Phosphorus Removal

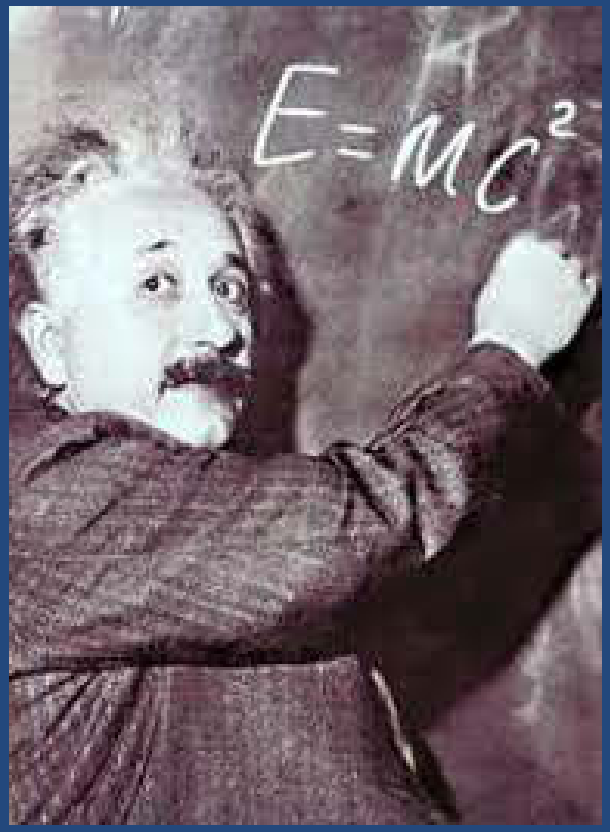
Grant Weaver, PE & wastewater operator

Helena, Montana
June 9&10, 2015

THE WATER PLANET COMPANY

www.cleanwaterops.com

Optimizing wastewater treatment for nutrient removal

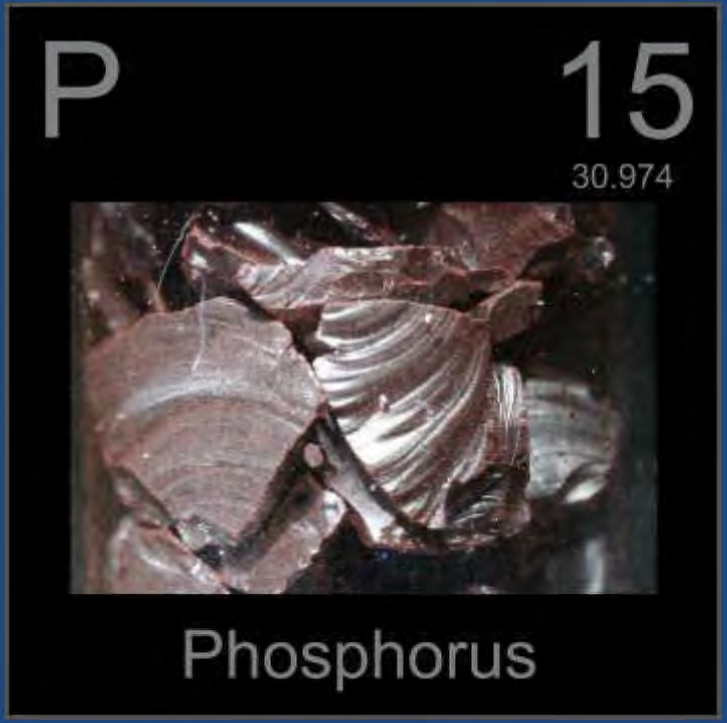


<u>Today</u>

Operators Make a Difference !
Nitrogen Removal
    Habitats, Theory & Process Control
Phosphorus Removal
    Wastewater Habitats
    Design Theory
    Process Control
Why Nutrient Removal is Important to Montana
Case Studies

<u>Tomorrow</u>

Cost-Savings / Sludge Reduction Modifications
Review
Group Discussion & Design


P
15
30.974
Phosphorus

Phosphorus Removal

Costly Facility Upgrade!

… or …

Process Changes?

Compliance may be easier and

and more affordable than you've

been led to believe…

Phosphorus: Soluble and Particulate

Soluble Phosphorus

- Convert to TSS (Particulate)
  - Biological P removal
  - Chemical P removal

Particulate Phosphorus

- Remove phosphorus by removing TSS

Phosphorus Removal Strategy

Convert up to 0.05 mg/L of Soluble Phosphorus to TSS (Particulate)

- Biologically
- Chemically

Particulate Phosphorus

- Remove as much TSS as necessary to meet Phosphorus Limit

Rule of Thumb: **2** mg/L TSS = **0.1** mg/L t-P

TSS Removal Requirements

If all but 0.05 mg/L of Soluble Phosphorus is Converted to Particulate Phosphorus (Biologically and/or Chemically)

And, if Effluent TSS is 5% total-Phosphorus, Effluent TSS cannot exceed the numbers 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

Science is on Your Side

Better Settling Mixed Liquor…

Chemical Phosphorus Removal

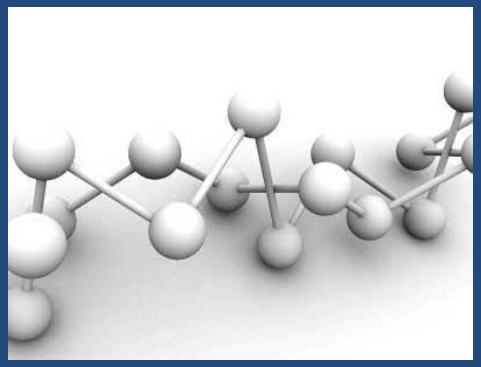
Soluble ortho-Phosphate is taken out of solution and made into TSS .
The particulate Phosphorus is settled.

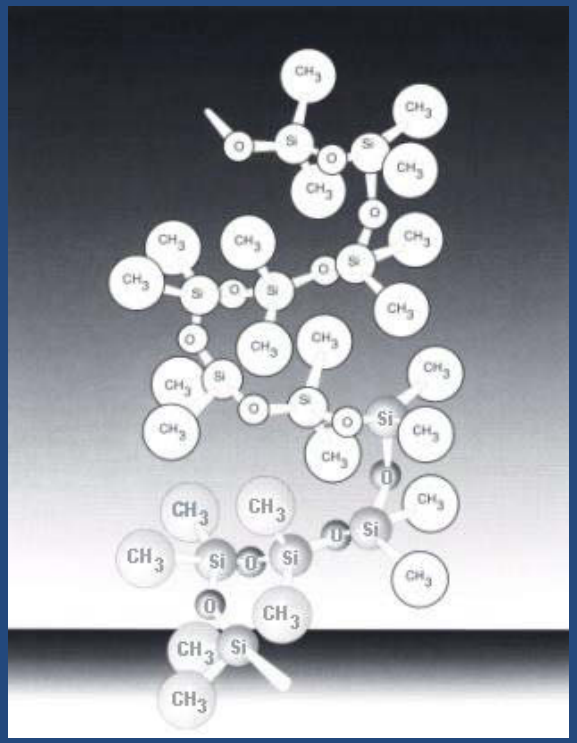
Iron
- *Ferric*
- *Ferrous*

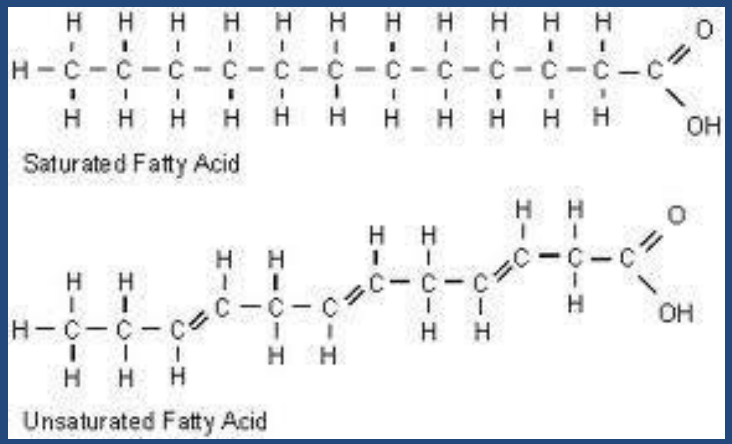
Aluminum
- Alu
- m
- PAC
- Sodium Aluminate

Biological Phosphorus Removal

$C_{60}H_{113}N_{13}O_{37}P$







Habitats

Anaerobic Zone
Volatile Fatty Acid (VFA) Production and
VFA Uptake by PAOs (Phosphate Accumulating Organisms)…

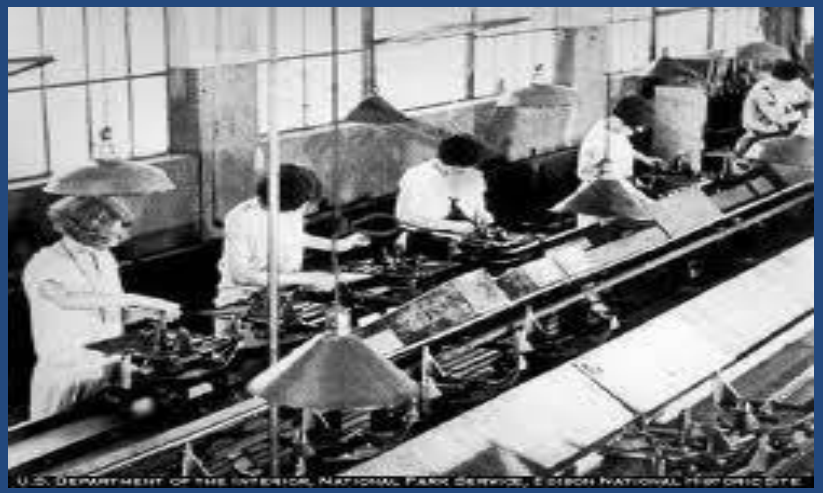
followed by

Aerobic Zone
Phosphorus Uptake by PAOs
("Luxury Uptake")

Anaerobic Zone -
Volatile Fatty Acid (VFA) formation

One family of bacteria create VFAs . . . .

… PAOs "eat" the VFAs



AND

. . . . In the process, the PAO bacteria release some of their Phosphorus

Aerobic Zone

Phosphorus Accumulating Organisms (PAO) concentrate soluble Phosphorus.

PAOs contain 3 times as much Phosphorus as "regular" bacteria do.

