Nutrient Removal in Sequencing Batch Reactors (SBRs)

Webinar for Tennessee Wastewater Treatment Plant Operators
March 3, 2021

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President
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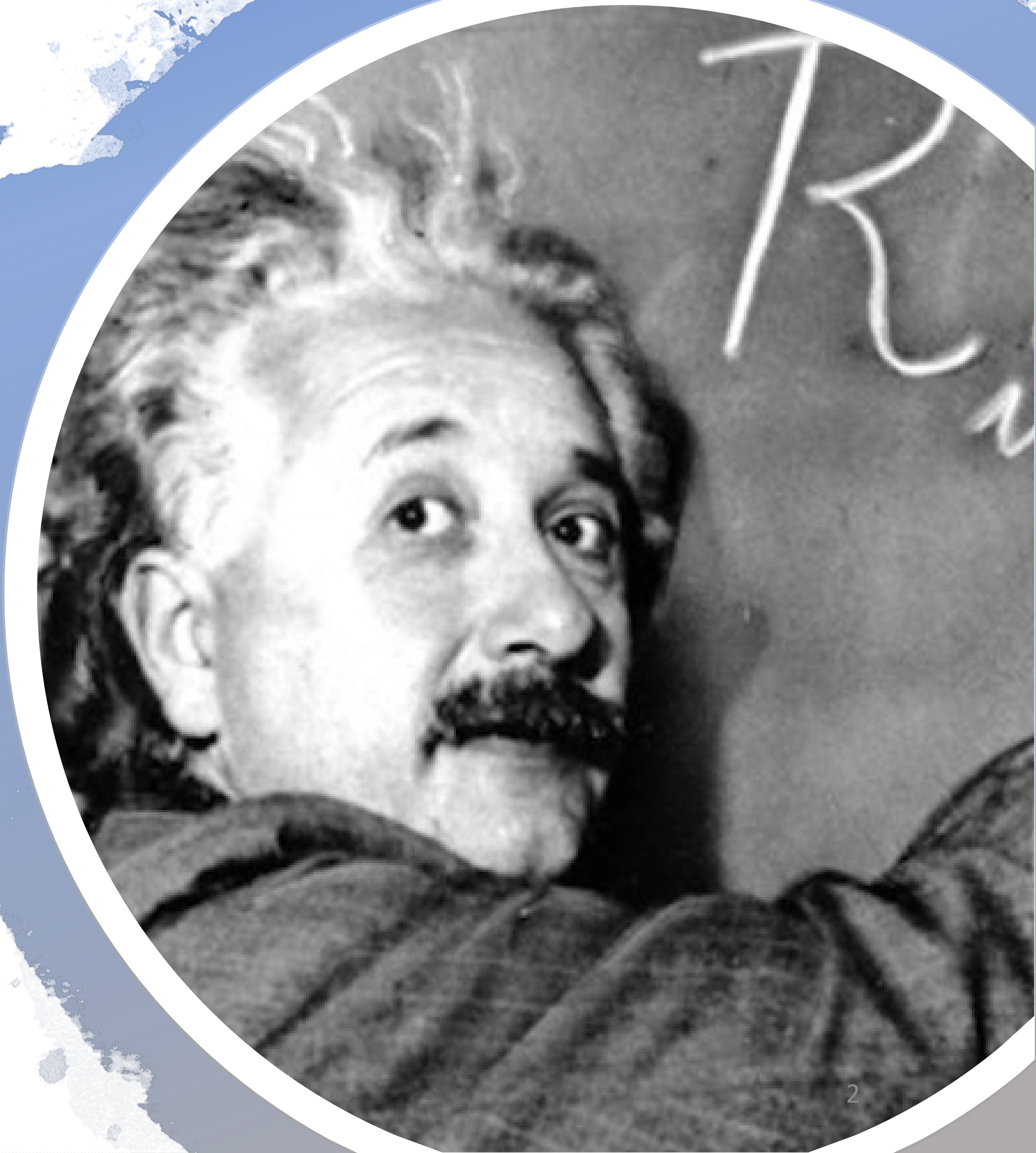
Strategies for Optimizing Nutrient Removal

Week 1: Nitrogen Removal
Week 2: Phosphorus Removal
Week 3: N&P Review and Case Studies
Week 4: N&P Removal in Oxidation Ditches

Today: Nitrogen & Phosphorus Removal in SBRs (Sequencing Batch Reactors)

Mar 10: N&P Removal in Conventional Activated Sludge

Mar 17: Brainstorming N&P Removal Opportunities for Tennessee Wastewater Treatment Plants



Rate your SBR knowledge


REVIEW

N

7

Nitrogen

Step 1: Convert Ammonia (NH_4) to Nitrate (NO_3)

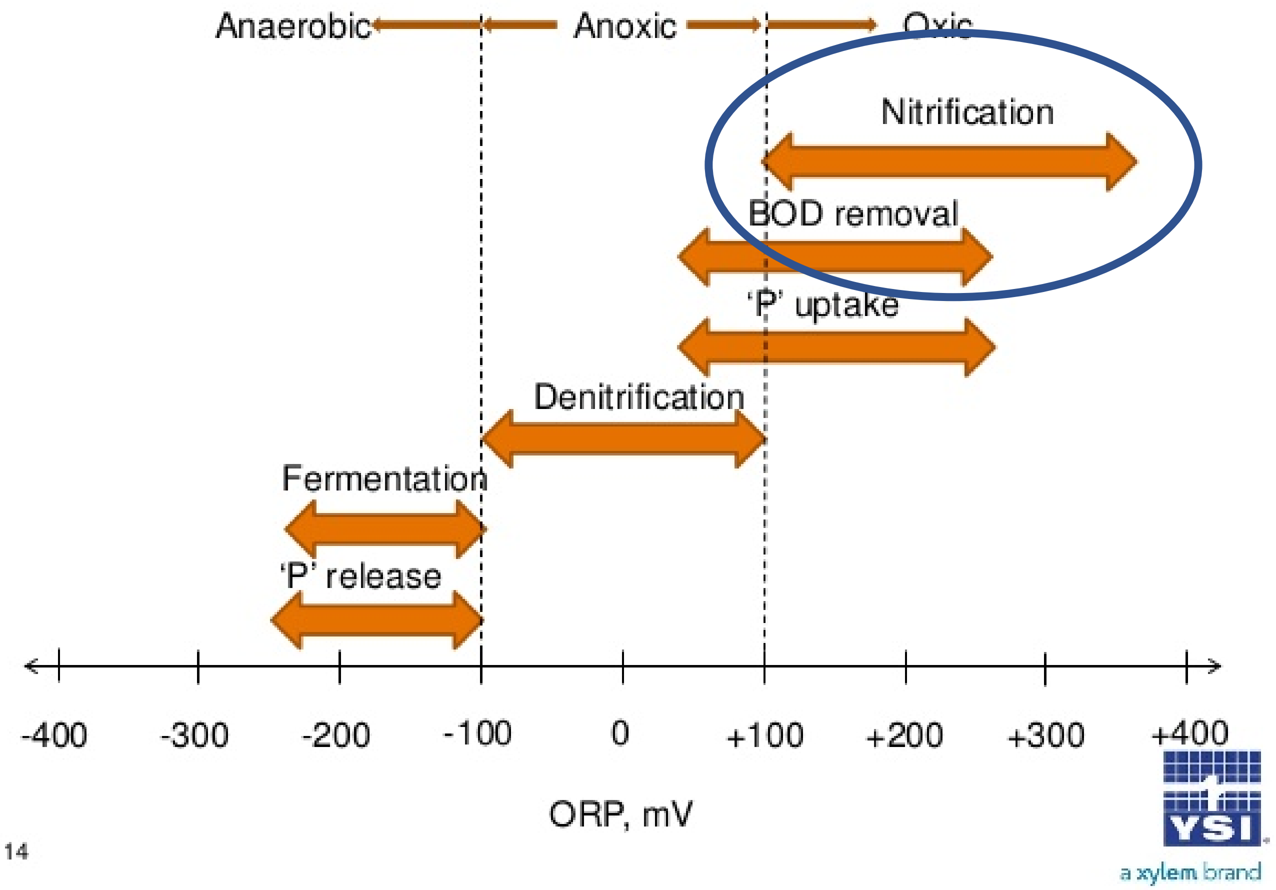
Oxygen-rich Aerobic Process
Don't need BOD for bacteria to grow
Bacteria are sensitive to pH and temperature

