen Interference

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 (3-4 times influent ortho-P)*

Aeration Tank

High DO / High ORP

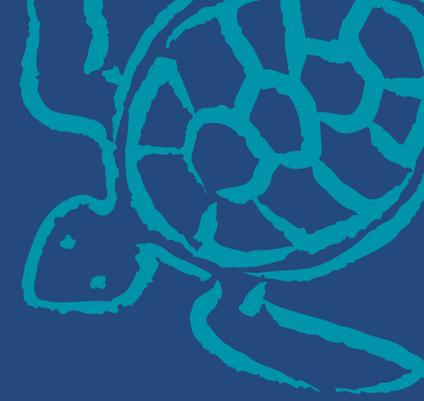
pH of 6.8+*

Ortho-P concentration of 0.05 mg/L*

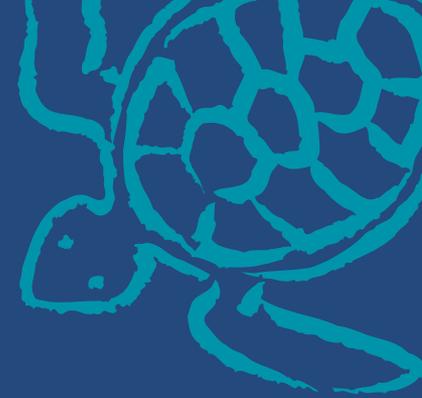
*Approximate: Every Plant is Different



**BACKGROUND
INFORMATION**

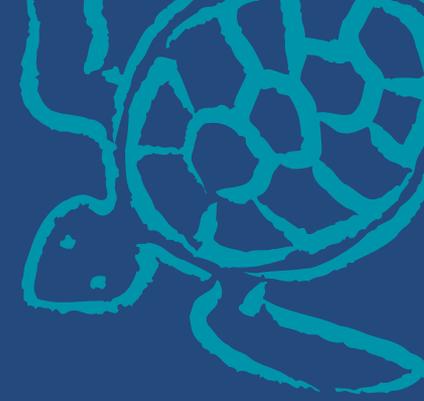


*Experimenting with YOUR plant:
Finding the “Right” Process Control Strategy*