The phosphorus concentration in the mixed liquor increases from less than 2% total-P to as much as 5% total-P.

Biological Phosphorus Removal

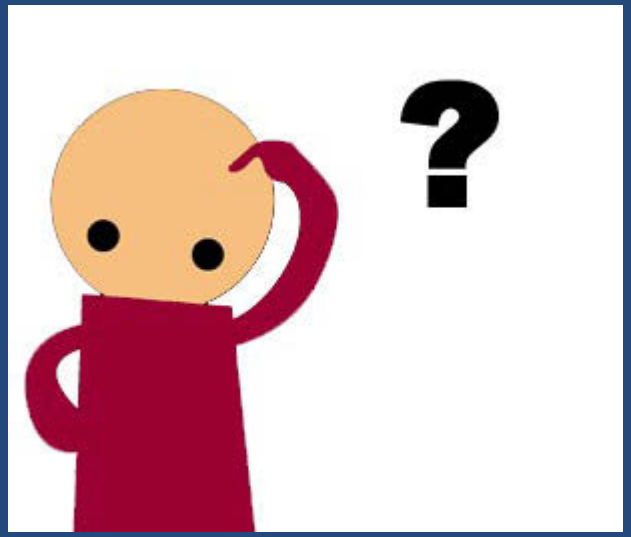
ANAEROBIC zone for

1. VFA (volatile fatty acid) production
2. VFA uptake by PAOs (phosphate accumulating organisms), bio-P bugs

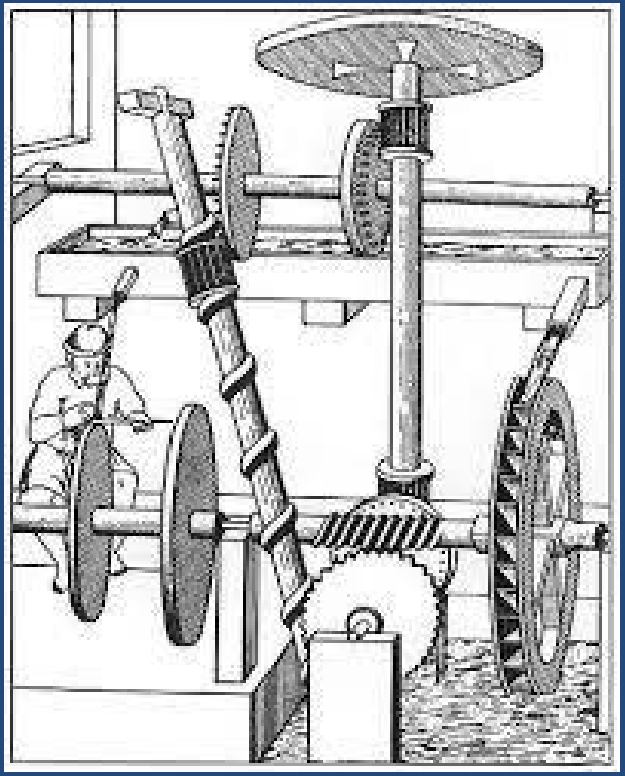
… followed by

AEROBIC zone for Phosphorus uptake
by PAO bacteria

Phosphorus Science Discussion

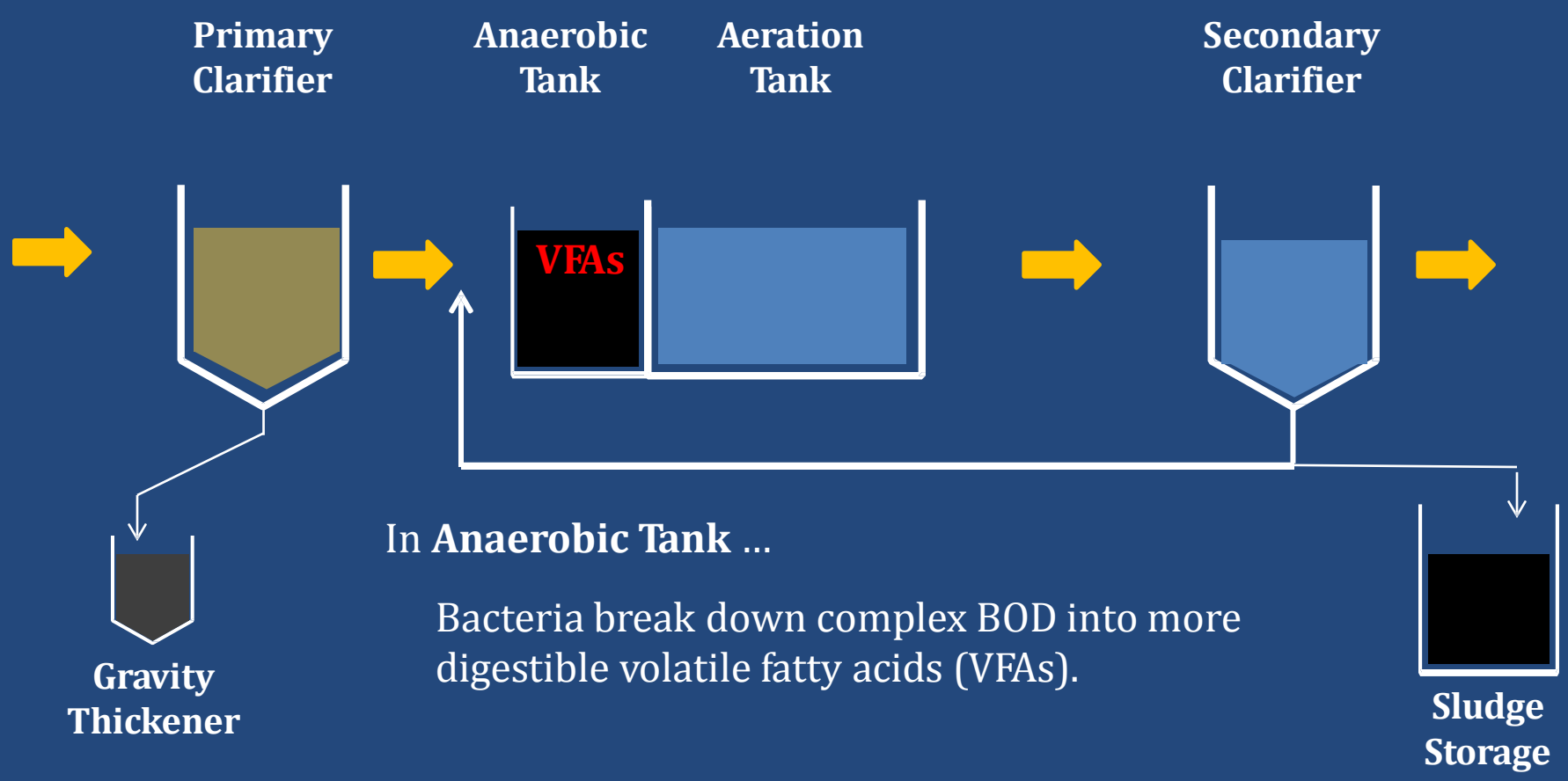


Phosphorus Removal Technology



Mainstream bio-P removal

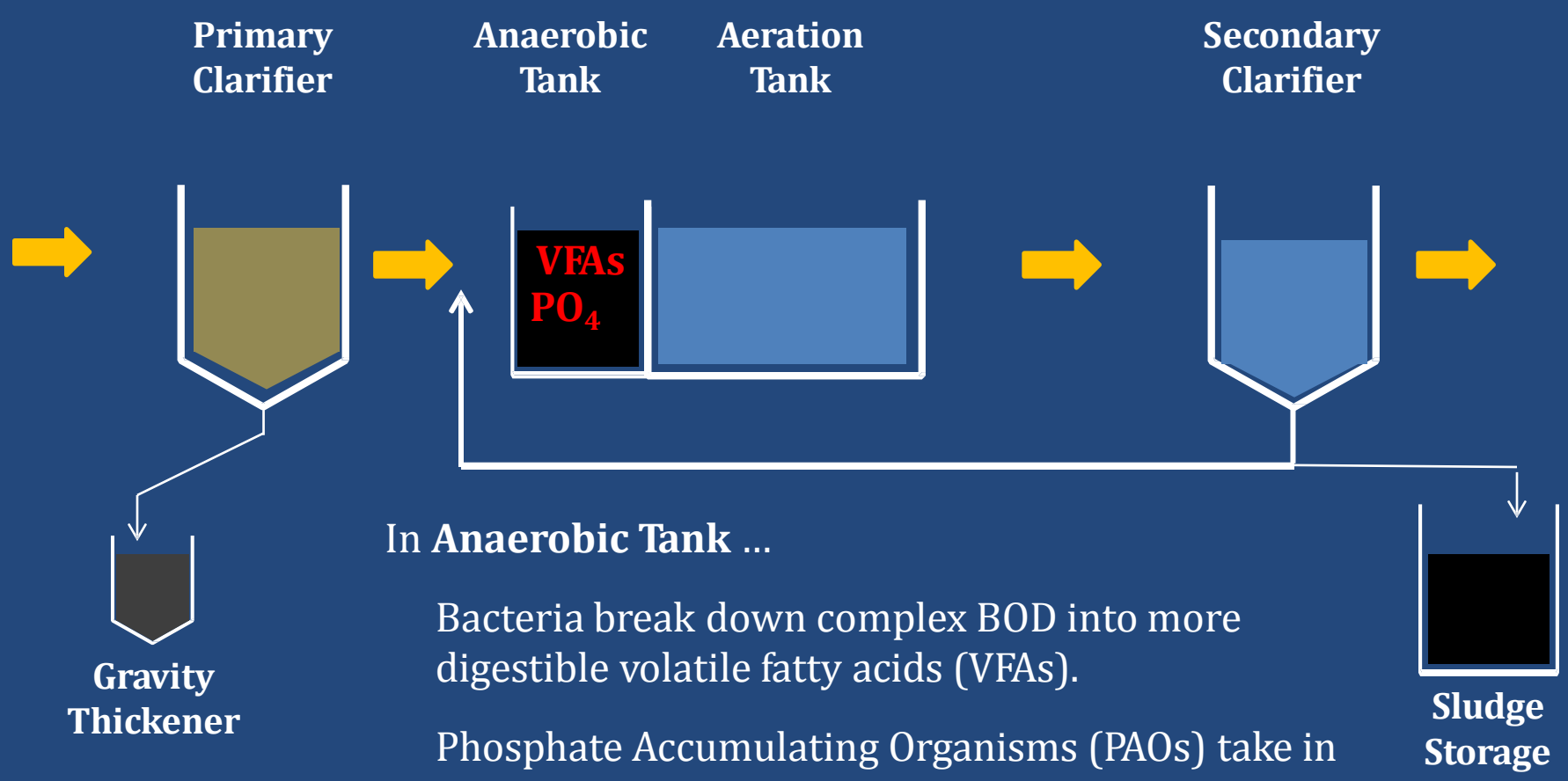
Bio-P Removal: Mainstream Fermentation Process