Step 2: Convert Nitrate (NO_3) to Nitrogen Gas (N_2)

Oxygen-poor Anoxic Process
Do need BOD for bacteria to grow
Bacteria are hardy

Ammonia Removal - 1st Step of N Removal

What Does ORP Tell Us About Our Process?



7

Step 1: Ammonia Removal

pH of 6.5+

Plenty of D[illegible]/L

ORP of +15[illegible]mV

Little to no [illegible]D

4+ hours retention time

N

Nitrogen

Ammonia Removal

Ammonia (NH_4) is converted to Nitrate (NO_3)

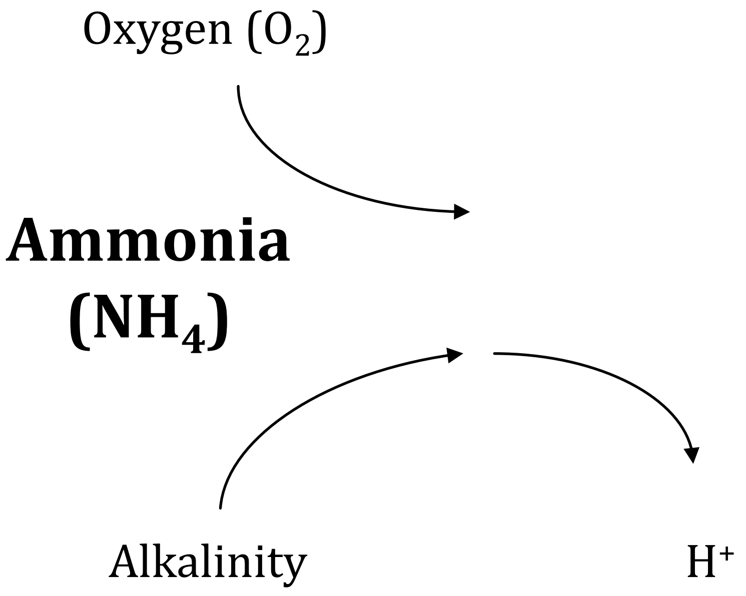
Ammonia
(NH_4)

Ammonia Removal

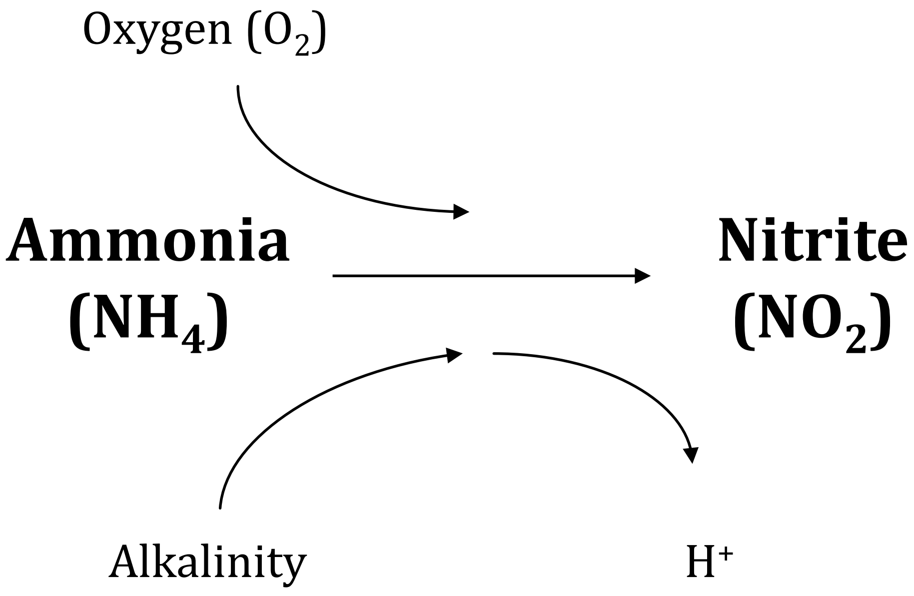
Oxygen (O_2)

Ammonia (NH_4)

