Phosphorus Removal Methods

Presented by
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Phosphorus

IS A MACRONUTRIENT ESSENTIAL TO ALL BIOLOGICAL LIFE!!

P is needed to form cell membrane and DNA

P demand of organisms due to special role It plays in their energy metabolism

WHY THE CONCERN?

P

Use it before you remove it!!!

Phosphorus

WHY IT IS REGULATED:

Not Good for Aquatic Systems

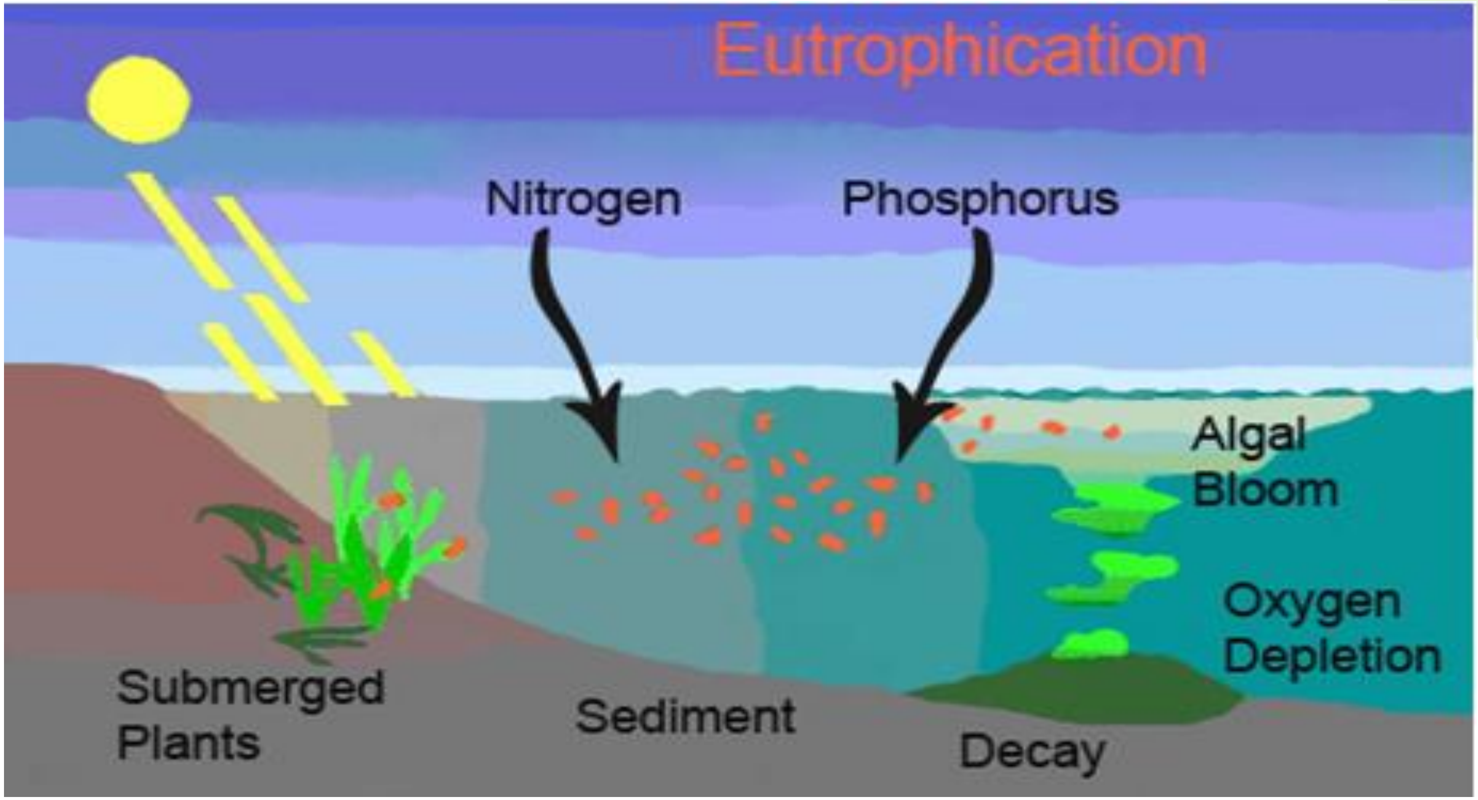
  

INCREASES EUTROPHICATION

Eutrophication

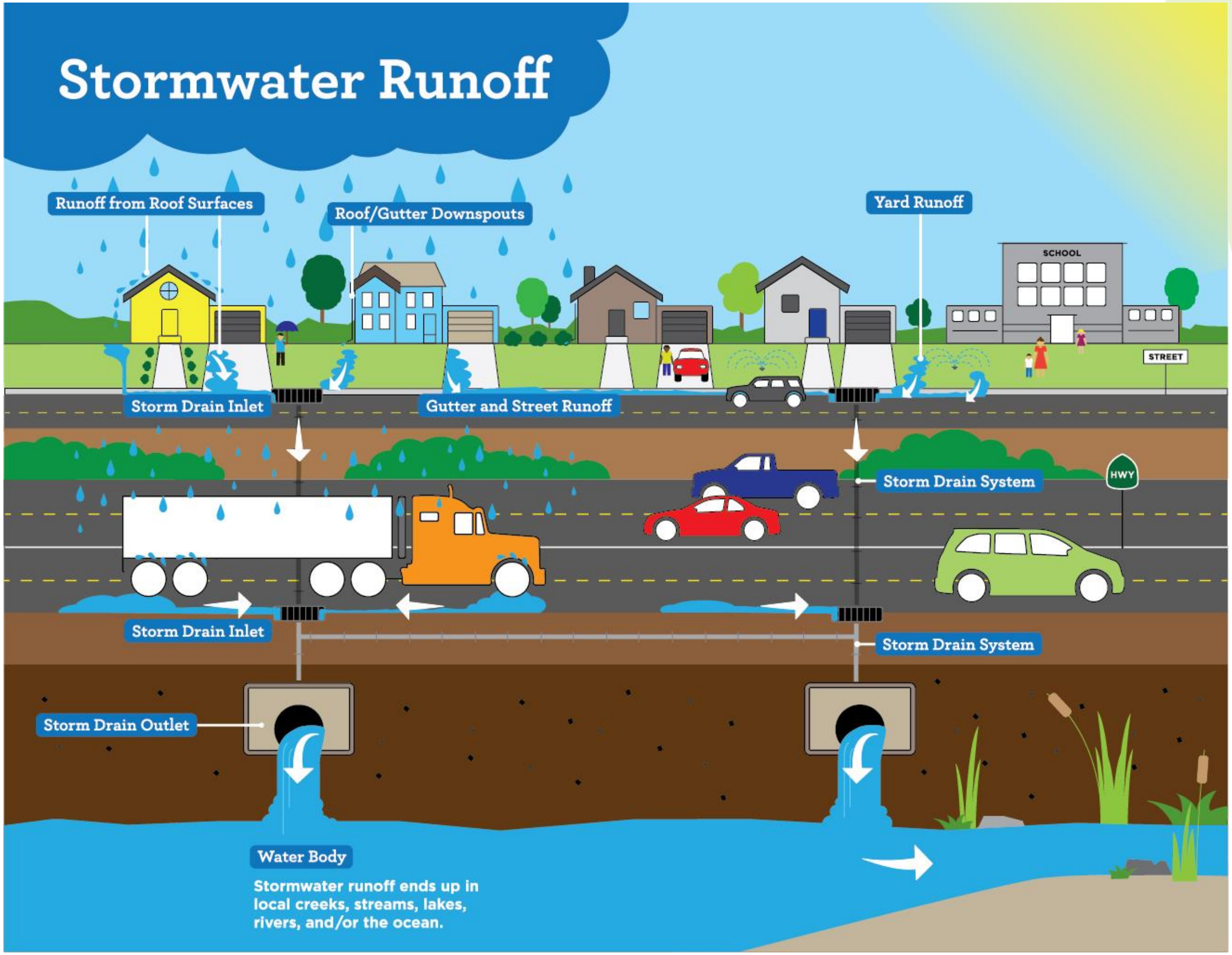
Control of Eutrophication

Control Nutrient Load



Control of Eutrophication

Rate is increased by human activities



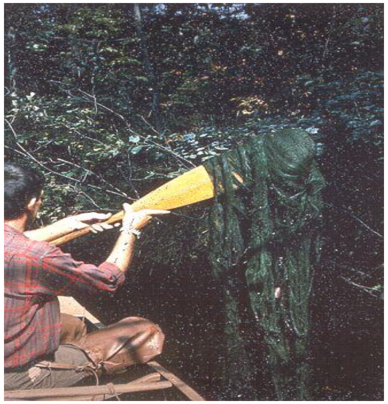
Phosphorus

Wastewater Discharges

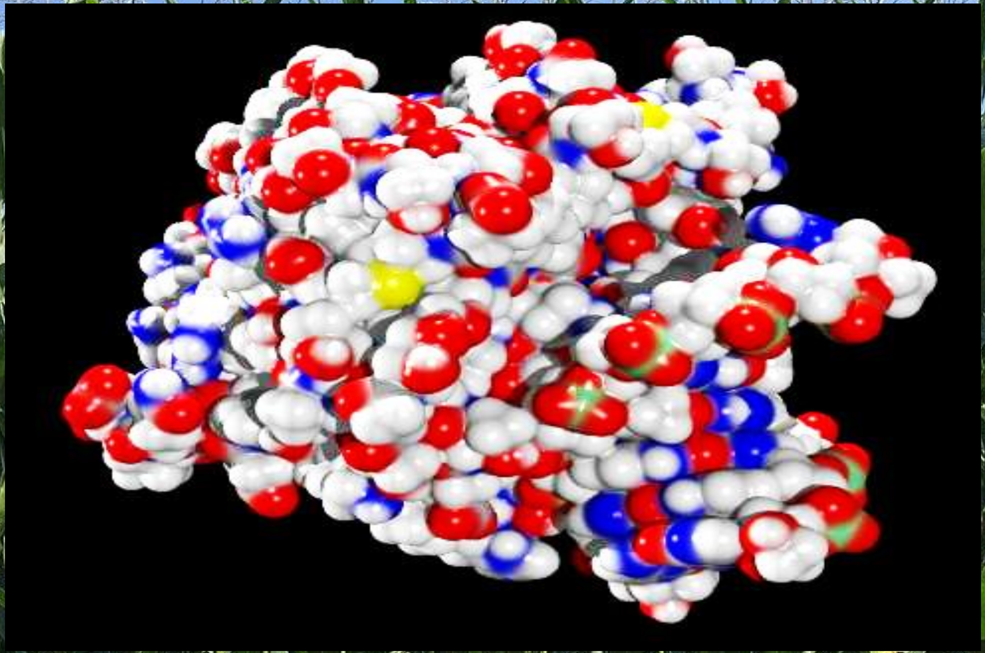
USUALLY LIMITED IN MOST STATES TO
1 mg/L OR LESS IN DISCHARGES
TO SURFACE WATER

(Many Have Pounds Limit)

Limits Getting More Restrictive



Forms and Sources of Phosphorus



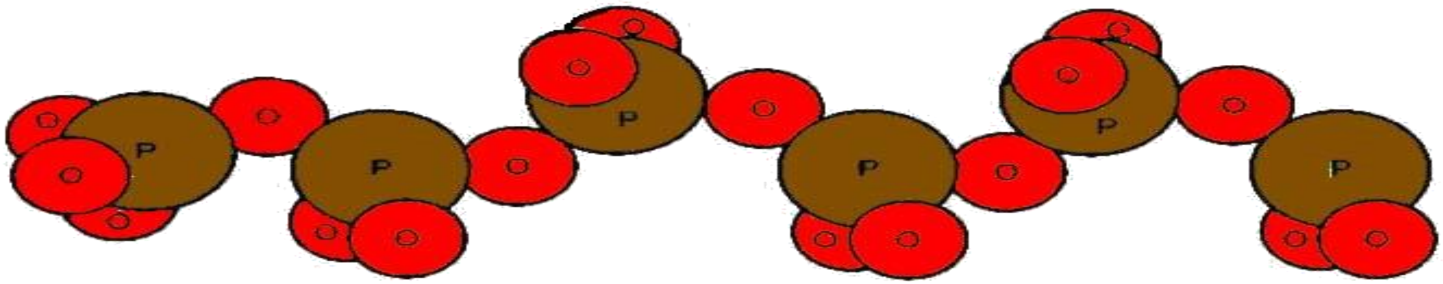
Organic Phosphorus

- **complex organic compounds**
- **soluble or particulate**
- **decomposes to Ortho-P**

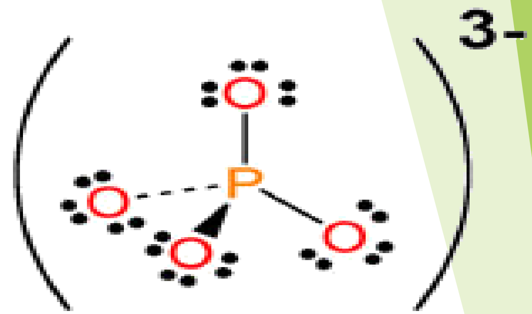
Forms and Sources of Phosphorus

Polyphosphate (condensed phosphate)

- chained molecules
- soluble
- home, industrial detergents