In **Anaerobic Tank** …

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

Bio-P Removal: Mainstream Fermentation Process



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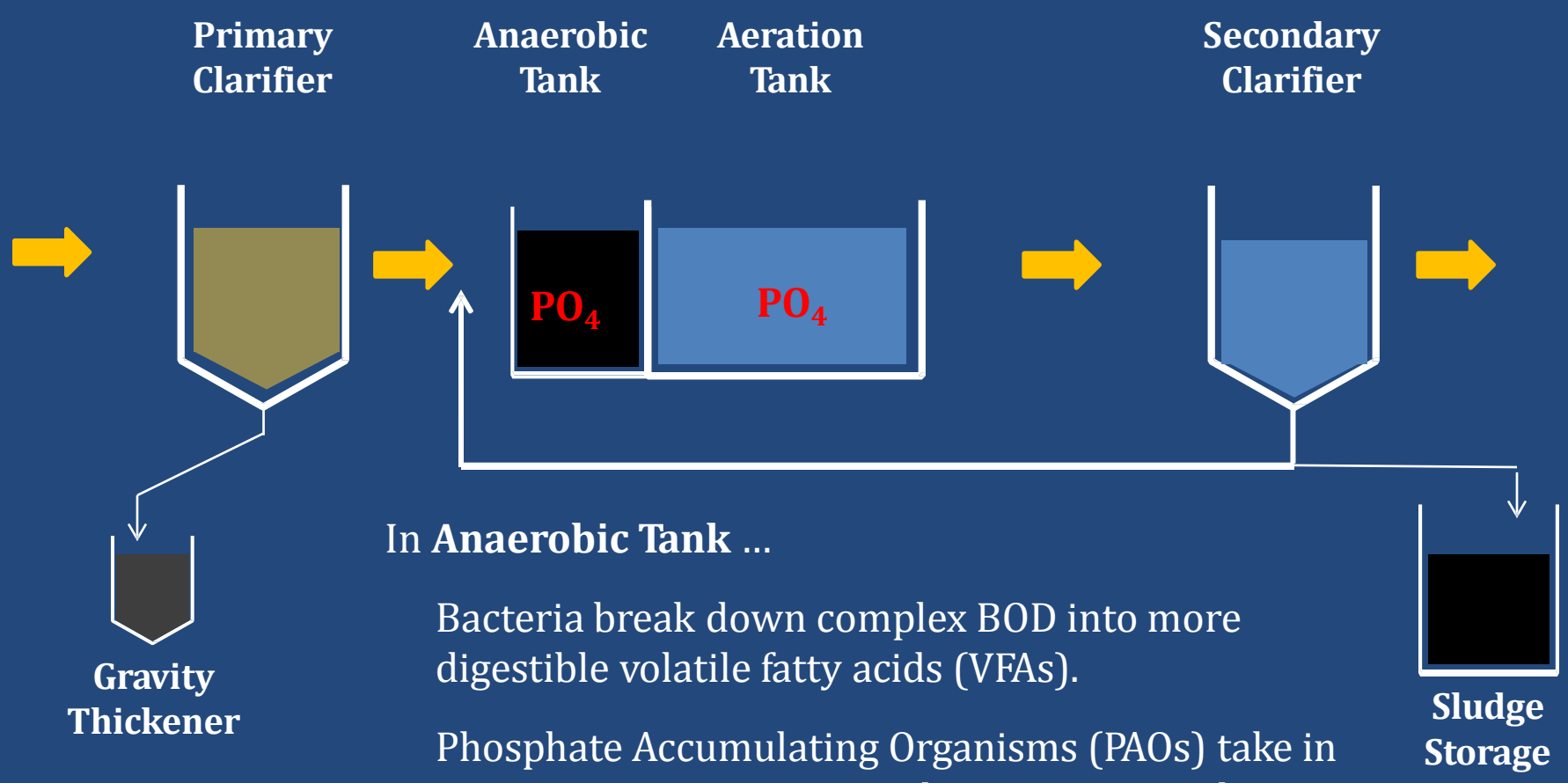
Bacteria break down complex BOD into more digestible volatile fatty acids (VFAs).

Phosphate Accumulating Organisms (PAOs) take in VFAs as energy source & release PO_4 into solution.

In **Aeration Tank** …

PAO bacteria use VFAs to take PO_4 out of solution.

Bio-P Removal: Mainstream Fermentation Process



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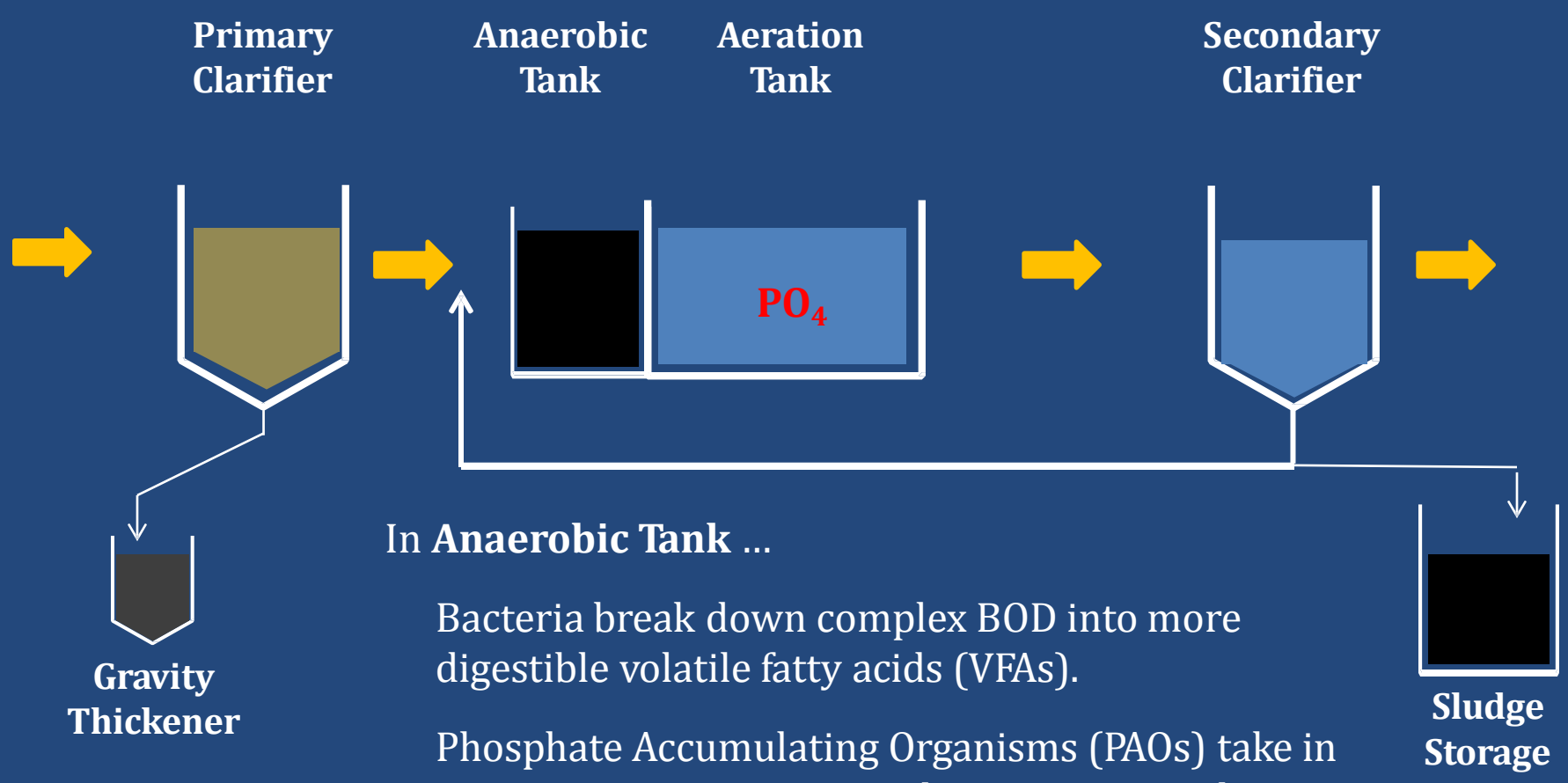