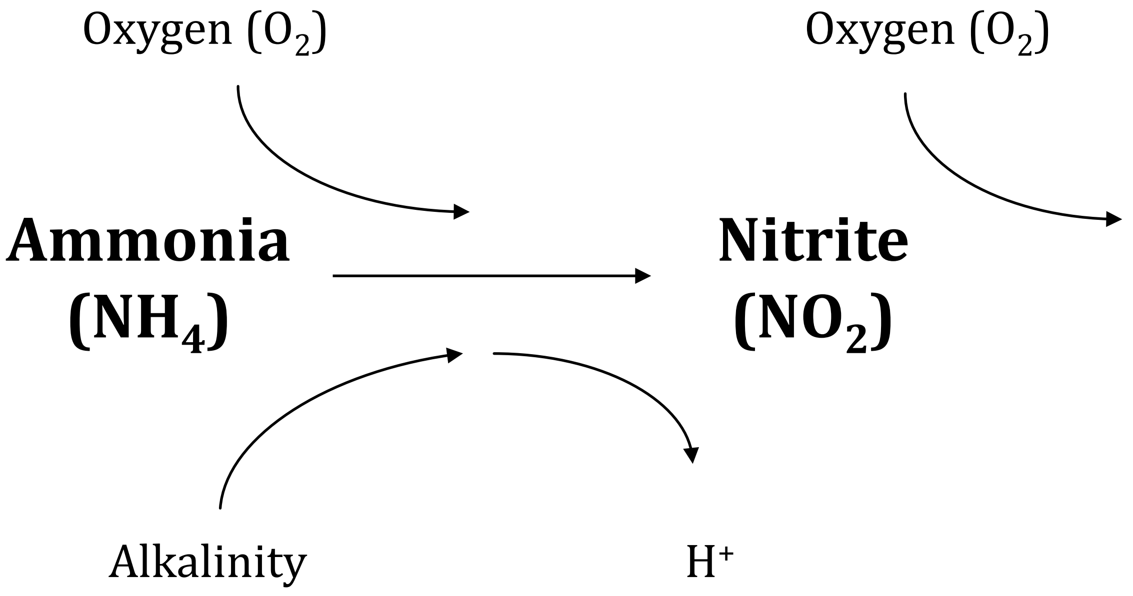
Ammonia Removal



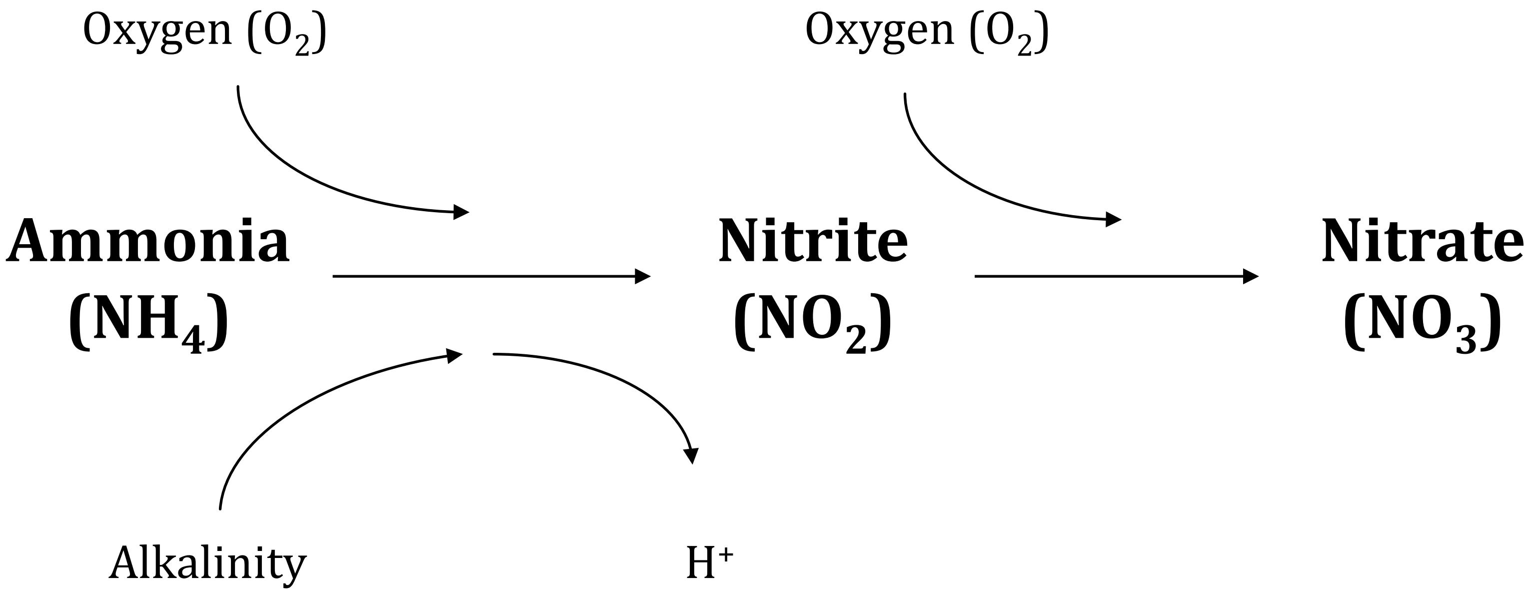
Ammonia Removal



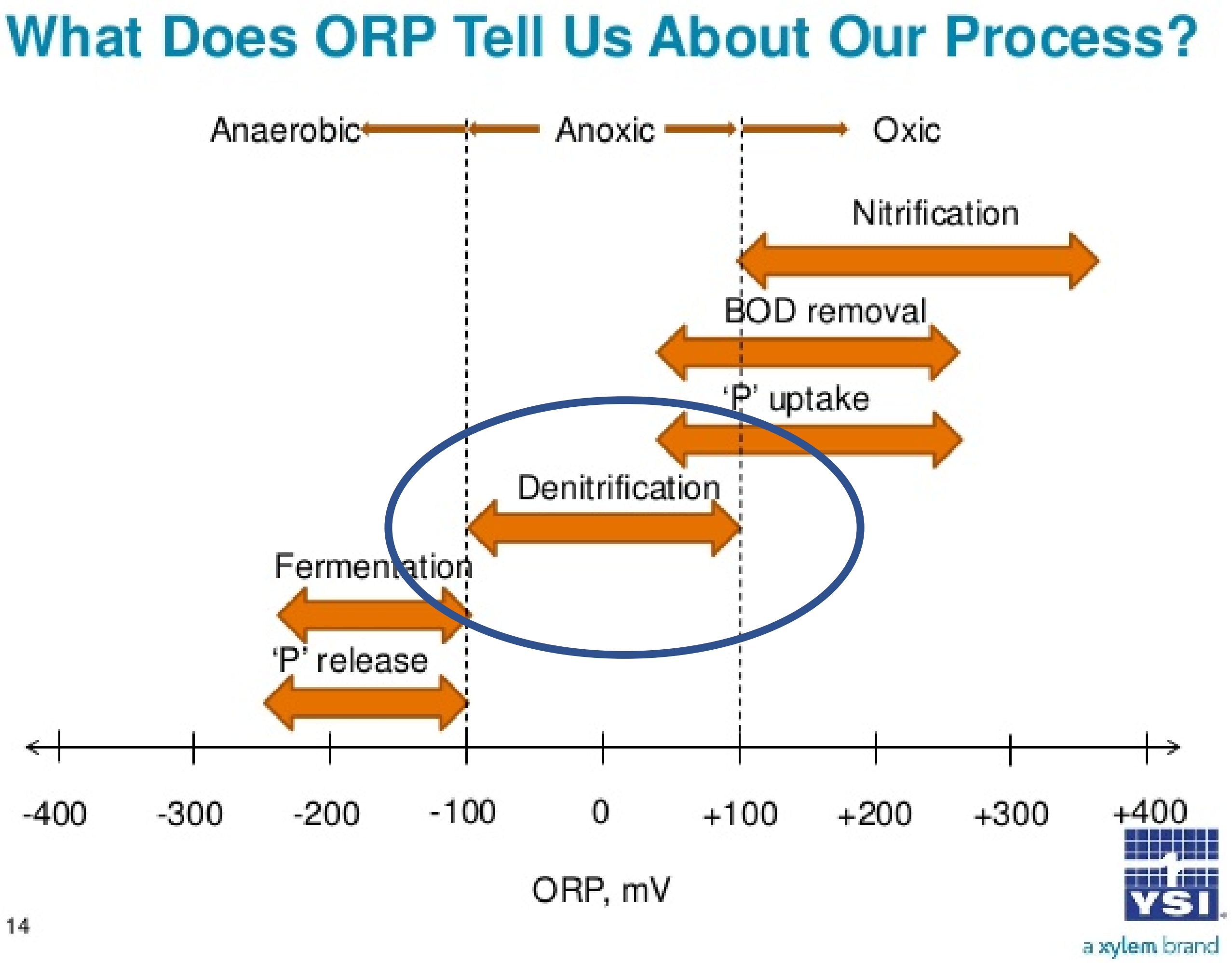
Ammonia Removal



Ammonia Removal



Nitrate Removal - 2^{nd} Step of N removal



Step 2: Nit e Remo l

Little to no rable

ORP of -10 V

5-10 times much s Nitrate

2+ hours re tion tim

Nitrate Removal

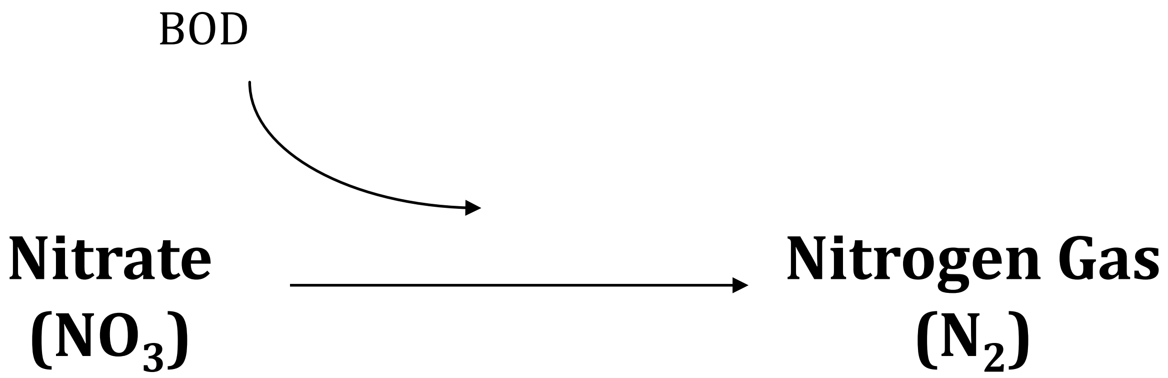
Nitrate
(NO_3)