- potable water treatment
- decomposes to Ortho-P

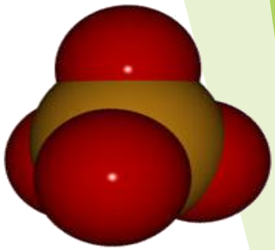


Forms and Sources of Phosphorus



Orthophosphate

- **Simple Phosphate, PO_4**
- **soluble**
- **household cleaning agents**
- **industrial cleaners;**
- **phosphoric acid**
- **conversion of organic and poly phosphate**



Phosphorus Ratios Needed

- Content of wastewater should correspond to the needs of the bacteria in the activated sludge
- Need a balanced relationship between C, N and P
- Need right pH
- Need enough alkalinity
- Need magnesium

During aerobic treatment C:N:P should be in range of 100:10:1 to 100:5:1

ALL of which are crucial to the biodegradation process

Phosphorus Ratios Today

- **Content of wastewater do not always meet the needs of the bacteria in the activated sludge**

- **Many plants are lacking enough alkalinity**

During aerobic treatment C:N:P typically is closer to 100:20:5

Excess P and N can be removed without great difficulty using modern methods

Phosphorus Removal

Biological Wastewater Treatment Systems Will Remove Phosphorus

100:5:1 (C:N:P)
Primary and TF 20 - 30 %
Primary and AS 30 - 50 %

Total Influent P Ranges from 2.5 to 20 mg/L

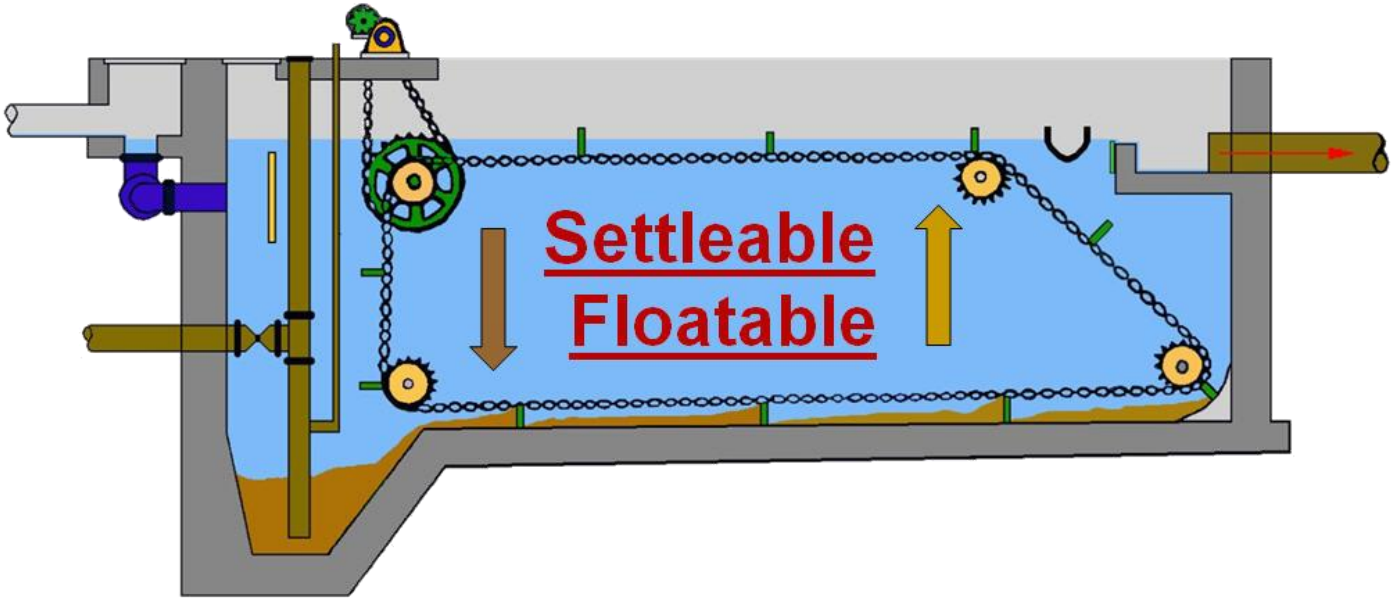
NPDES Permits Limit Effluent P @ 1 mg/L and Lower