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Sidestream bio-P removal

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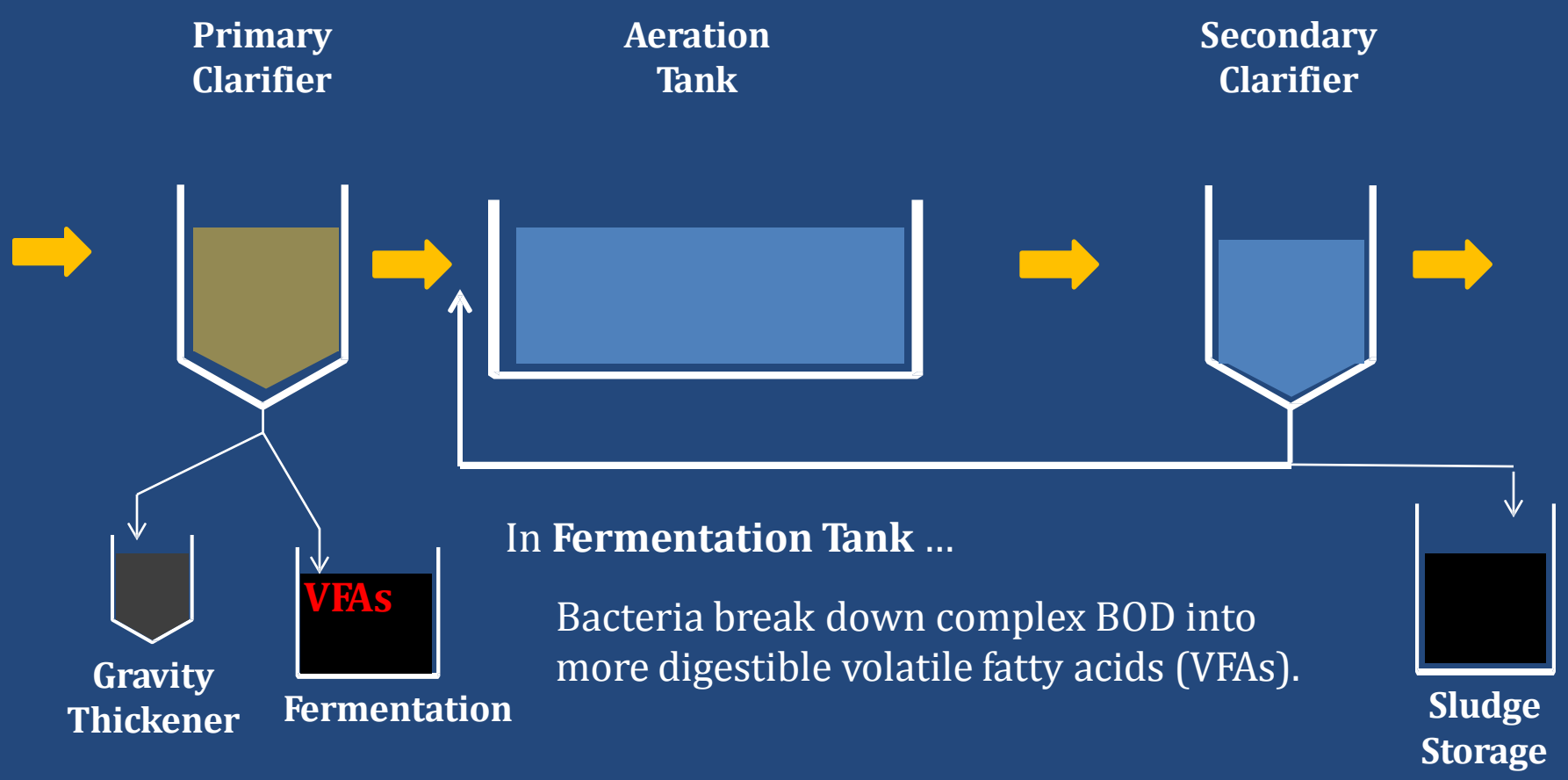

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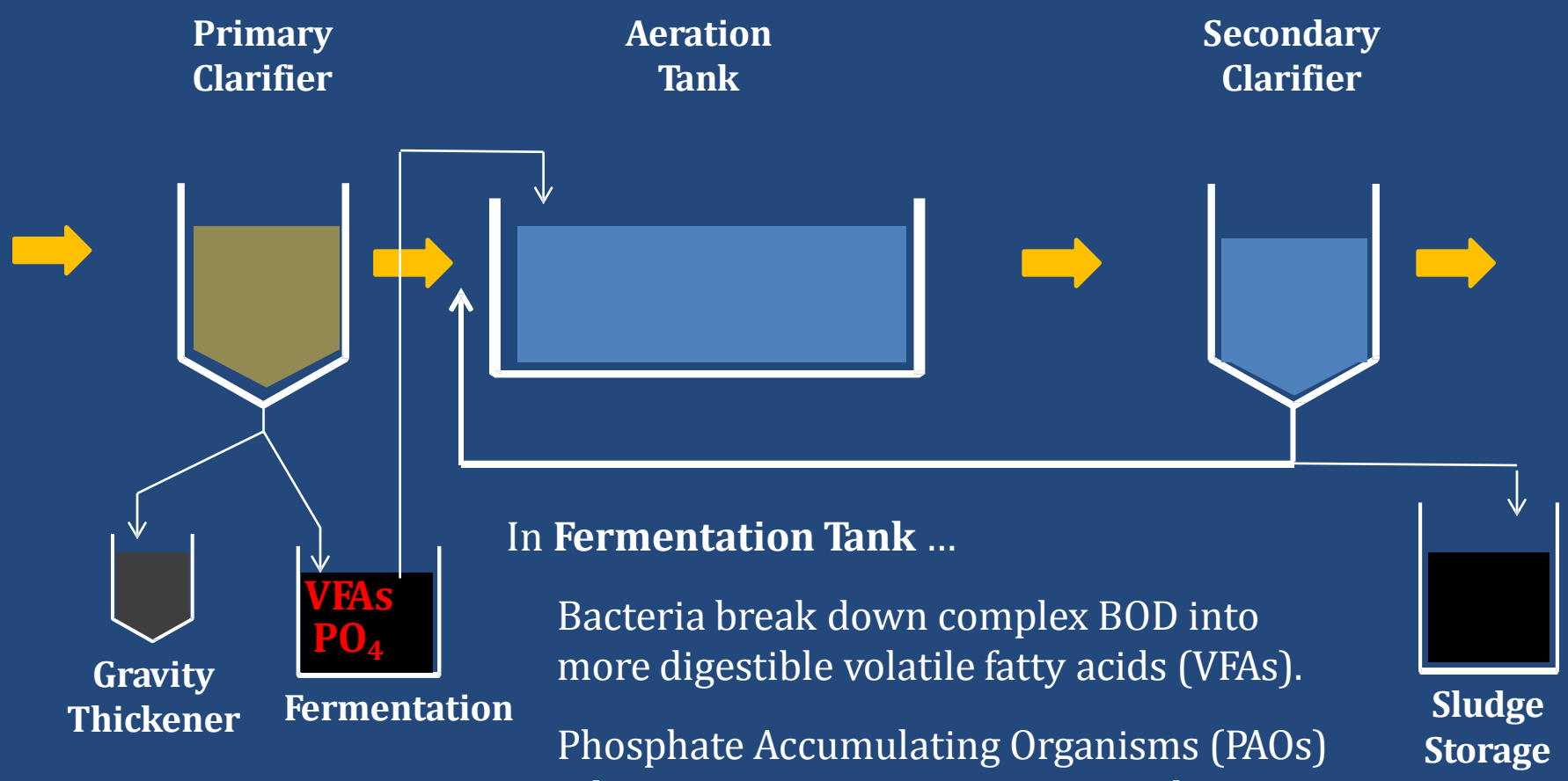
Bio-P Removal: Sidestream Fermentation Process



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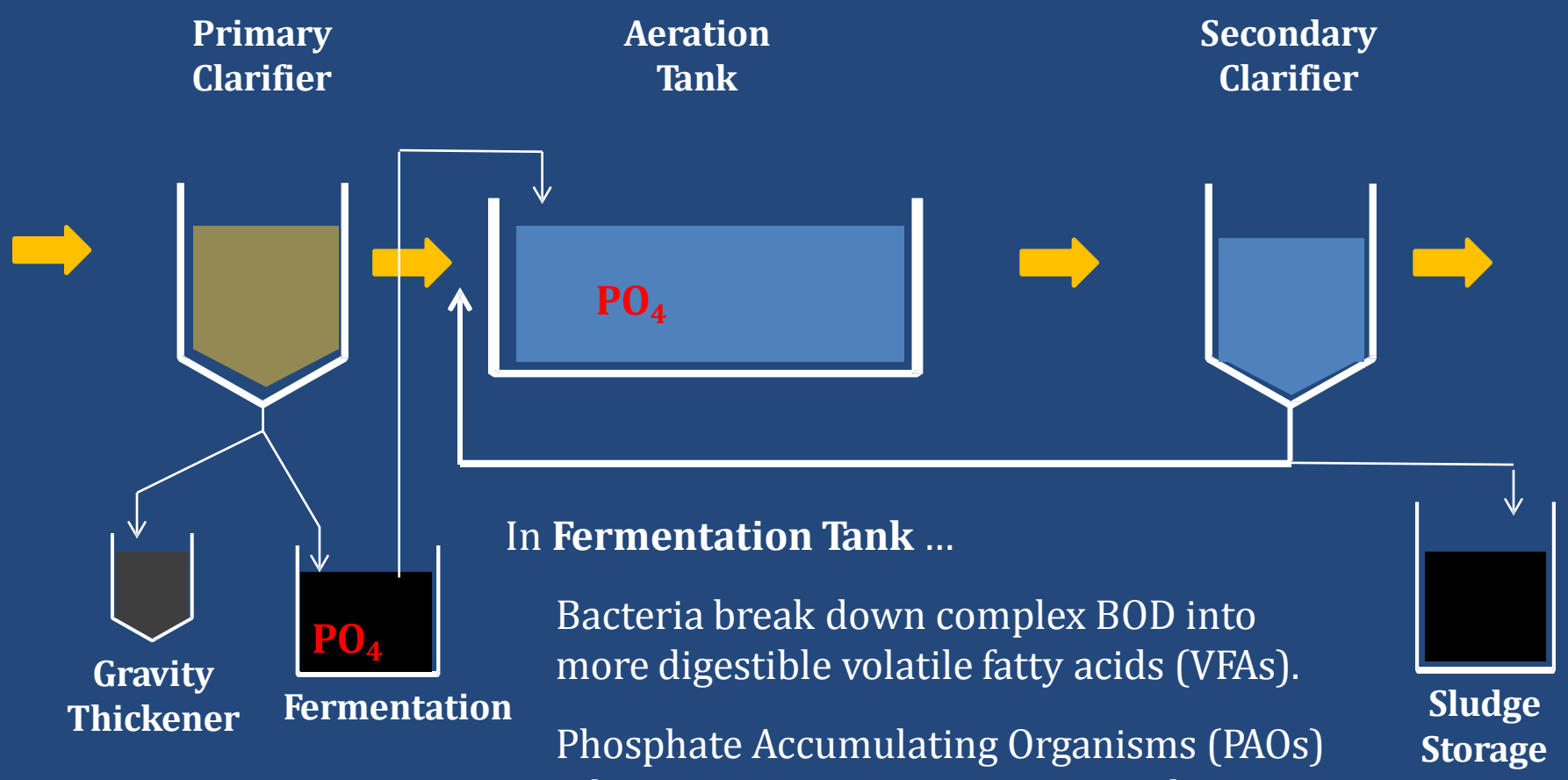