... and, Optimizing Phosphorus Removal

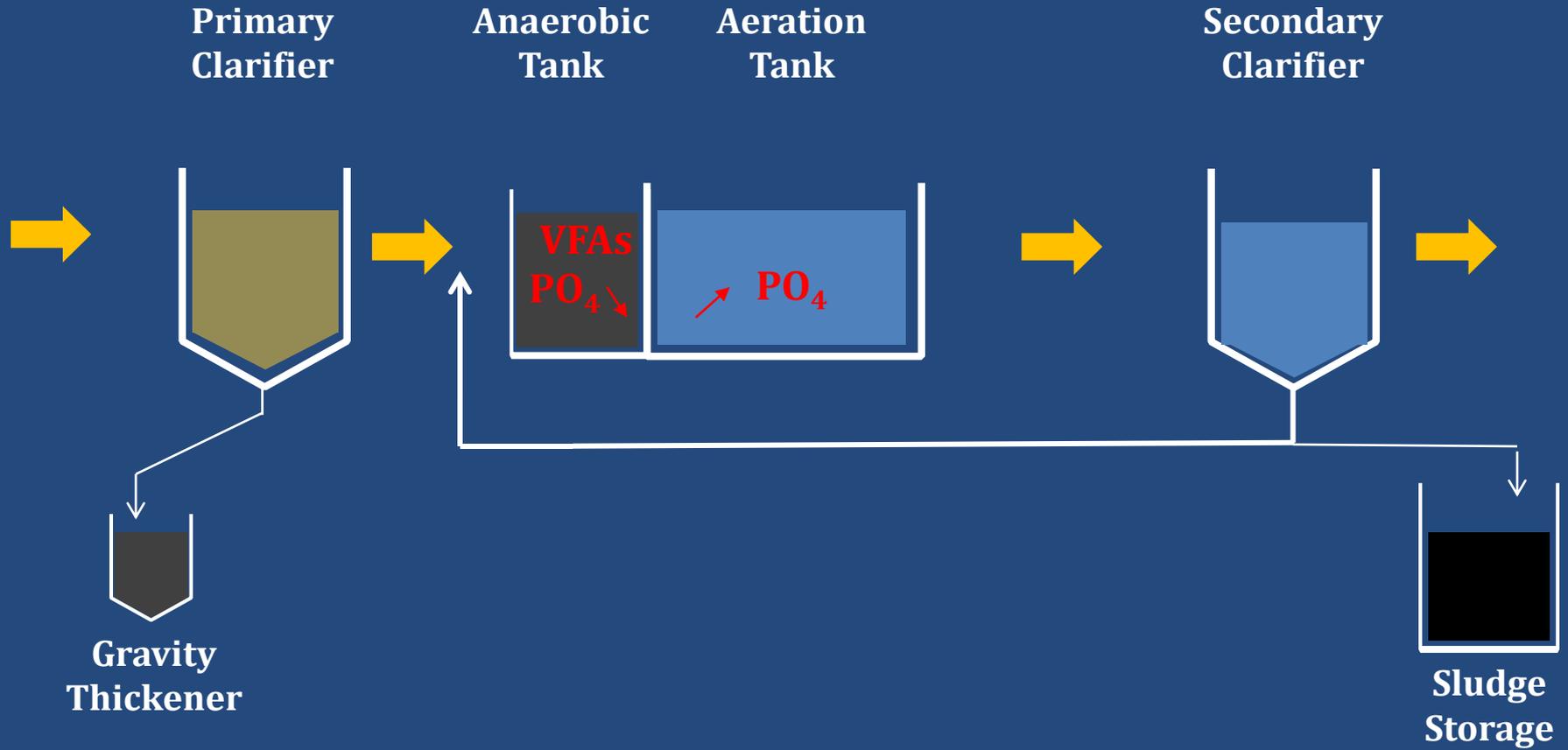




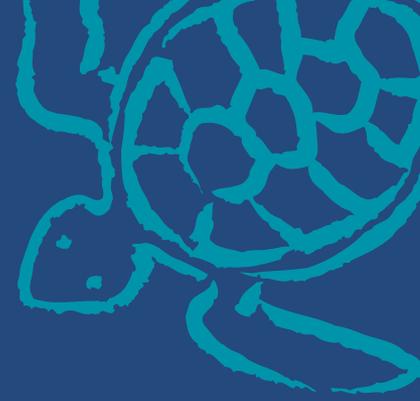
Create a Mainstream Fermentation Zone



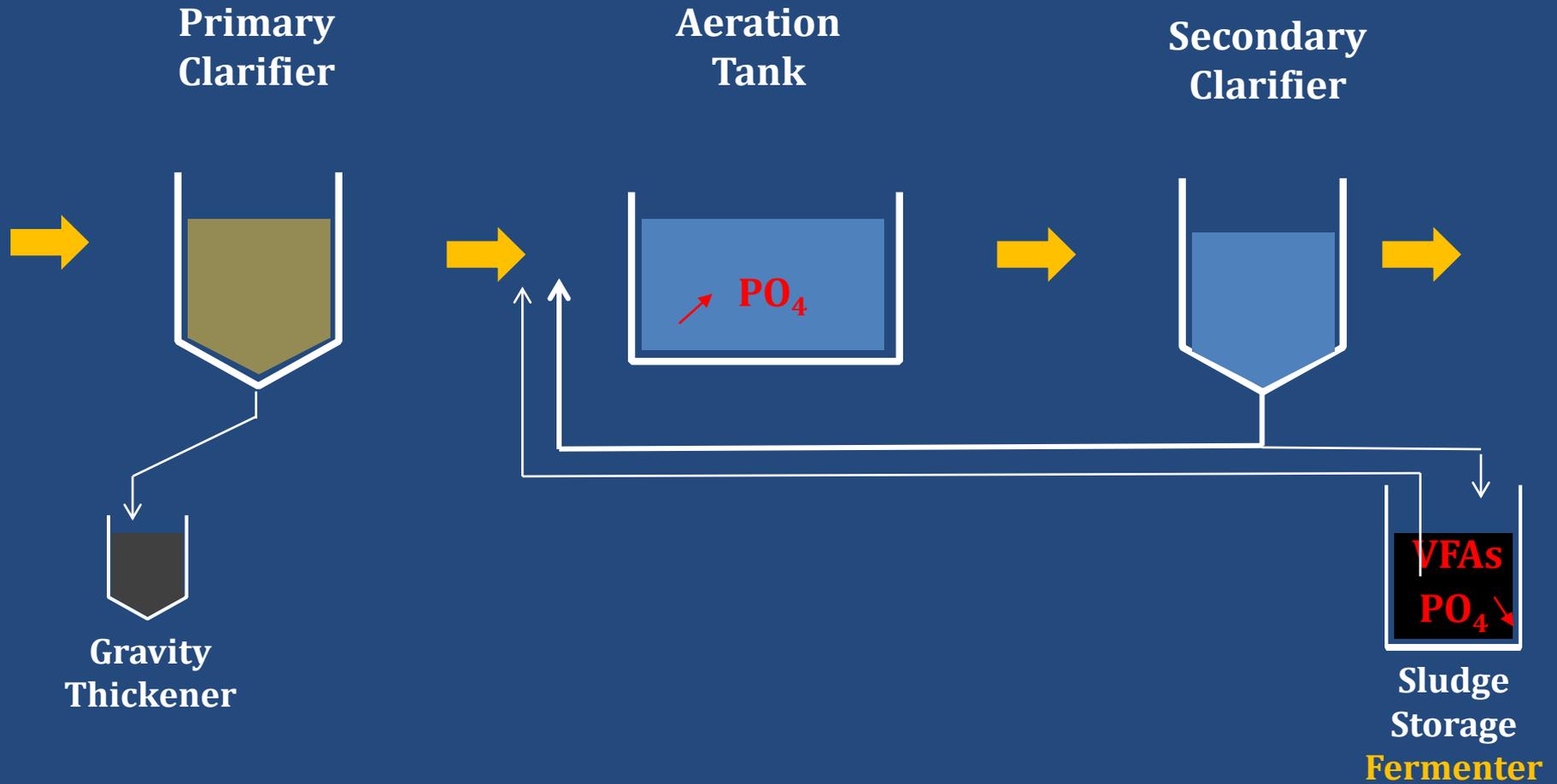
Mainstream Bio-P Removal in Conventional AS Plant