Most Facilities Will Require Additional Process for Phosphorous Removal

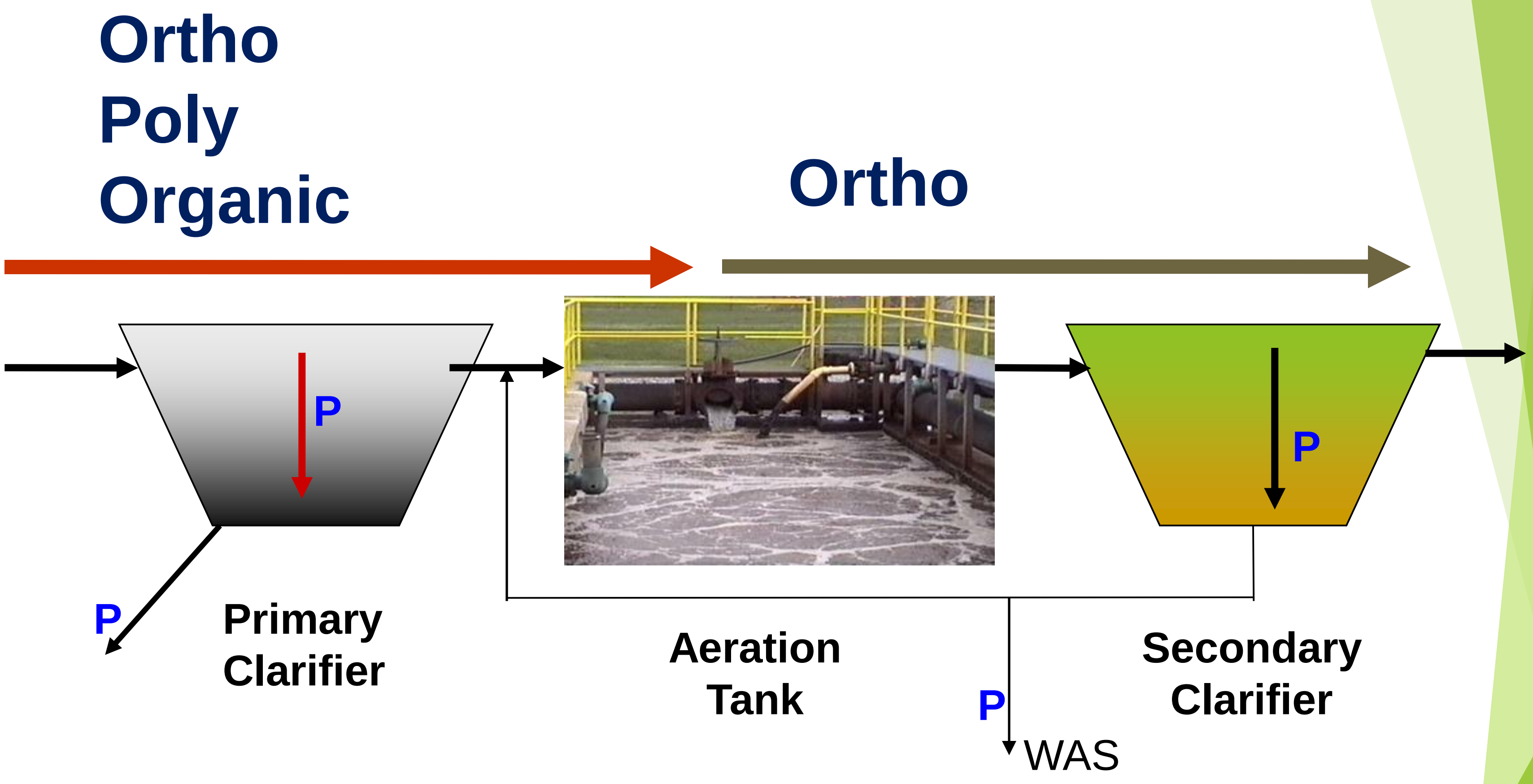
Phosphorus Removal

Removal of Solids Provides Some Phosphorus Removal

Primary Sedimentation 5 - 15 %



Conversion to Ortho-P



Phosphorus Removal

Removal of Ortho-P may Occur:

1. **Enhanced Biological Uptake**

2. **Chemical Precipitation**

Phosphorus Removal

Removal of Ortho-P may Occur Through:

Often Just Called
BIOLOGICAL P REMOVAL

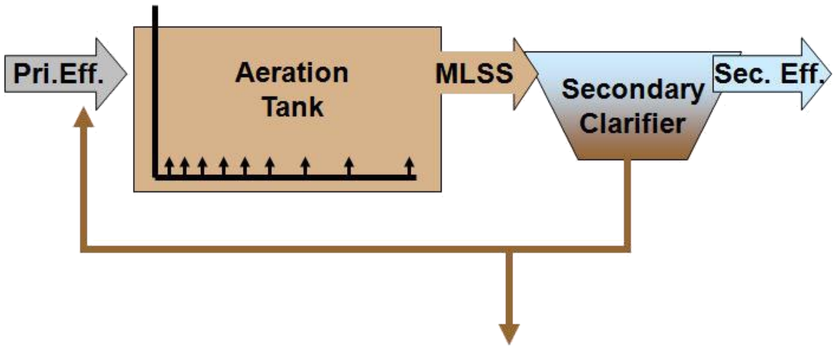
Enhanced Biological Uptake

(EBPR)