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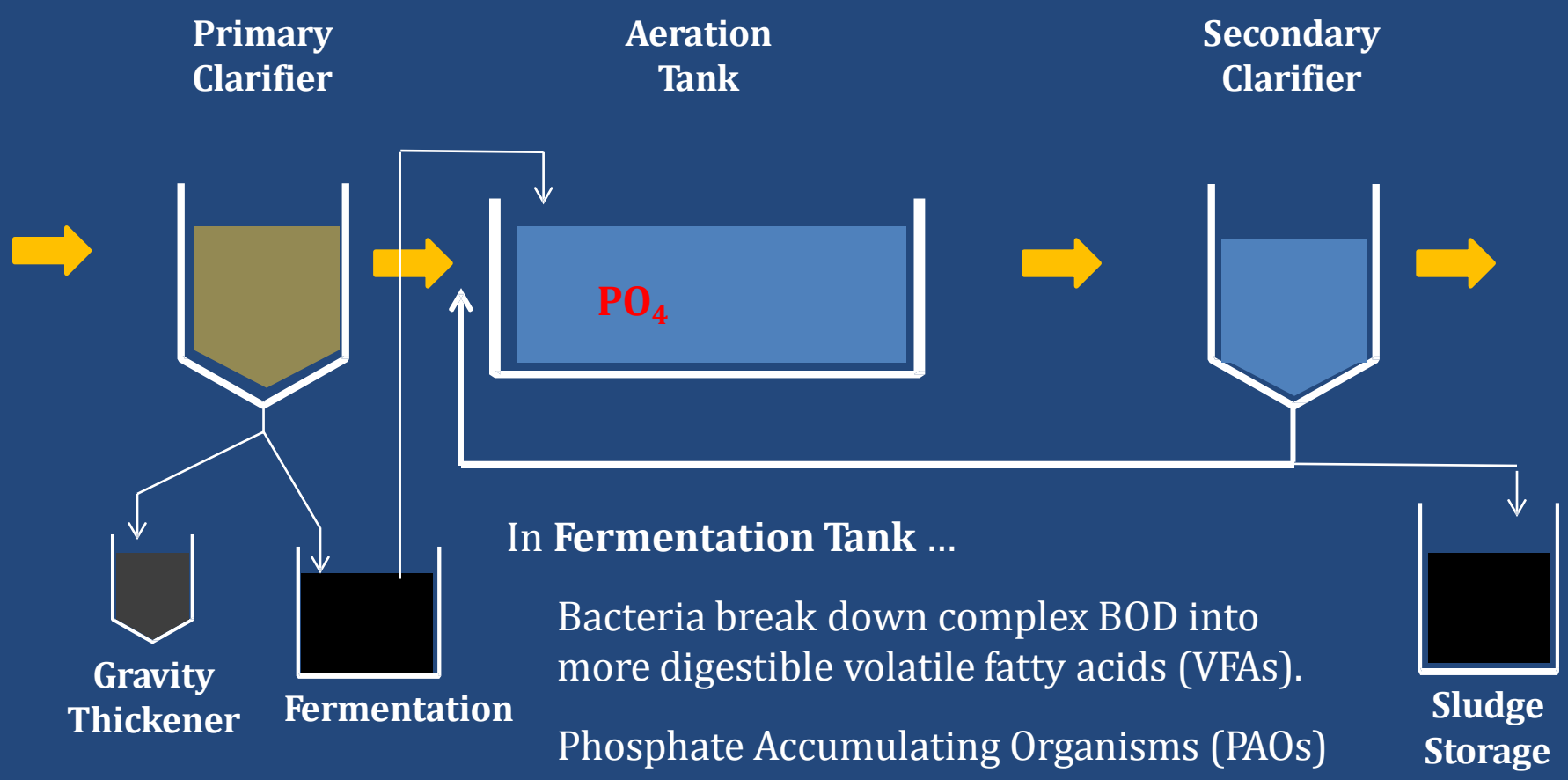

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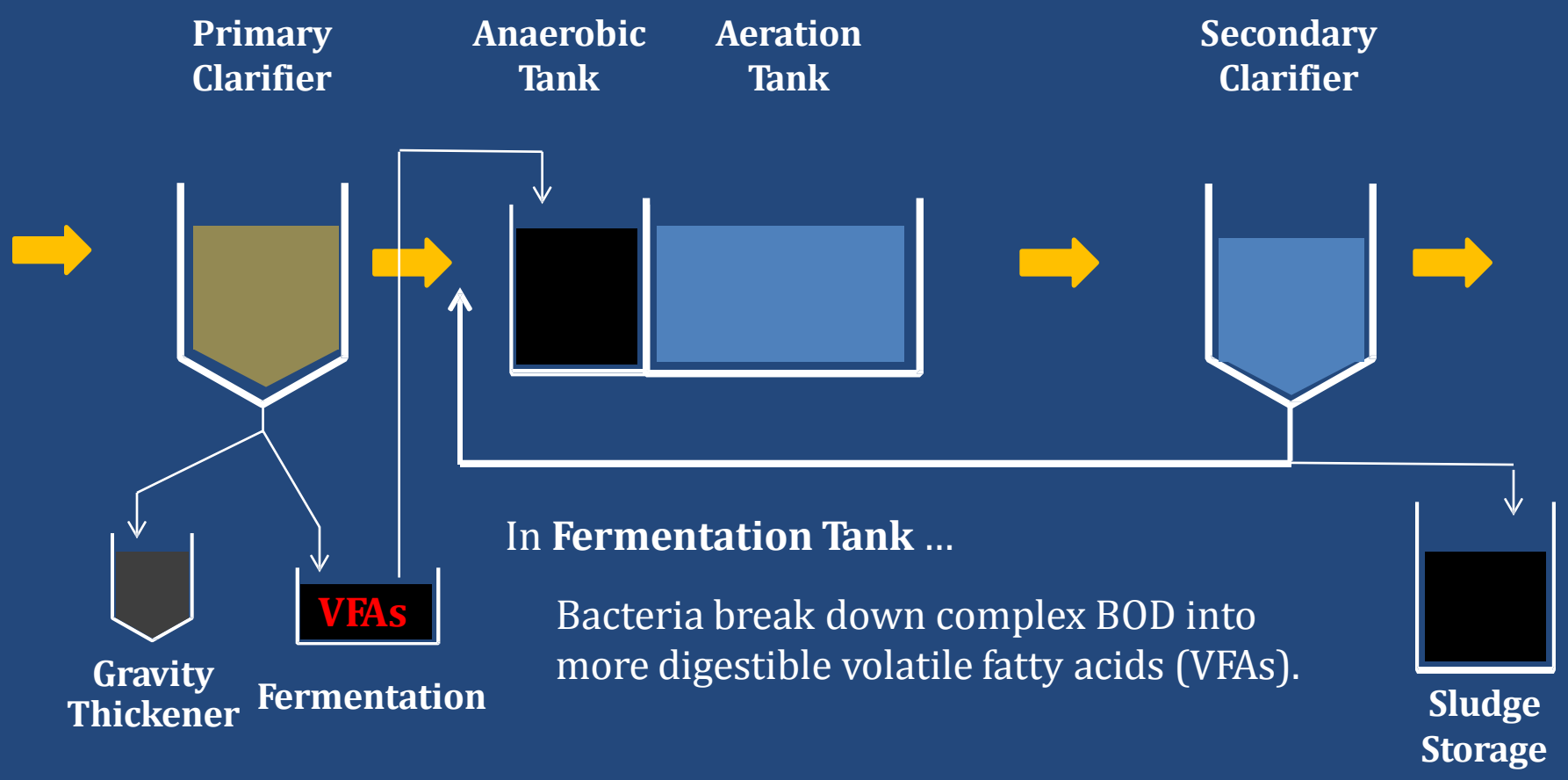
Sidestream & Mainstream bio-P removal

Bio-P Removal: Sidestream & Mainstream Process



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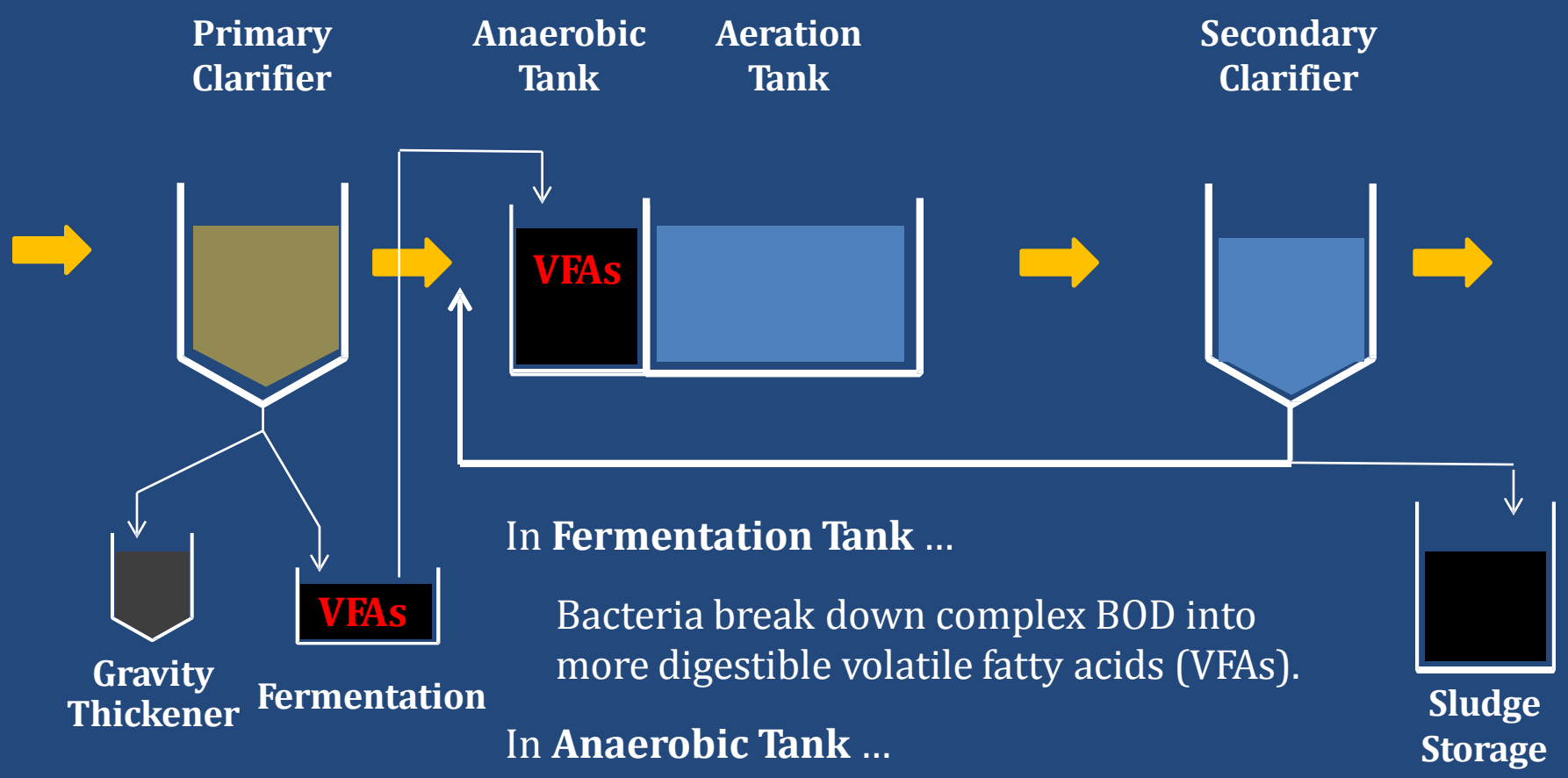