Nitrate Removal

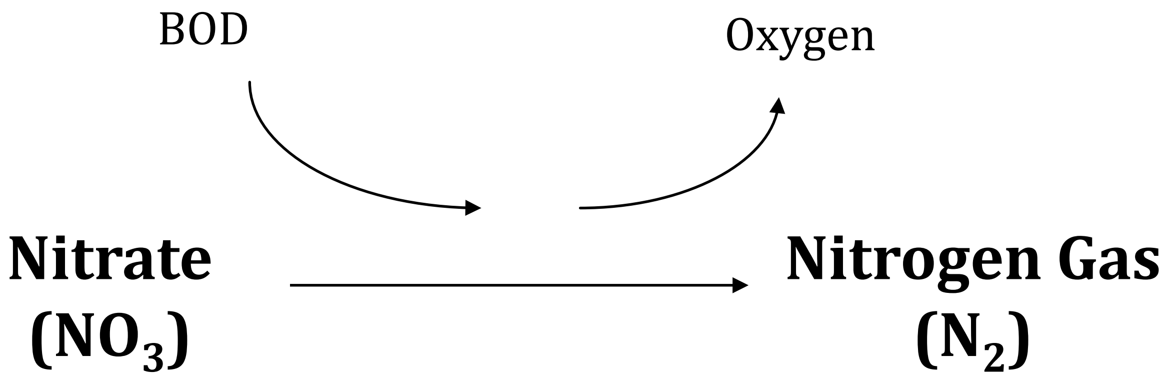
BOD

Nitrate
(NO_3)

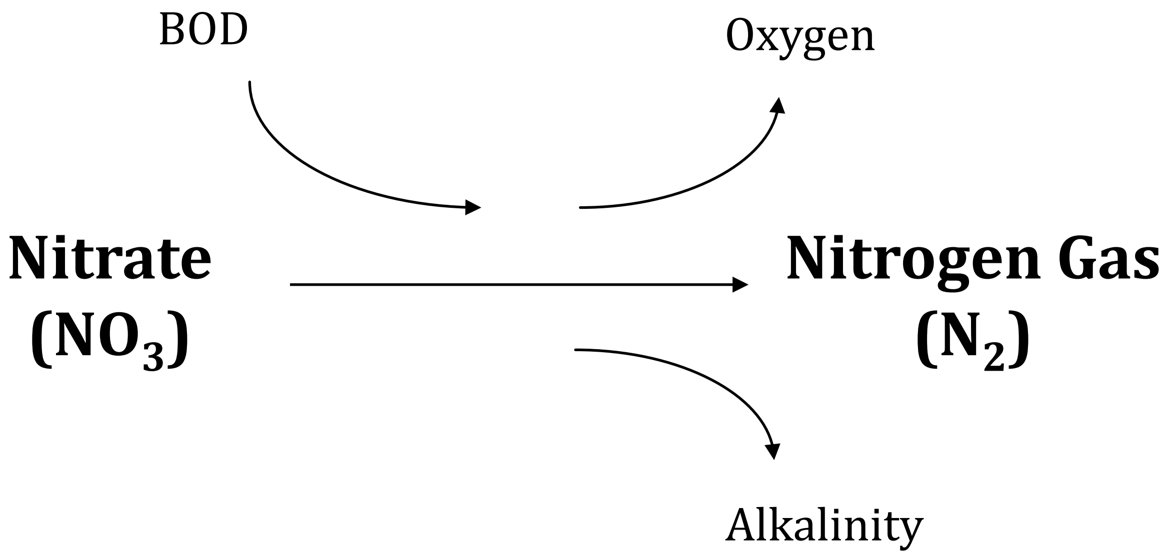
Nitrate Removal



Nitrate Removal



Nitrate Removal



Adds DO (dissolved oxygen)

Consumes BOD … Denitrifiers out compete bio-P bugs for VFAs!

Gives back alkalinity … beneficially raises pH

Nitrogen Removal

	Step 1: Nitrification (Ammonia Removal)	**Step 1: Denitrification** (Nitrate Removal)
DO: Dissolved Oxygen	1 mg/L or more	Less than 0.2 mg/L
ORP: Oxygen Reduction Potential	+100 mV or more +	Less than -100 mV
MLSS: Mixed Liquor Suspended Solids	2500 mg/L or more	Same
HRT: Hydraulic Retention Time	6 or more hours	1 or more hours
BOD: Biochemical Oxygen Demand	less than 20 mg/L	**100 mg/L or more … VFAs preferred!**
Alkalinity	60 mg/L or more	
	Alkalinity is lost	***Alkalinity is gained***

Note: All numbers are approximations, “rules of thumb”

Questions?
Comments?

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Phosphorus

15

P

30.974


THREE
steps

Biological Phosphorus Removal

Step 1: prepare "dinner"

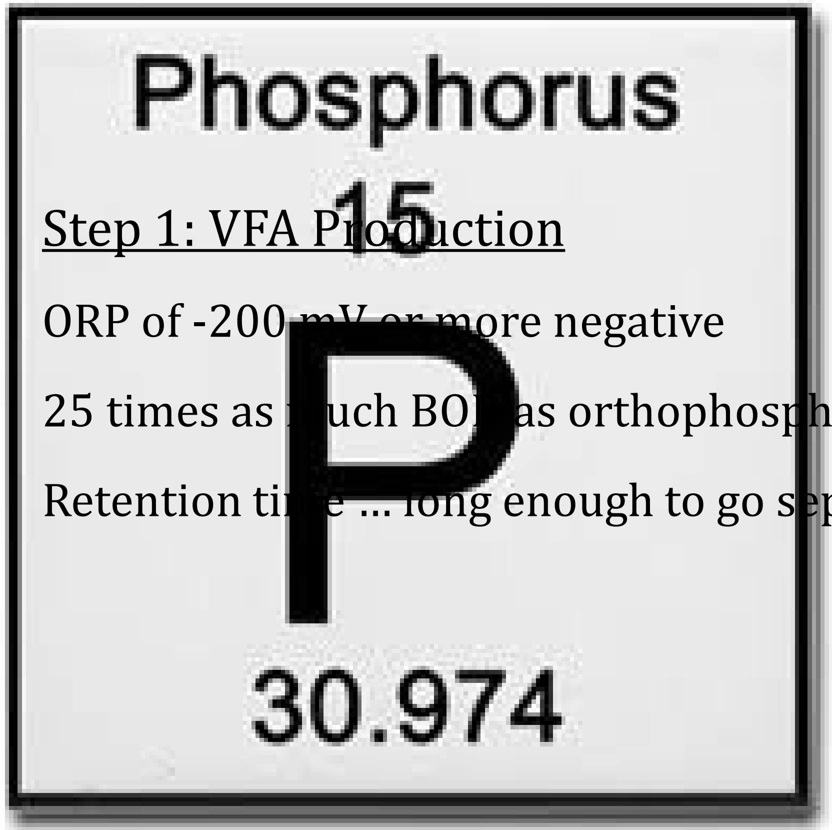
VFA (volatile fatty acids) production in anaerobic/fermentive conditions