Biological P Removal

All Biological Systems Take Up P

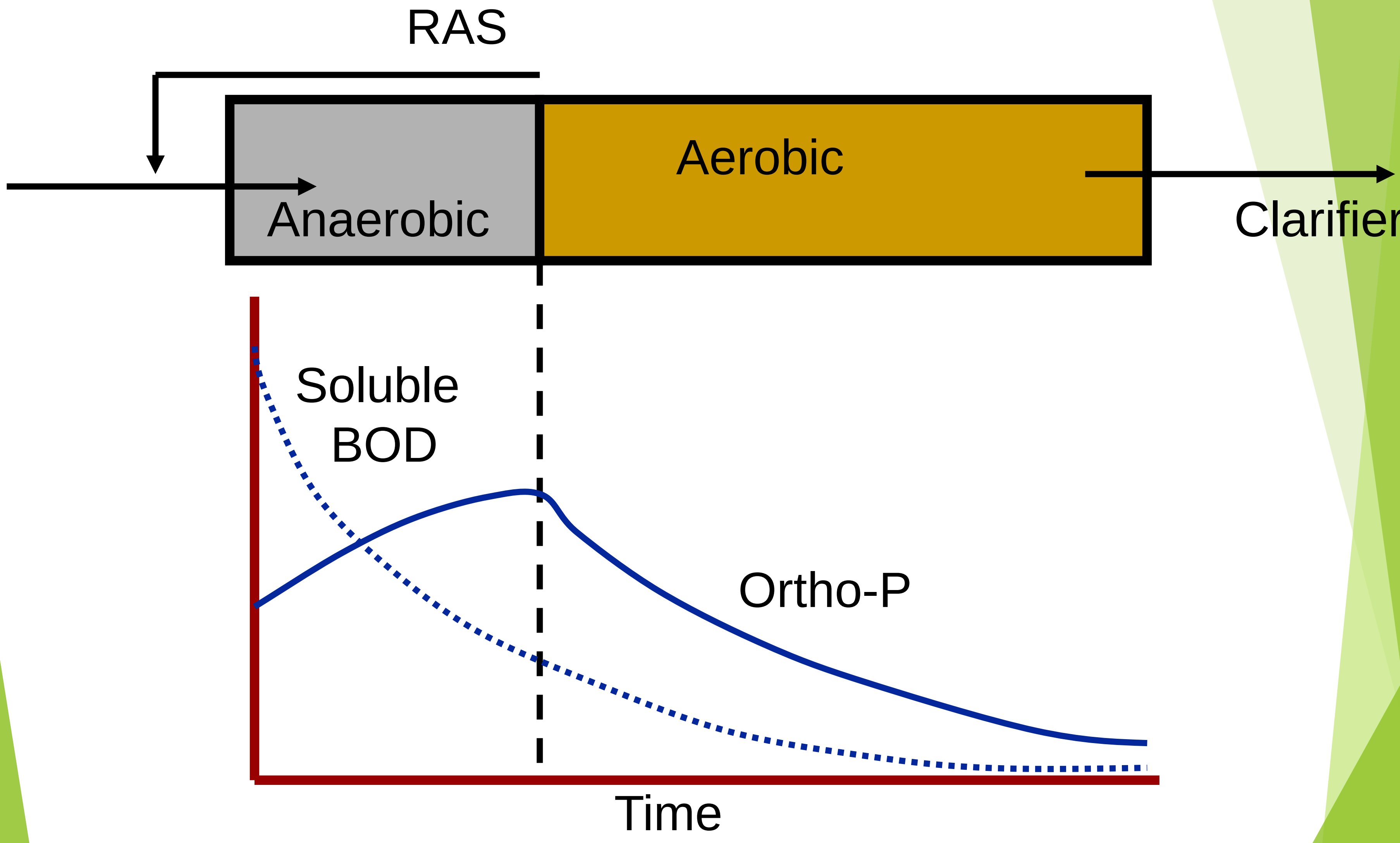
100:5:1
C:N:P



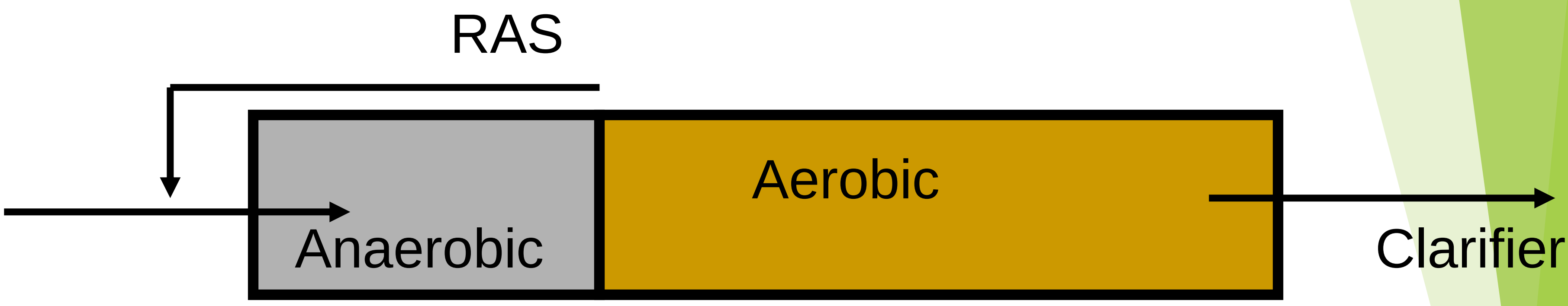
Some Facilities Removed More P Than 1P:100BOD

?

The MLSS in Those Facilities Cycled From Anaerobic to Aerobic



The MLSS in Those Facilities Cycled From Anaerobic to Aerobic



This Promoted the Accumulation of Bacteria that Uses P as an Energy Storage Mechanism

Acinetobacter (Assin Eato Back Ter)

& Other

Phosphate Accumulating Organisms (PAO)

Biological P Removal

Anaerobic Conditions

Heterotrophic Bacteria Break Down Organics

Fermentation

Volatile Fatty Acids (VFAs)

Acetate (Acetic Acid)

Also

Selection of PAO - Phosphate Accumulating Organisms

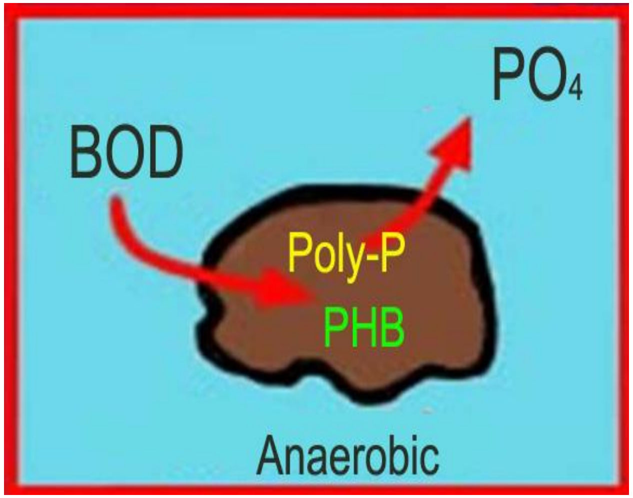
(Able to Out-Compete Other Aerobic Heterotrophic Bacteria for Food When Anaerobic)

Biological P Removal

Anaerobic Conditions

PAO Able to store soluble organics as Polyhydroxybutyrate (PHB)

PAO Break Energy-Rich Poly-P Bonds To Produce Energy Needed for the Production of PHB



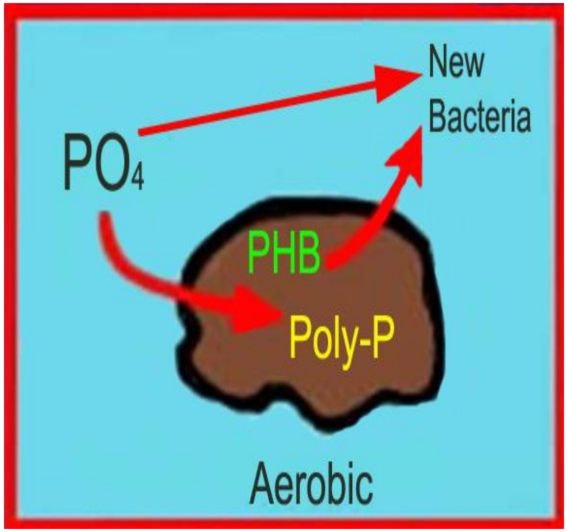
Ortho-P is Released Into Solution

Biological P Removal

Aerobic Conditions

Rapid Aerobic Metabolism of Stored Food (PHB) Producing New Cells

$\underline{PO_4}$ Used in Cell Production
Excess Stored as Polyphosphate
("Luxury Uptake")



Biological P Removal

Phosphorus Accumulating Bacteria (PAO)

Anaerobic

Fermentation
Acetate Production
Selection of Acinetobacter/PAO
P Released to Produce Energy

Aerobic

Stored Food Consumed
Excess P Taken Up
Sludge Wasted

Biological P Removal

Most often Used Processes:

Phostrip
A2/O
Concentric Ring Oxidation Ditch
Sequencing Batch Reactor

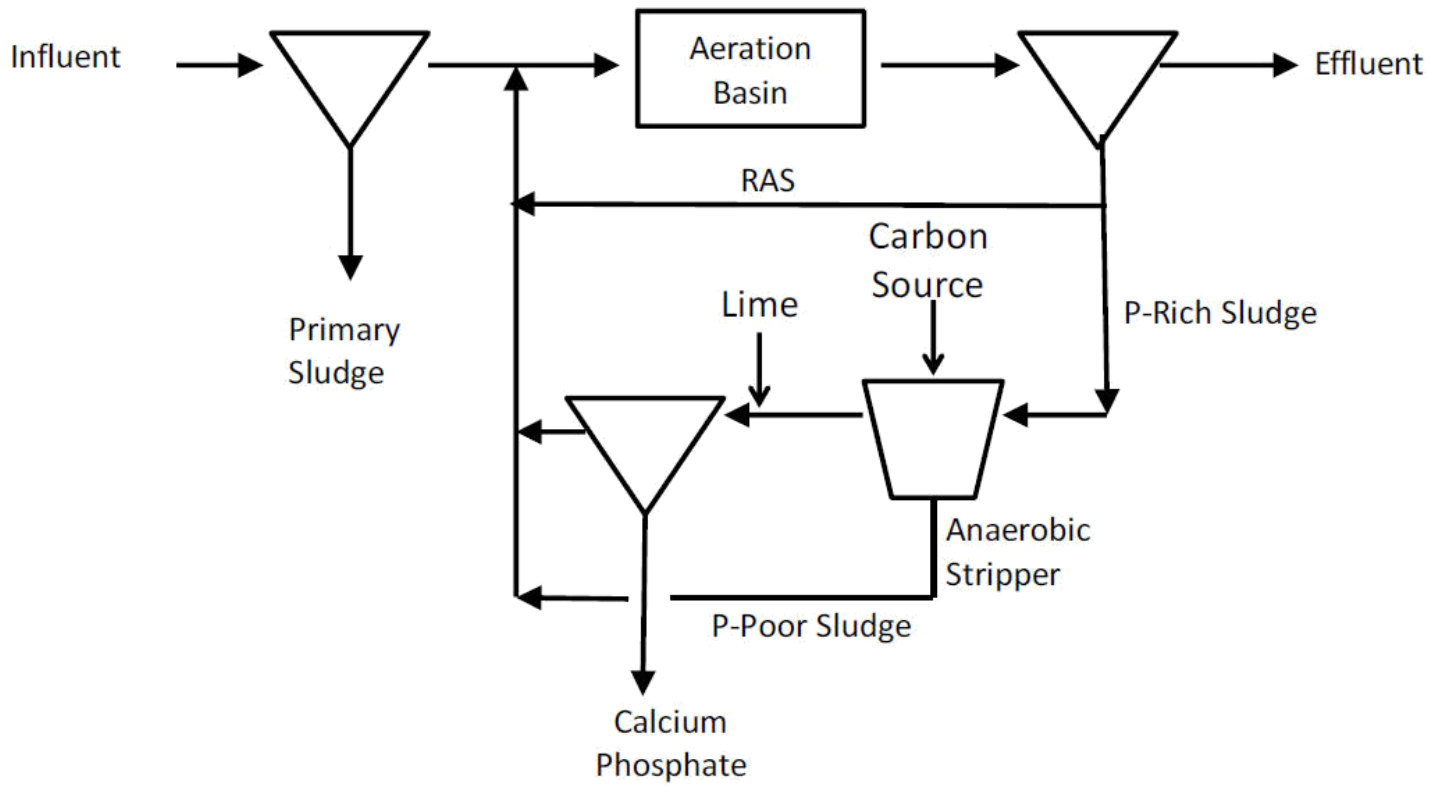
Phostrip

Some Return Sludge Diverted to Anaerobic Stripper

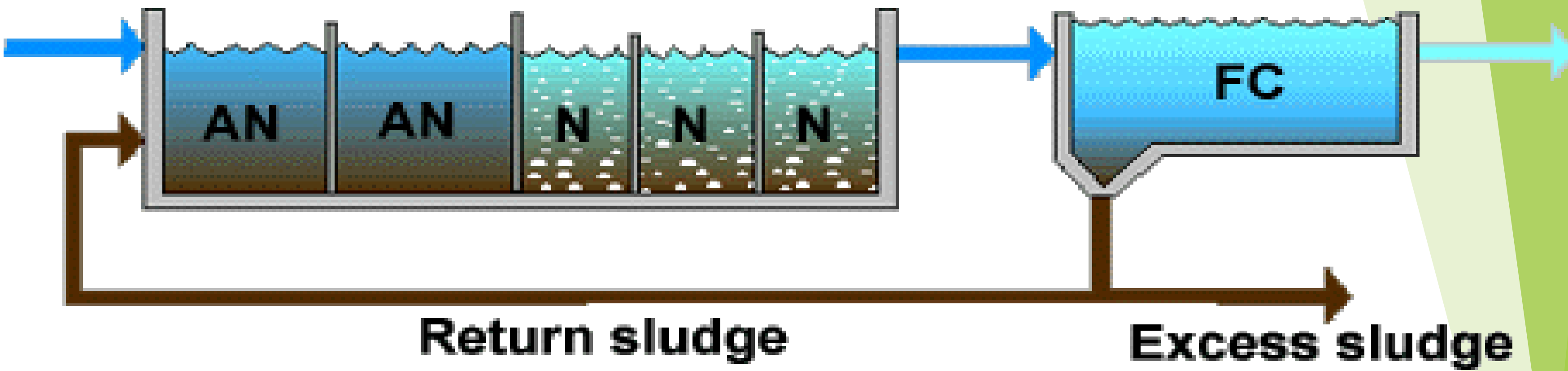
Phosphorus Released

Elutriated (Washed) to a Precipitation Tank

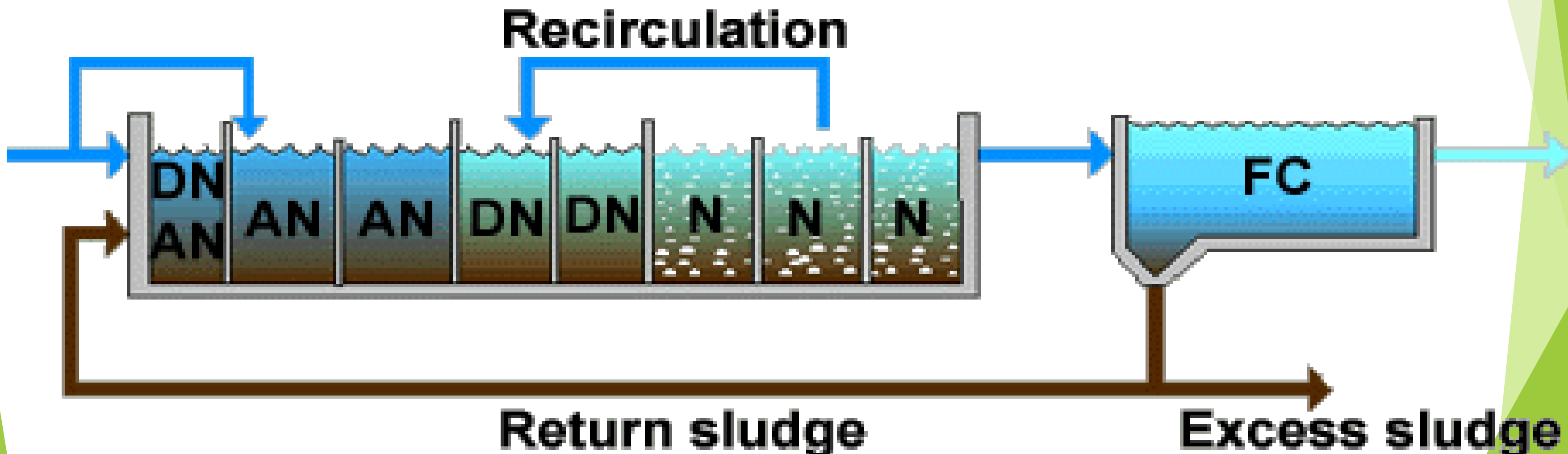
Precipitated With Lime – Sludge Removed

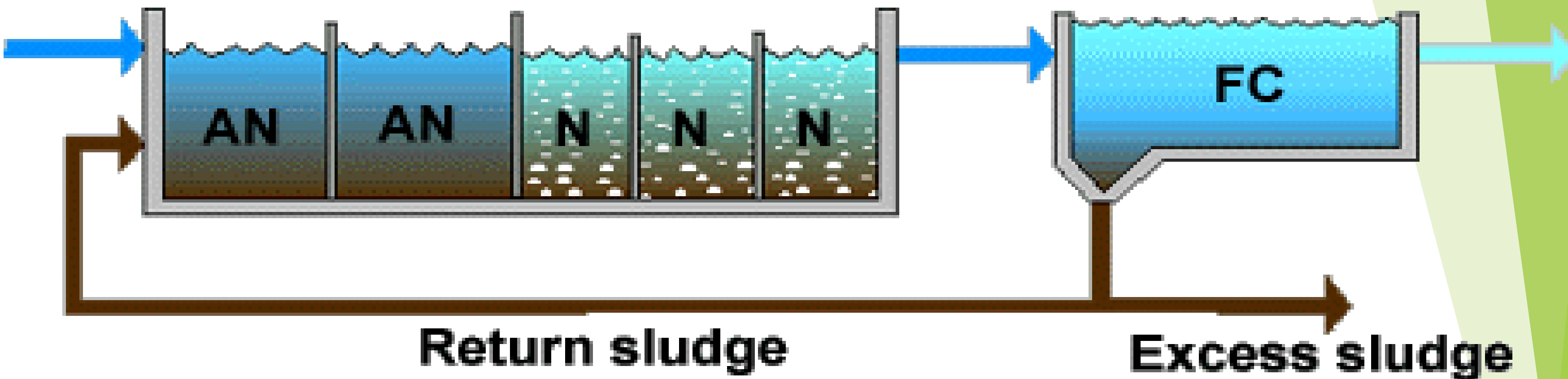


A/O Process (Anaerobic/Oxic)