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In **Anaerobic Tank** …

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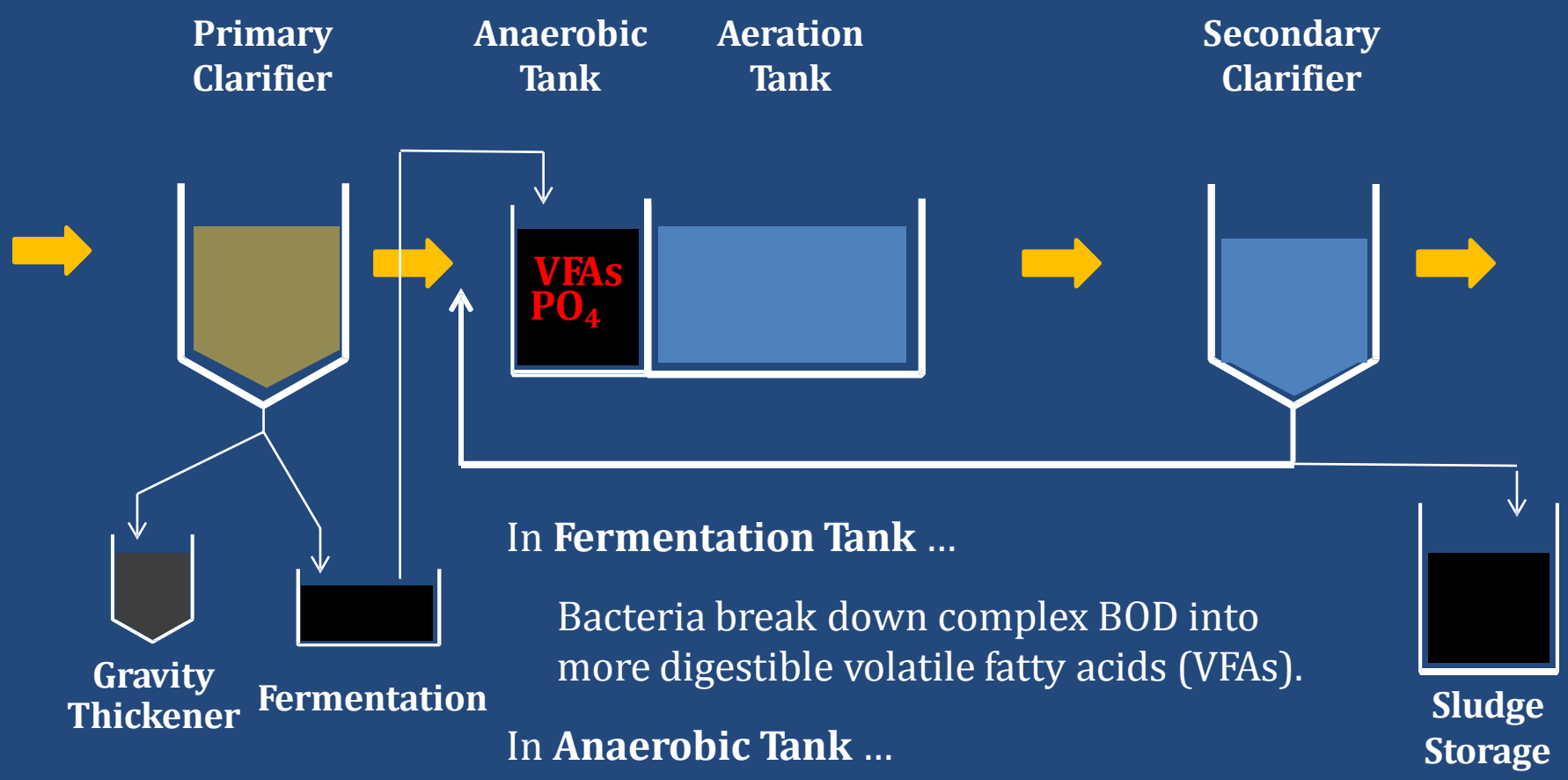
Bio-P Removal: Sidestream & Mainstream Process



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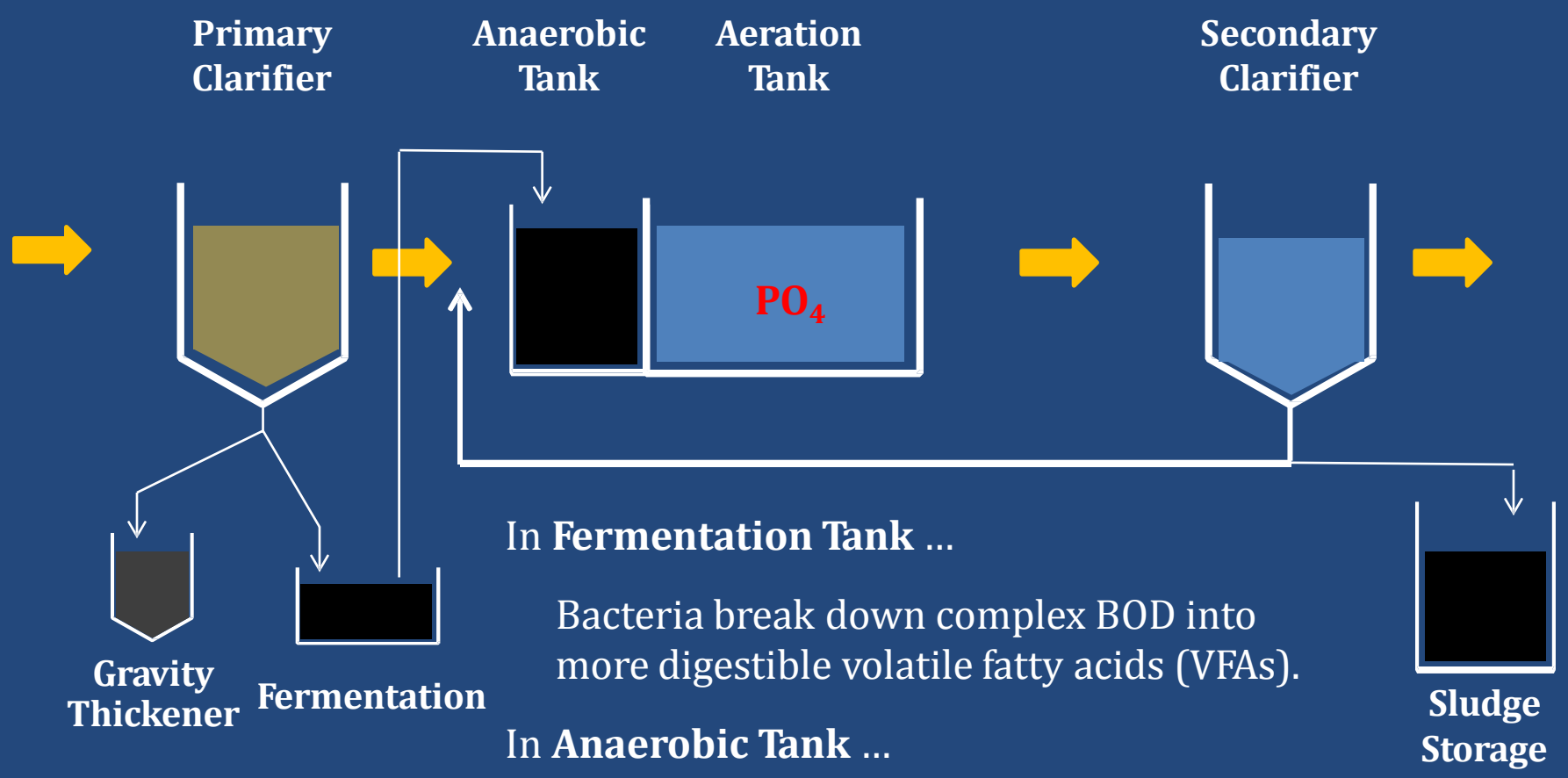