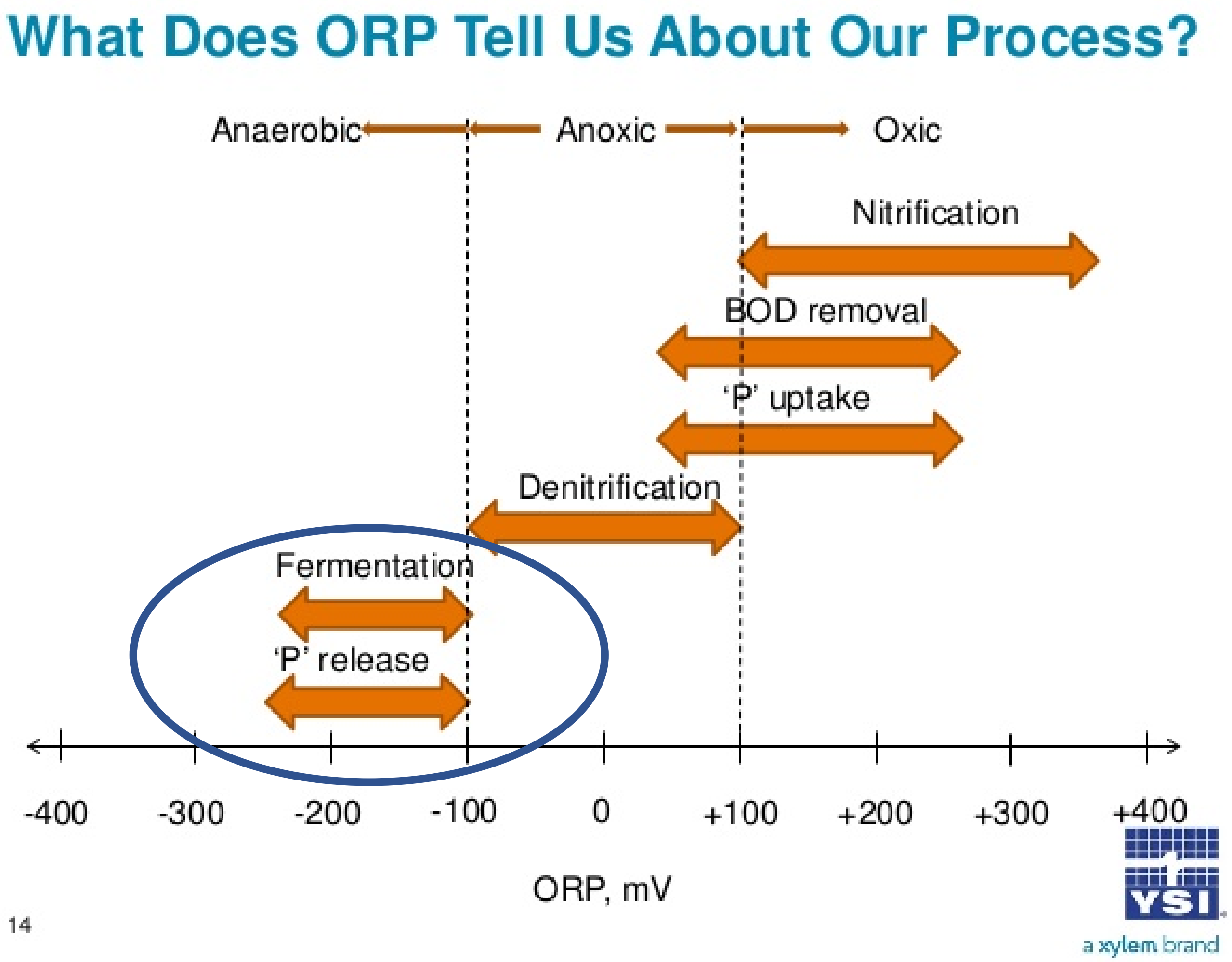
Step 1: VFA Production

ORP of -200 mV or more negative

25 times as much BOD as orthophosphate

Retention time ... long enough to go septic





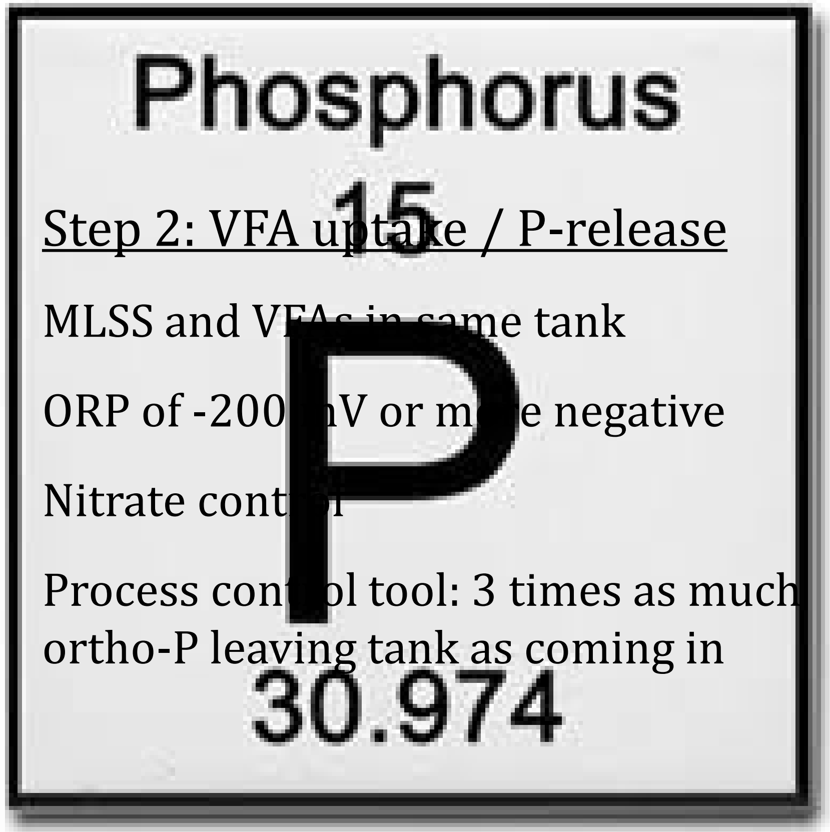
Biological Phosphorus Removal

Step 1: prepare "dinner"

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

Step 2: "eat"

Bio-P bugs (PAOs, "phosphate accumulating organisms") eat VFAs in anaerobic/fermentive conditions … temporarily releasing more P into the water