A2/O (Anaerobic/Anoxic/Oxic)





Head End of Aeration Tank Baffled and Mechanically Mixed

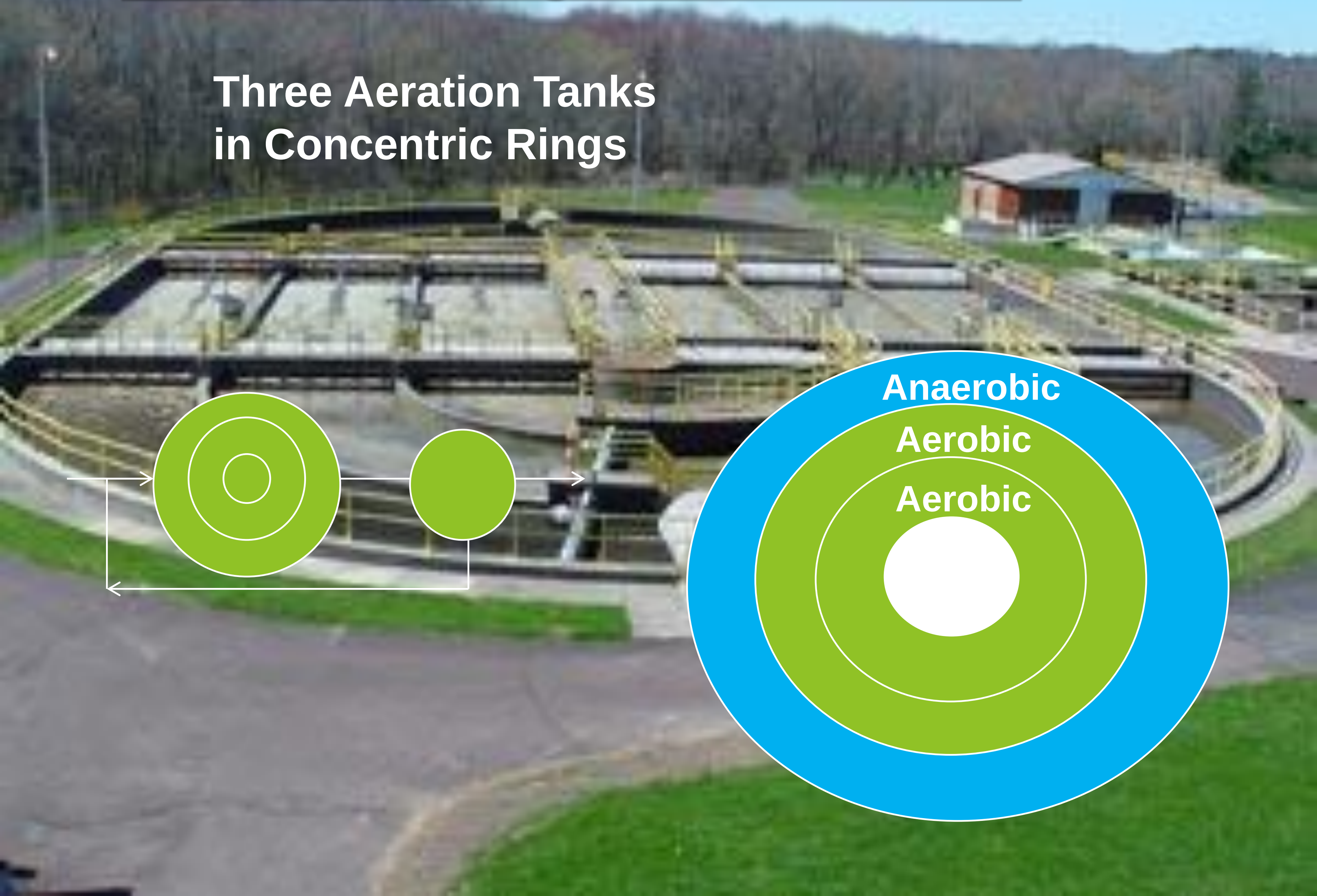
Primary Effluent and RAS Produce Anaerobic Conditions

Phosphorus Released

“Luxury Uptake” of Phosphorus in Aerated End

Concentric Ring Oxidation Ditch

Three Aeration Tanks
in Concentric Rings



Concentric Ring Oxidation Ditch

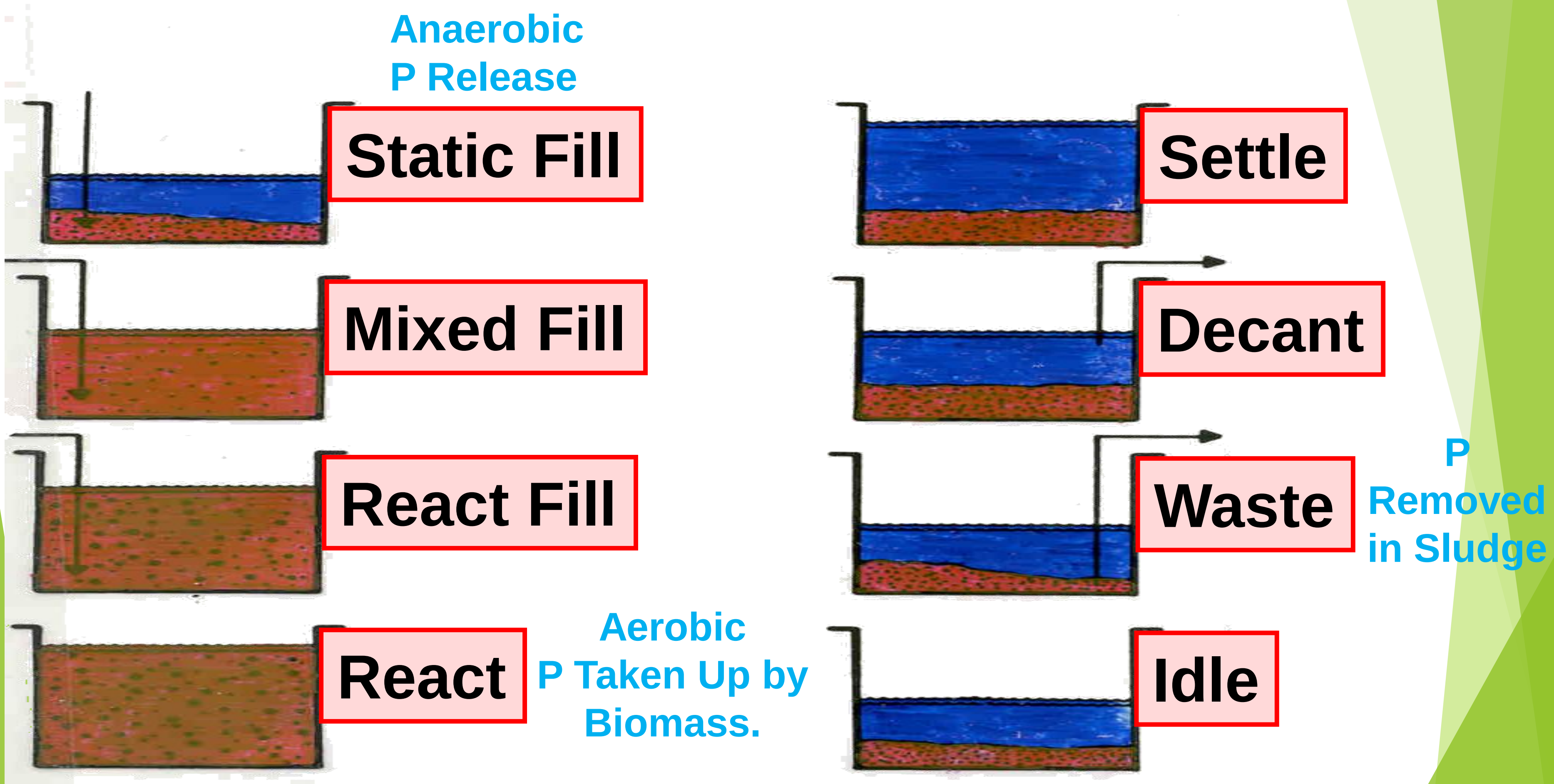
Three Aeration Tanks in Concentric Rings