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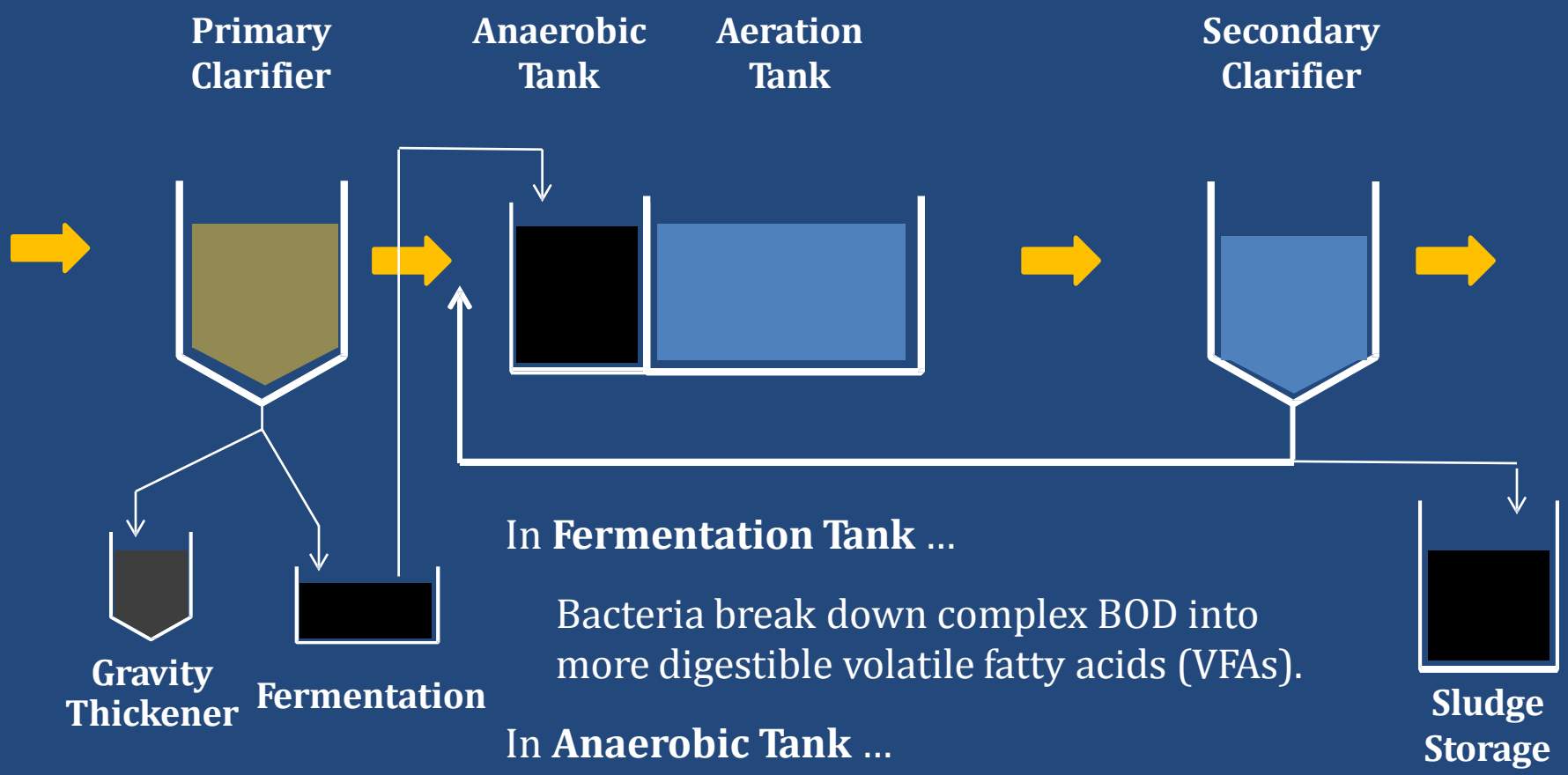

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Nitrogen Interference In **Aeration Tank** …

Aerobic Nitrate (NO_3) will consume VFAs

PAO bacteria take PO_4 out of solution.

Anaerobic Zone

<u>Mainstream</u>

Pre- Anaerobic Zone

Modify Pre-Anoxic

Modify Existing Tanks

<u>Sidestream</u>

RAS piping

Gravity Thickener

Primary Sludge

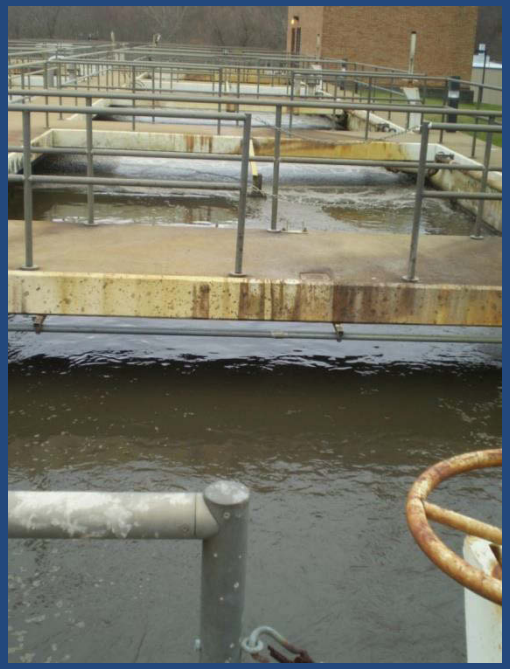
WAS

Combined Primary & Secondary

Sludge Storage

Septage

Anaerobic Zone – Mainstream



Anaerobic Zone – Side Stream

Aerobic Zone

Biological Phosphorus Removal

Convert soluble Phosphorus to particulate Phosphorus

Remove the particulate Phosphorus with TSS

Maintaining compliance requires …

- Low to no soluble P
- Low effluent TSS

Process Control

Phosphorus Process Control

Monitor treatment …

- Measure effluent soluble Phosphorus
- Measure effluent TSS

Compute effluent quality …

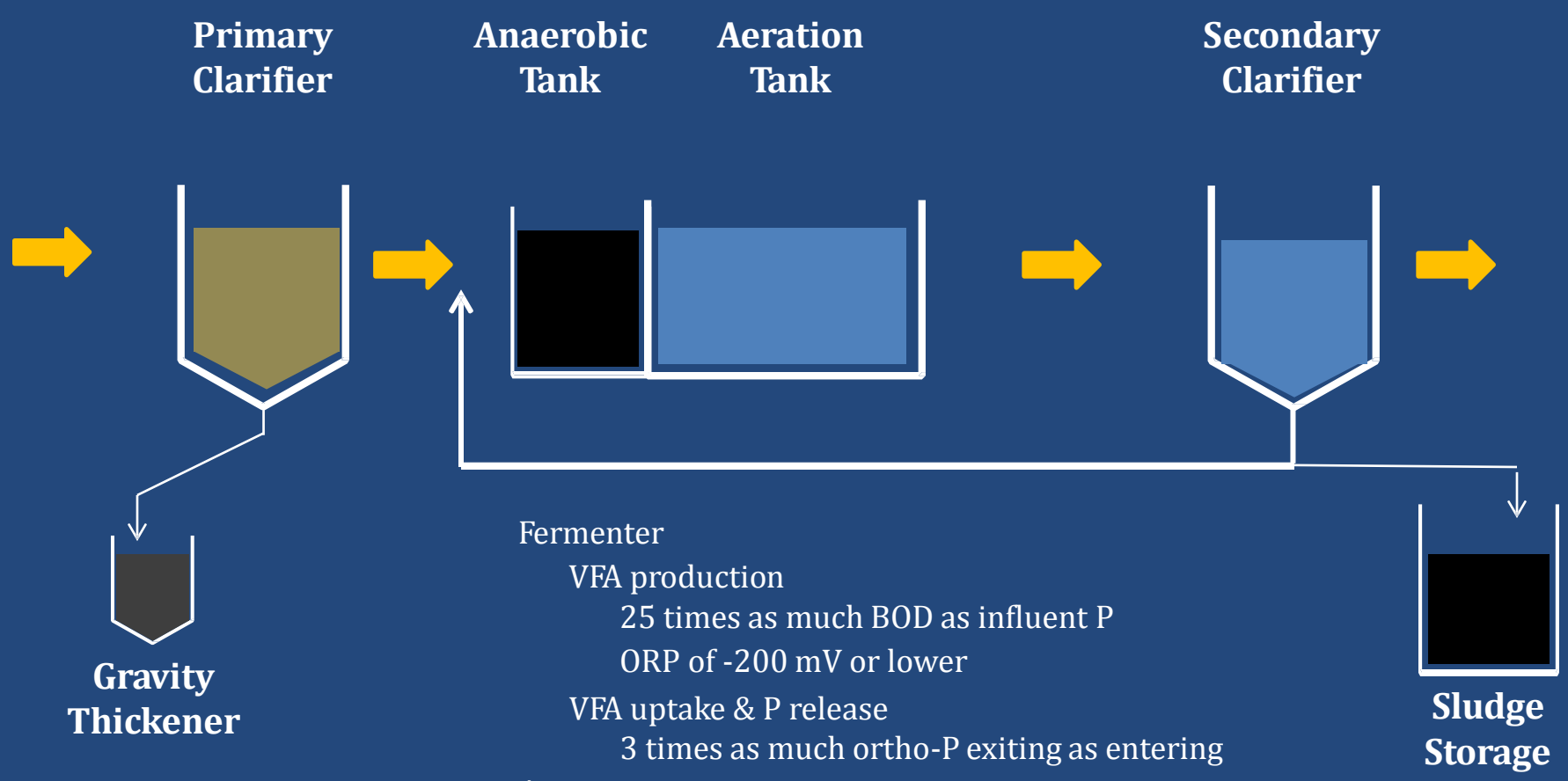
- ortho-P + 5% effluent TSS

Phosphorus Process Control

Monitor habitats …

- Anaerobic conditions (pre-aeration)
  - VFA production
    - 25 times as much BOD as influent P
    - ORP of -200 mV or lower
  - VFA uptake & P release
    - 3 times as much ortho-P exiting as entering
- Aerobic conditions (aeration)
  - DO of 2.0 mg/L
  - ORP of +100? mV
  - pH of 7.0 or higher
- Watch for phosphorus release!