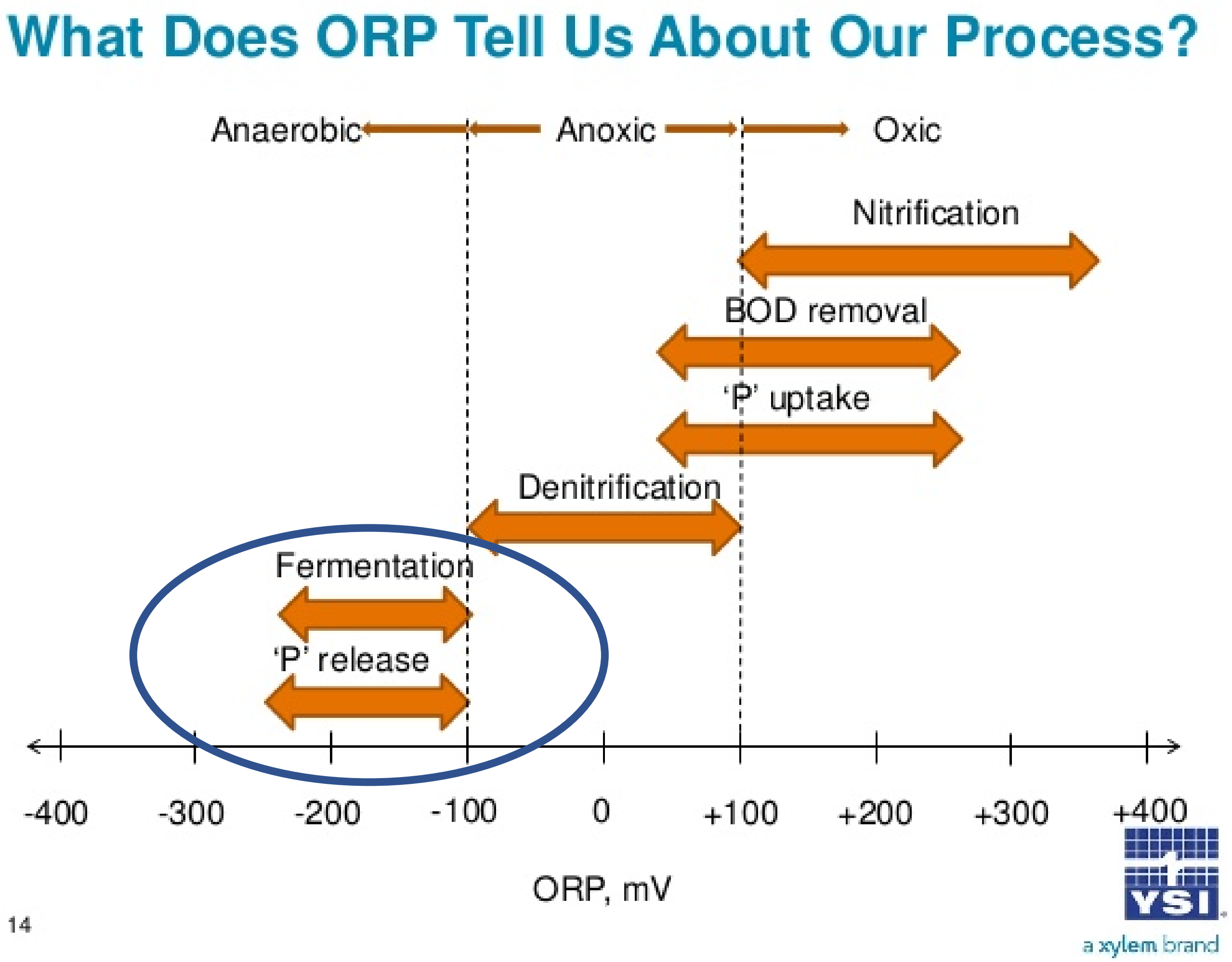
Step 2: VFA uptake / P-release

MLSS and VFAs in same tank

ORP of -200 mV or more negative

Nitrate control

Process control tool: 3 times as much ortho-P leaving tank as coming in



Biological Phosphorus Removal

Step 1: prepare "dinner"

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

Step 2: "eat"

Bio-P bugs (PAOs, "phosphate accumulating organisms") 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