Wasting Aerobic the Bio-solids Removes Phosphorus

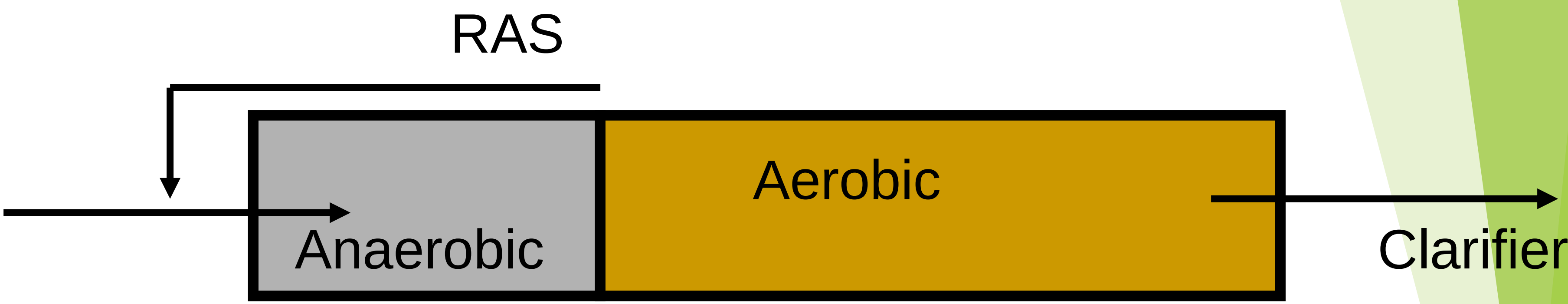
Sequencing Batch Reactor

Sequencing Batch Reactor

Batch Treatment in Sequence of Steps



Biological P Removal



The MLSS Cycles From Anaerobic to Aerobic

This Promotes
Phosphate Accumulating Organisms (PAO)

Anaerobic

Fermentation
Acetate Production
P Released to Produce Energy

Aerobic

Stored Food Consumed
Excess P Taken Up
Sludge Wasted

Biological P Removal

Important Considerations

Adequate Influent BOD

(Enough O_2 demand to achieve anaerobic conditions)

BOD:P
20:1

Adequate Anaerobic Detention Time 1-3 hrs

(Not so long as to reduce sulfate to sulfide-septicity)

Adequate Aerobic Detention Time 4-5 hrs.

(Enough time for BOD removal & Nitrification)

Biological P Removal

Benefits

Lower Cost

Safer to Handle

No Tramp Metals

No Chemical Sludge Produced

Inhibits Growth of Filamentous Organisms

(Cycling between Anaerobic & Aerobic)

Chemical Phosphorus Removal

Ortho Phosphate

(Soluble)

PLUS

Metal Salts

(Soluble)

FORM

Insoluble

Phosphorus Compounds

Chemical Phosphorus Removal

Total Phosphorus

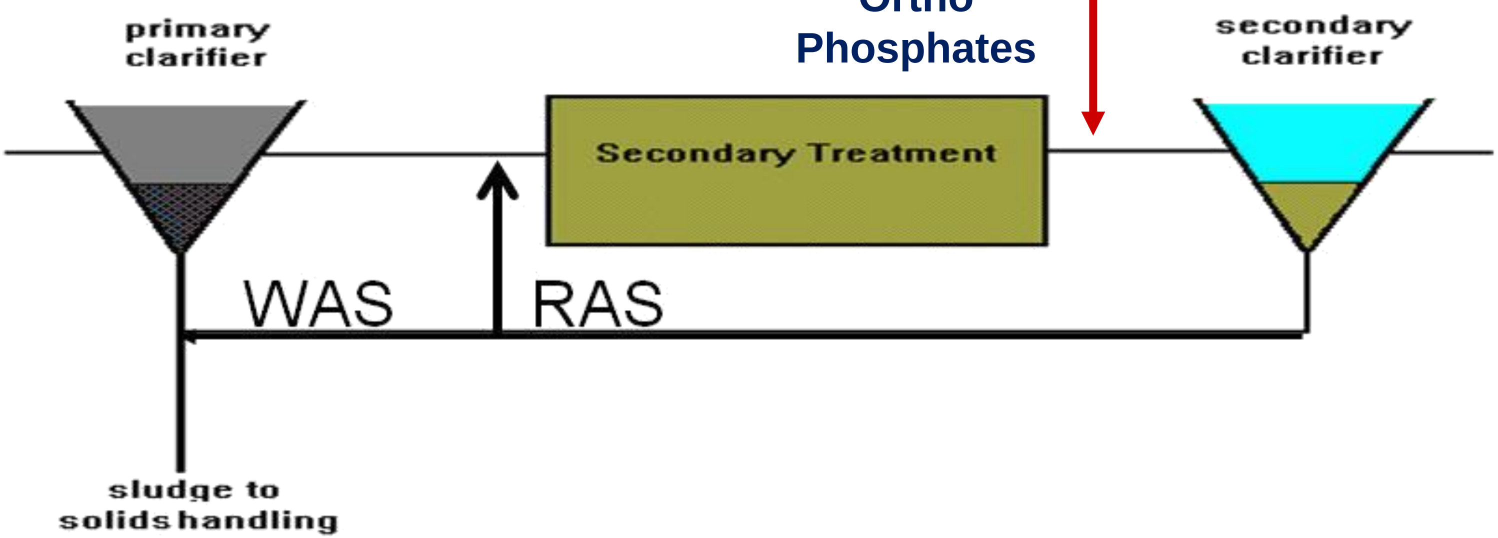
Organic Phosphorus

Condensed (Poly) Phosphates

Ortho Phosphates

Metal Salt Addition

Ortho Phosphates



Chemical Phosphorus Removal

$$M^{+3} + PO_4^{-3} \rightarrow MPO_4 \downarrow$$

(M^{+3} = Metal in Solution)

PRECIPITATION

Metals used are:

- **Aluminum (Al)**
- **Iron (Fe)**

Chemicals Used for Phosphorus Removal

Most Common:

Ferric Chloride
Ferrous Chloride
Alum
PAC (Polyaluminum Chloride)
Magnesium Hydroxide

FERRIC IRON - Fe^{+3}

$$M^{+3} + PO_4^{-3} \rightarrow MPO_4 \downarrow$$

$$Fe^{+3} + PO_4^{-3} \rightarrow FePO_4 \downarrow$$

Weight Ratio

Fe^{+3} to P

1.8 : 1

$FeCl_3$: P

5.2 : 1

Starting Dosage 20-25 mg/L

Aluminum Sulfate Dosage Rates

$$Al_2(SO_4)_3 + 2PO_4^{-3} \longrightarrow 2AlPO_4 \downarrow$$

Weight Ratio

Al^{+3} : P

0.87 : 1

Alum to Phosphorus

9.6 : 1

Starting Dosage 40-50 mg/L

Chemical Dosage Rates

Ferric Iron – apx 20-25 mg/L
Aluminum Sulfate – apx 40-50 mg/L
Magnesium Hydroxide – apx 30-40 mg/L

What about when used in combination?