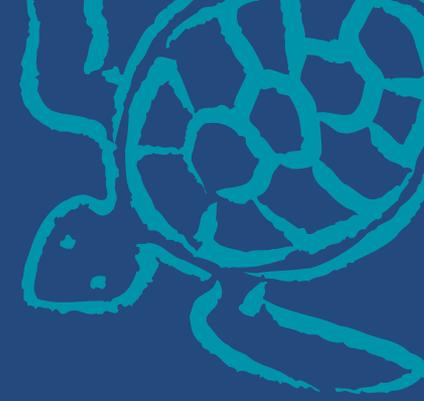


Create a Sidestream Fermentation Zone



Sidestream Biological-P Removal: Sludge Storage

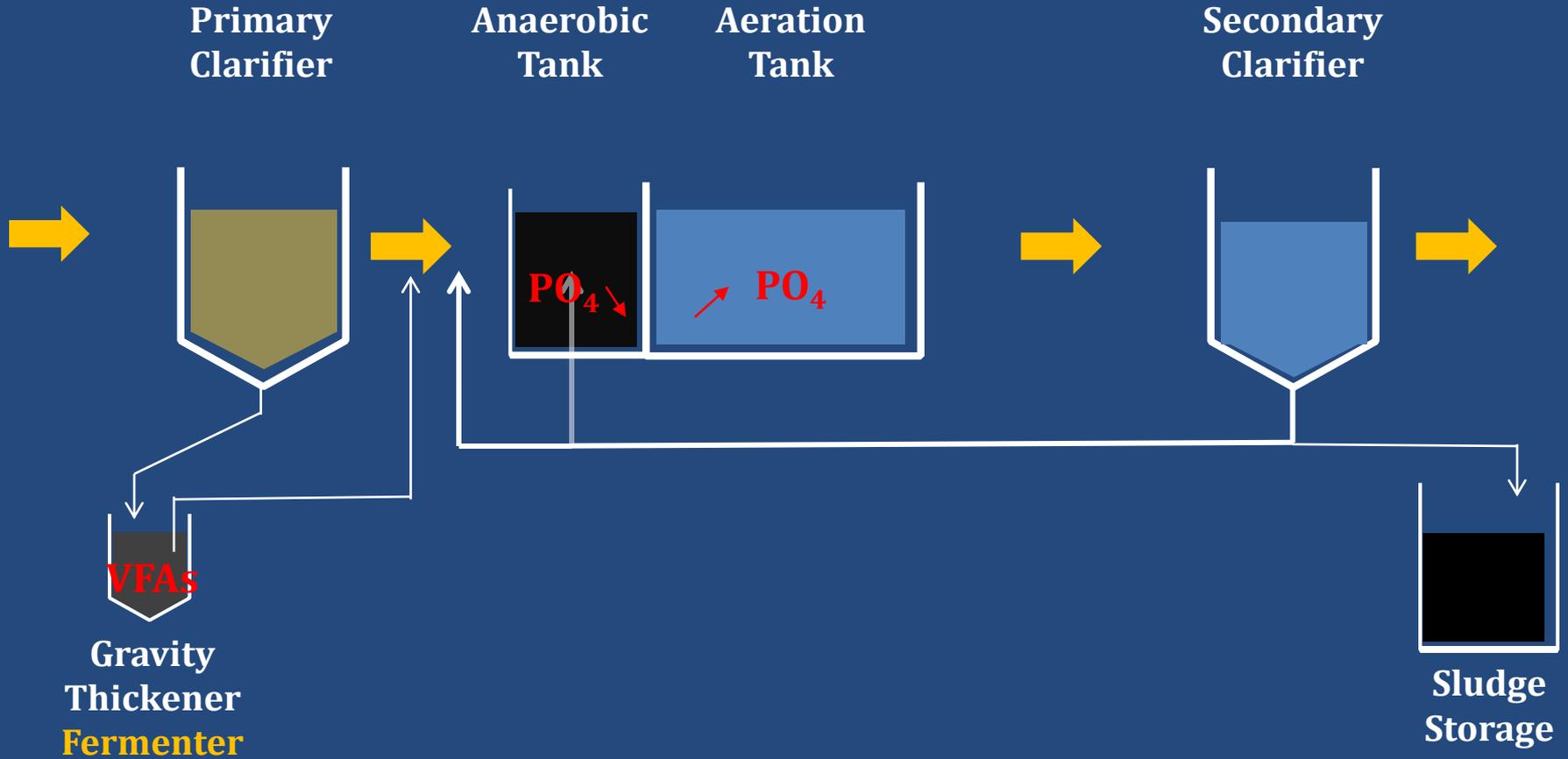




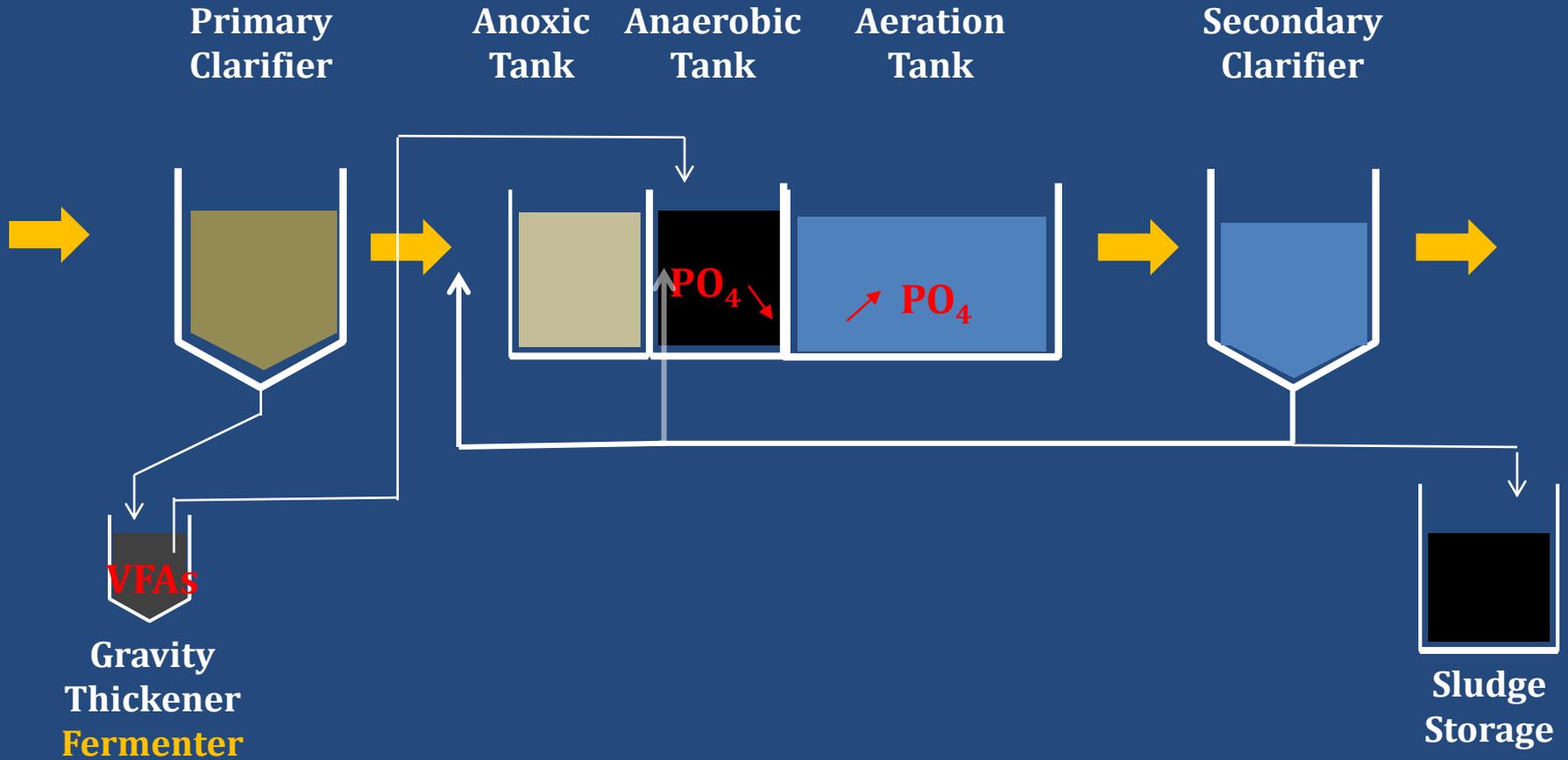
Create Both Mainstream & Sidestream Fermentation Zones



Sidestream & Mainstream Bio-P Removal



Sidestream & Mainstream Bio-P Removal



No Nitrogen Interference

Optimizing Fermentation: Mainstream or Sidestream

Anaerobic Tank

~1 hour HRT*

ORP of -200 mV*

25* times as much BOD as influent ortho-P
ortho-P release (3-4 times influent ortho-P)*

Aeration Tank

DO of 2.0 mg/L*

pH of 6.8+*

ortho-P concentration of 0.05 mg/L*

*Approximate: Every Plant is Different



Dialing In Biological N&P Removal



Denitrifiers outcompete PAOs for volatile fatty acids (VFAs)

03-Optimizing both Nitrogen and Phosphorus Removal in Activated Sludge Treatment Facilities

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Summary

Operational changes allow many (most) Activated Sludge Plants to biologically remove phosphorus - and - as a bonus create a **biological selector** for filament control.

Find opportunities for mainstream as well as sidestream fermentation zones.

Recognize that two things occur in the anaerobic tanks:

- VFA formation (hard to digest compounds converted to easy-to-eat molecules)

- PAOs use volatile fatty acids as an energy source (food)

Aeration Tank habitat is important: DO & pH

Bio-P converts soluble-P to an effluent TSS rich in P ...

- TSS control is critical!

Minimize VFA use by Nitrate (NO_3)

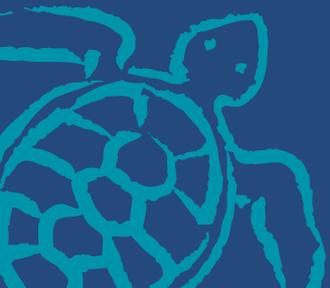
Monitor and Adjust DAILY for the rest of your life!





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