Monitoring Bio-P Removal: Mainstream



Fermenter
- VFA production
  - 25 times as much BOD as influent P
  - ORP of -200 mV or lower
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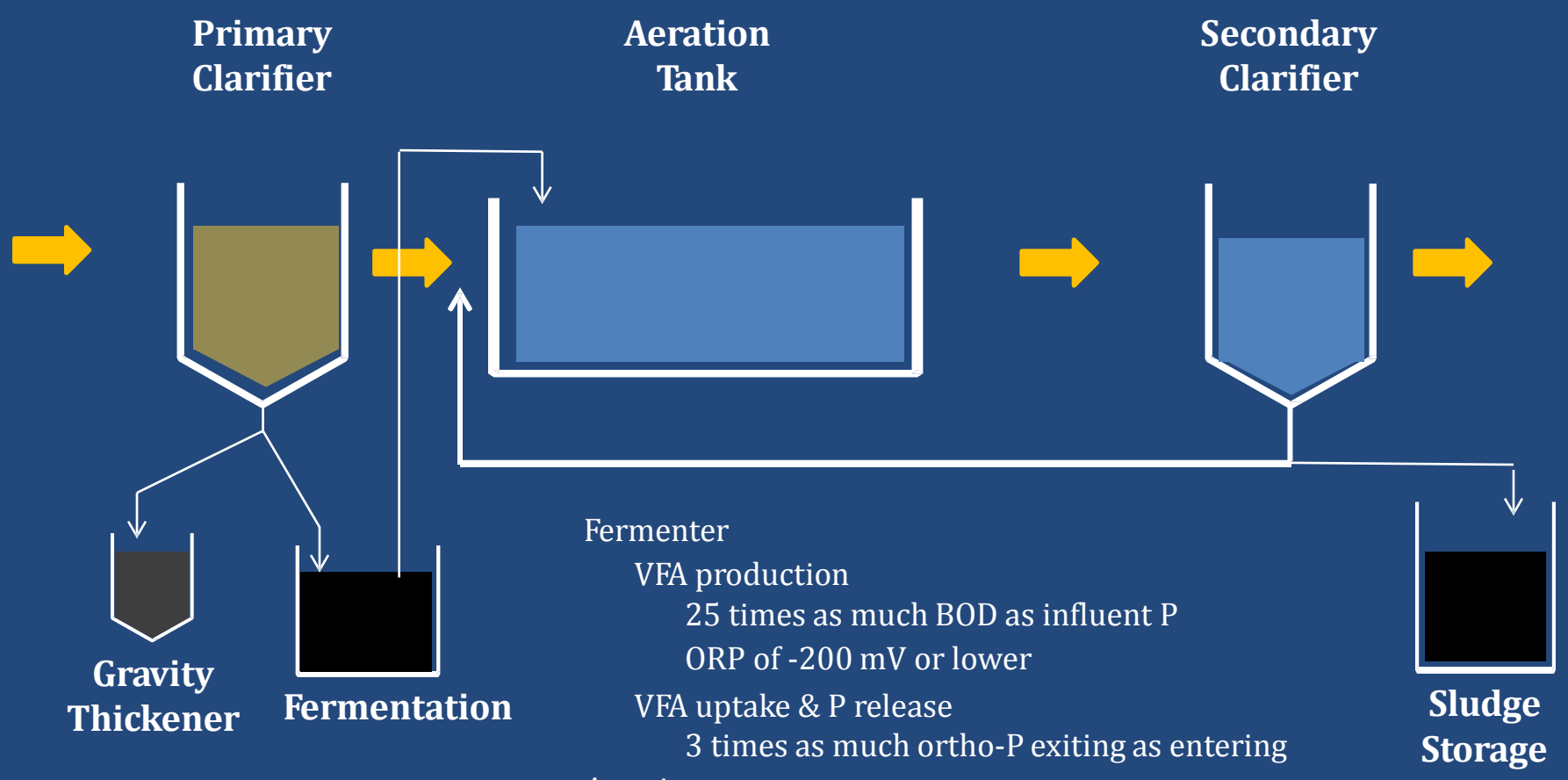
Aeration
- DO of 2.0 mg/L
- ORP of +100? mV
- pH of 7.0 or higher

Watch for phosphorus release!

Bio-P Removal: Sidestream Fermentation Process



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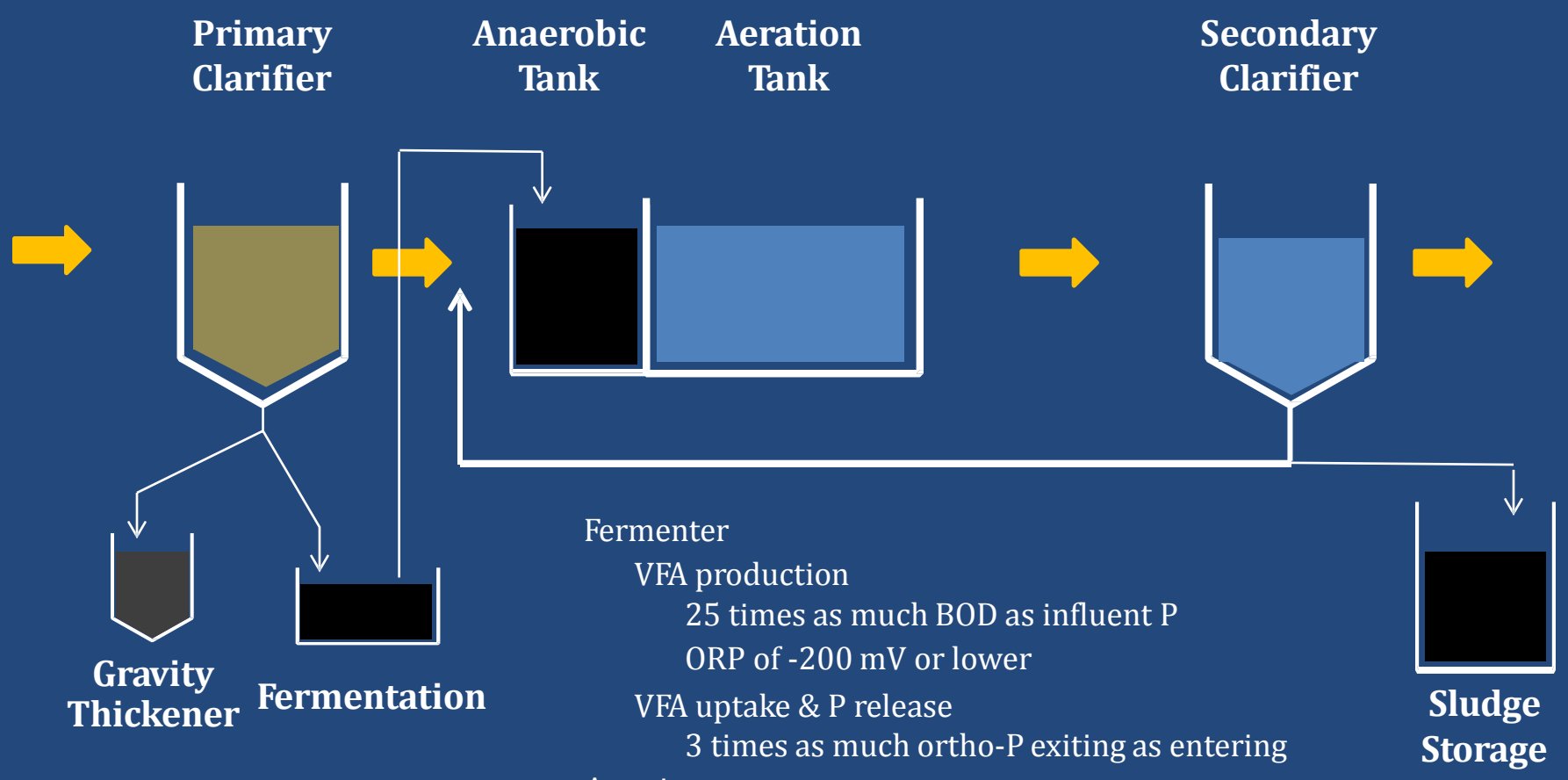
Bio-P Removal: Sidestream & Mainstream Process



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Watch for phosphorus release!

Summary

Phosphorus Removal requires

- Converting soluble P to TSS-P
- Removing TSS

Biological P-Removal is a two-step process

- Anaerobic followed by
- Aerobic

Anaerobic can be main flow and/or sidestream

Chemical treatment can supplement biological

Nitrogen AND Phosphorus Removal

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

www.cleanwaterops.com

Options for Monitoring Nitrogen and Phosphorus Removal

	Cheapest	Good	Better	Best	Ideal
Environmental conditions					
DO	hand held membrane DO meter	hand held LDO meter	hand held LDO with thumb drive	in-line DO probe	in-line connected to SCADA
ORP	pen/stick measure	hand held ORP meter	hand held ORP meter with thumb drive	in-line ORP probe	in-line connected to SCADA
pH	test strips	pen/stick measure	benchtop pH	in-line pH probe	in-line connected to SCADA
Alkalinity	test strips	test strips	spectrophotometer	benchtop pH w/ titration	benchtop pH w/ titration
Nitrogen					
TKN	estimate: Ammonia + 2.0 mg/L	estimate: Ammonia + 2.0 mg/L	spectrophotometer	spectrophotometer	spectrophotometer
Ammonia	test strips	test strips	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)
Nitrate	test strips	test strips	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)
Nitrite	test strips	test strips	spectrophotometer	spectrophotometer	spectrophotometer
Phosphorus					
total-P	estimate: TSSx0.05 + test strips	estimate: TSSx0.05 + test strips	spectrophotometer	spectrophotometer	spectrophotometer
ortho-P	test strips	test strips	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)

Questions, Comments, Discussion

"Sir, I have a question that's lunch-related."

THE WATER PLANET COMPANY

Making clean water affordable

Options for Monitoring Nitrogen and Phosphorus Removal: Small Plants – Less than 1.0 MGD

	Cheapest	Good	Better	Best	Ideal
Environmental conditions					
DO	hand held membrane DO meter	**hand held LDO meter**	hand held LDO with thumb drive	in-line DO probe	in-line connected to SCADA
ORP	pen/stick measure	**hand held ORP meter**	hand held ORP meter with thumb drive	in-line ORP probe	in-line connected to SCADA
pH	test strips	**pen/stick measure**	benchtop pH	in-line pH probe	in-line connected to SCADA
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Nitrogen					
TKN	estimate: Ammonia + 2.0 mg/L	**estimate: Ammonia + 2.0 mg/L**	spectrophotometer	spectrophotometer	spectrophotometer
Ammonia	test strips	**test strips**	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)
Nitrate	test strips	**test strips**	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)
Nitrite	test strips	**test strips**	spectrophotometer	spectrophotometer	spectrophotometer
Phosphorus					
total-P	estimate: TSSx0.05 + test strips	**estimate: TSSx0.05 + test strips**	spectrophotometer	spectrophotometer	spectrophotometer
ortho-P	test strips	**test strips**	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)

Options for Monitoring Nitrogen and Phosphorus Removal: 2-5 MGD

	Cheapest	Good	Better	Best	Ideal
Environmental conditions					
DO	hand held membrane DO meter	hand held LDO meter	hand held LDO with thumb drive	in-line DO probe	in-line connected to SCADA
ORP	pen/stick measure	hand held ORP meter	hand held ORP meter with thumb drive	in-line ORP probe	in-line connected to SCADA
pH	test strips	pen/stick measure	benchtop pH	in-line pH probe	in-line connected to SCADA
Alkalinity	test strips	test strips	spectrophotometer	benchtop pH w/ titration	benchtop pH w/ titration
Nitrogen					
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Ammonia	test strips	test strips	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)
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ortho-P	test strips	test strips	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)

Options for Monitoring Nitrogen and Phosphorus Removal: 5+ MGD … or, 6 mg/L tN limit or 0.5 mg/L tP limit

	Cheapest	Good	Better	Best	Ideal
Environmental conditions					
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ortho-P	test strips	test strips	spectrophotometer	in-line instrument ($$)	in-line connected to SCADA ($$)

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