New studies currently being conducted.

Magnesium Hydroxide Case Study

Side by side treatment plants, only Aeration 3 and Final 5 and 6 received treatment with Magnesium Hydroxide.

A1/2 and F3/4 were untreated for a control. Incoming influent was split between the two plants.

Magnesium Hydroxide Case Study

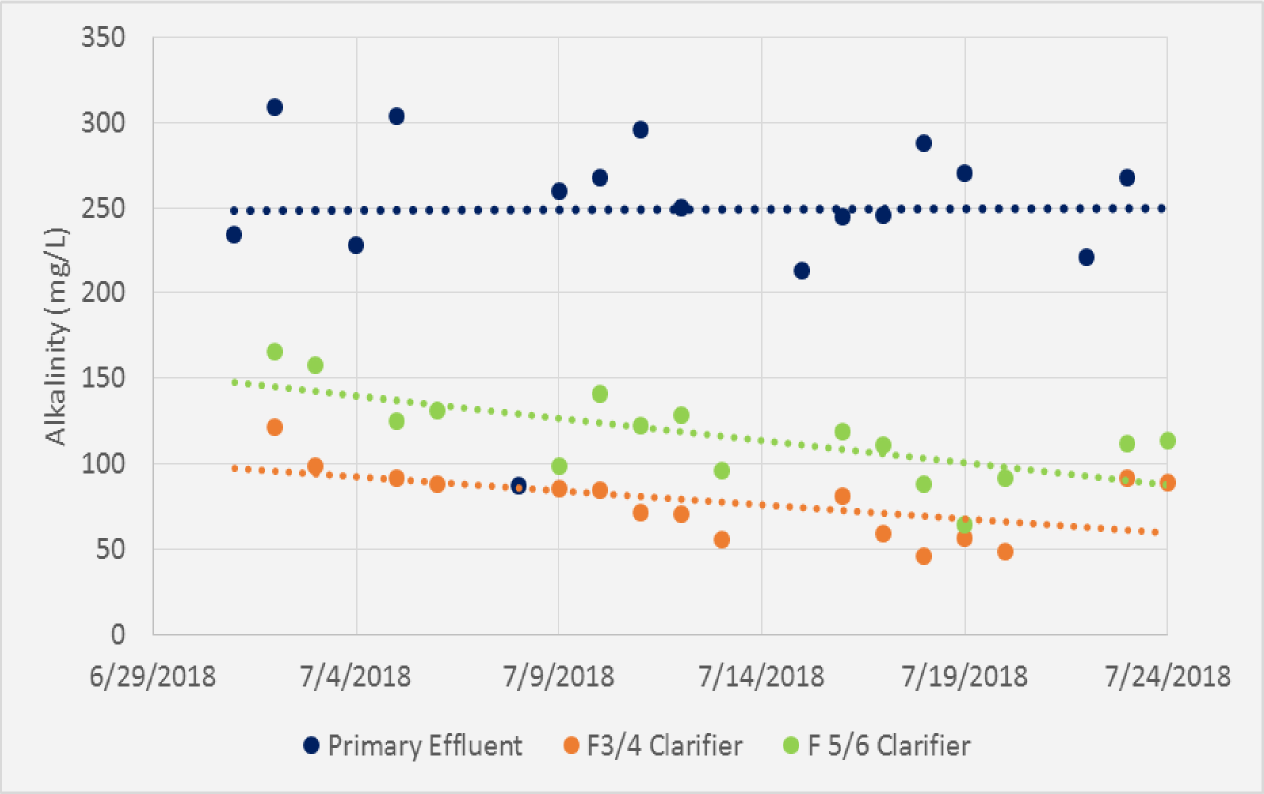


Figure 2. Alkalinity (mg/L) for the Primary process effluent and the Final Clarifiers effluent.

Magnesium Hydroxide Case Study

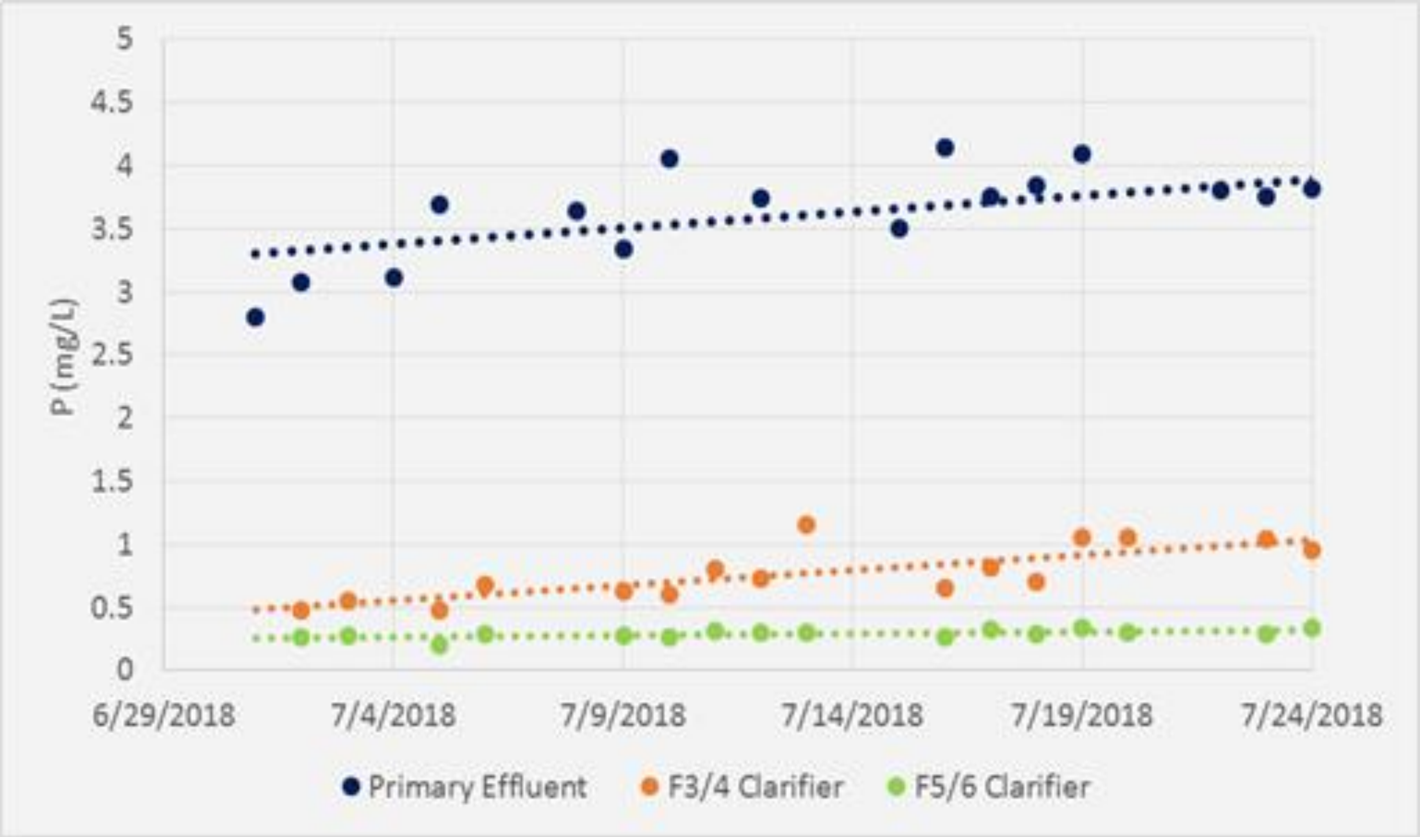


Figure 3. Alkalinity (mg/L) for the Primary process effluent and the Final Clarifiers effluent.

P Removal

Important Considerations

- Low Effluent Suspended Solids
- Magnesium – needed for ATP process
- Alkalinity – needed for nitrification process
- Nitrification –Nitrate
- Sludge Handling

References

Michigan DEQ - Operator Training and Certification Unit

Ian Miller, Chemist

Colorado State University, Research Center

US EPA, Phosphorous Removal Methodologies

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Questions?

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