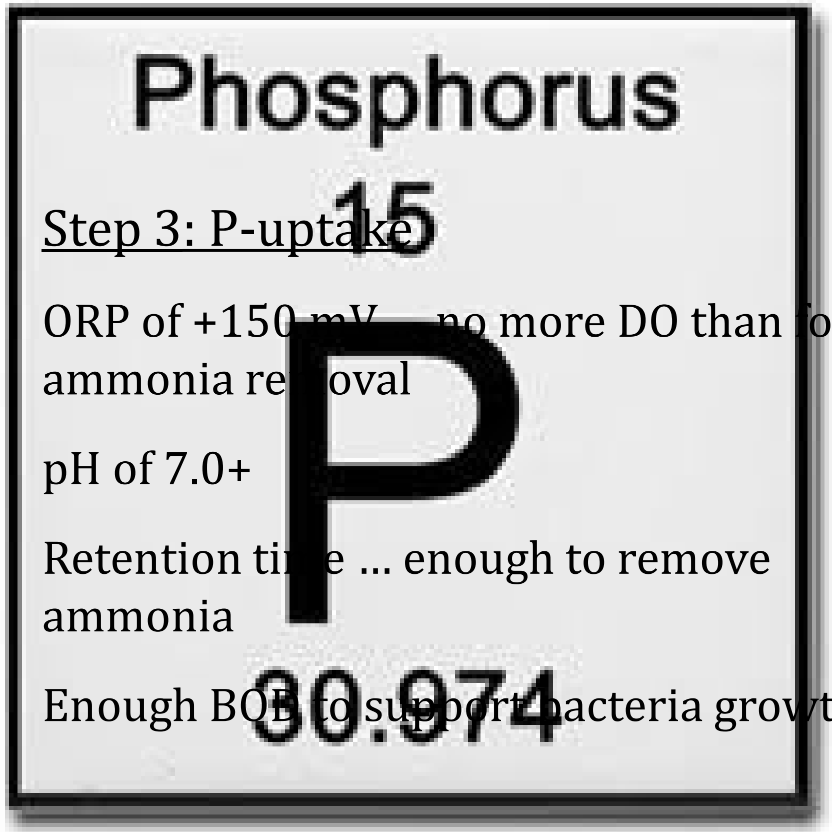
Step 3: P-uptake

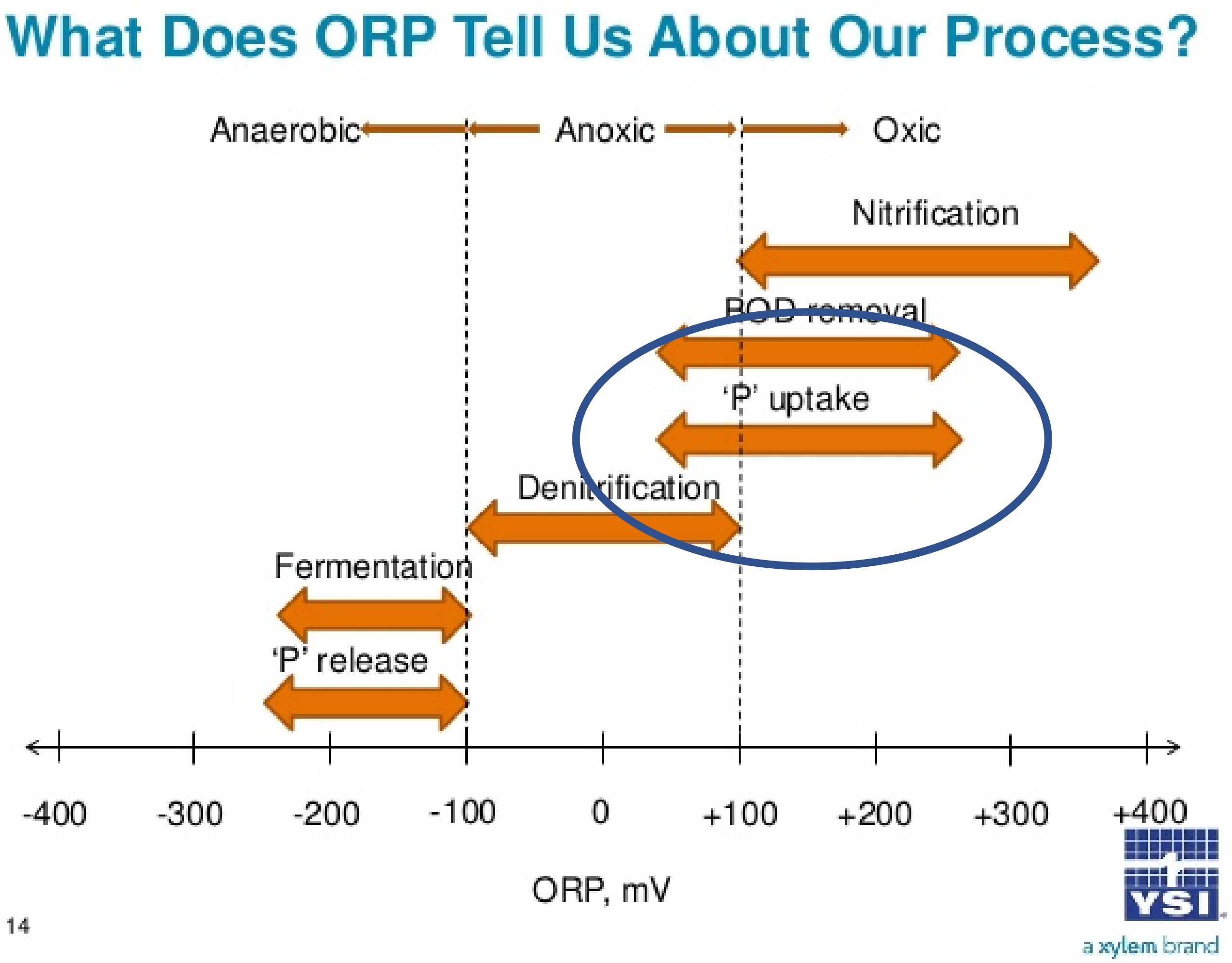
ORP of +150 mV … no more DO than for ammonia removal

pH of 7.0+

Retention time … enough to remove ammonia

Enough BOD to support bacteria growth





Optimizing Bio-P Removal: Mainstream or Sidestream Fermentation

<u>Anaerobic Tank</u>

2 hour HRT (hydraulic retention time)*

ORP of -200 mV*

25 times as much BOD as influent ortho-P*

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

<u>Aeration Tank</u>

DO of 2.0 mg/L

ORP of +150 mV

pH of 7.0+*

Ortho-P concentration of 0.05 mg/L*

*Approximate: Every Plant is Different

Questions?
Comments?

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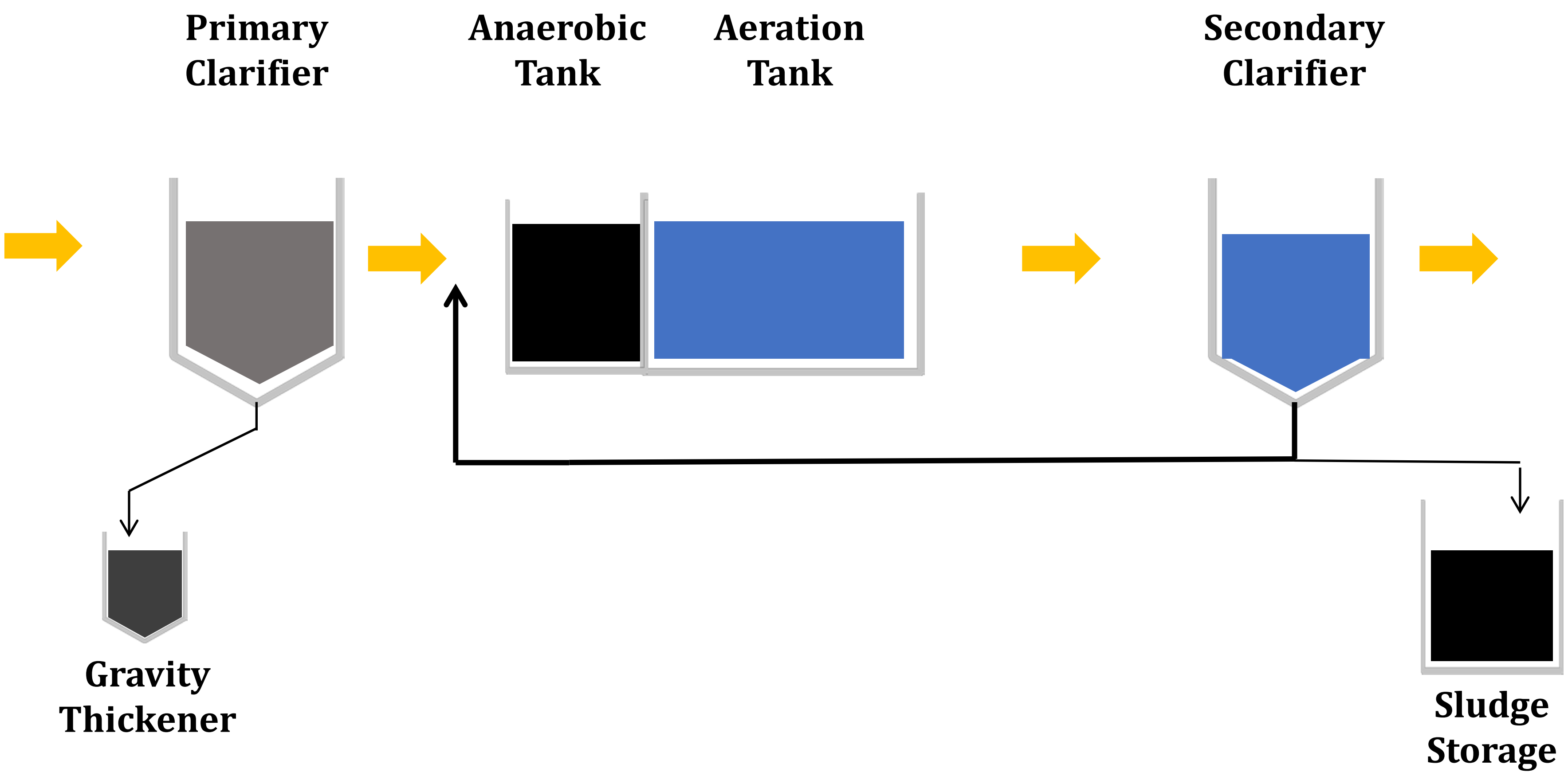
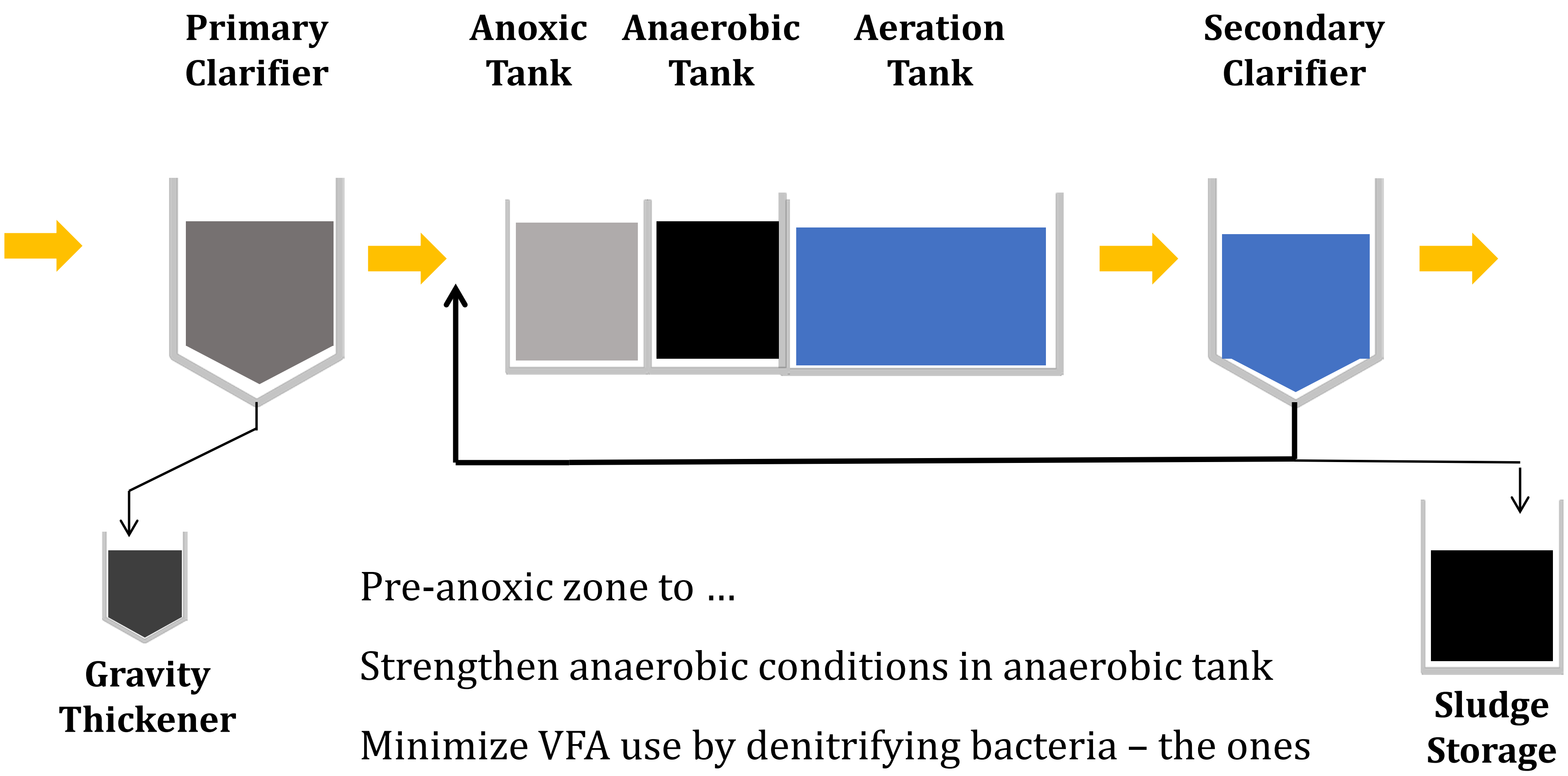
Biological Phosphorus Removal:

Mainstream Flow Fermentation Processes

Bio-P Removal: Mainstream Fermentation Process



Bio-P Removal: Mainstream Fermentation Process



Pre-anoxic zone to …

Strengthen anaerobic conditions in anaerobic tank

Minimize VFA use by denitrifying bacteria – the ones that convert Nitrate (NO_3) to Nitrogen Gas (N_2) – by "feeding" influent to the denitrifiers.

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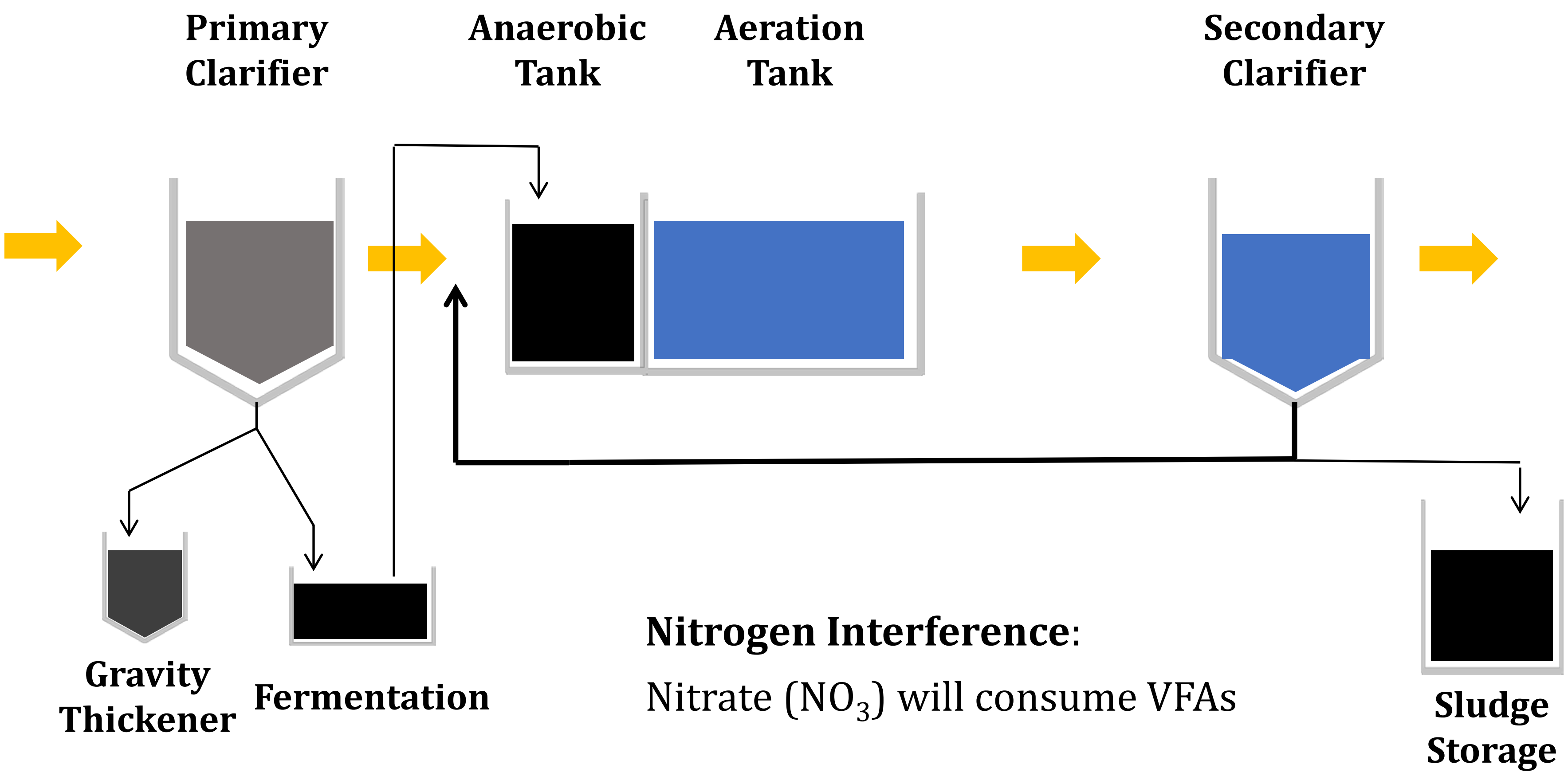
Biological Phosphorus Removal: Combined Sidestream & Mainstream Fermentation

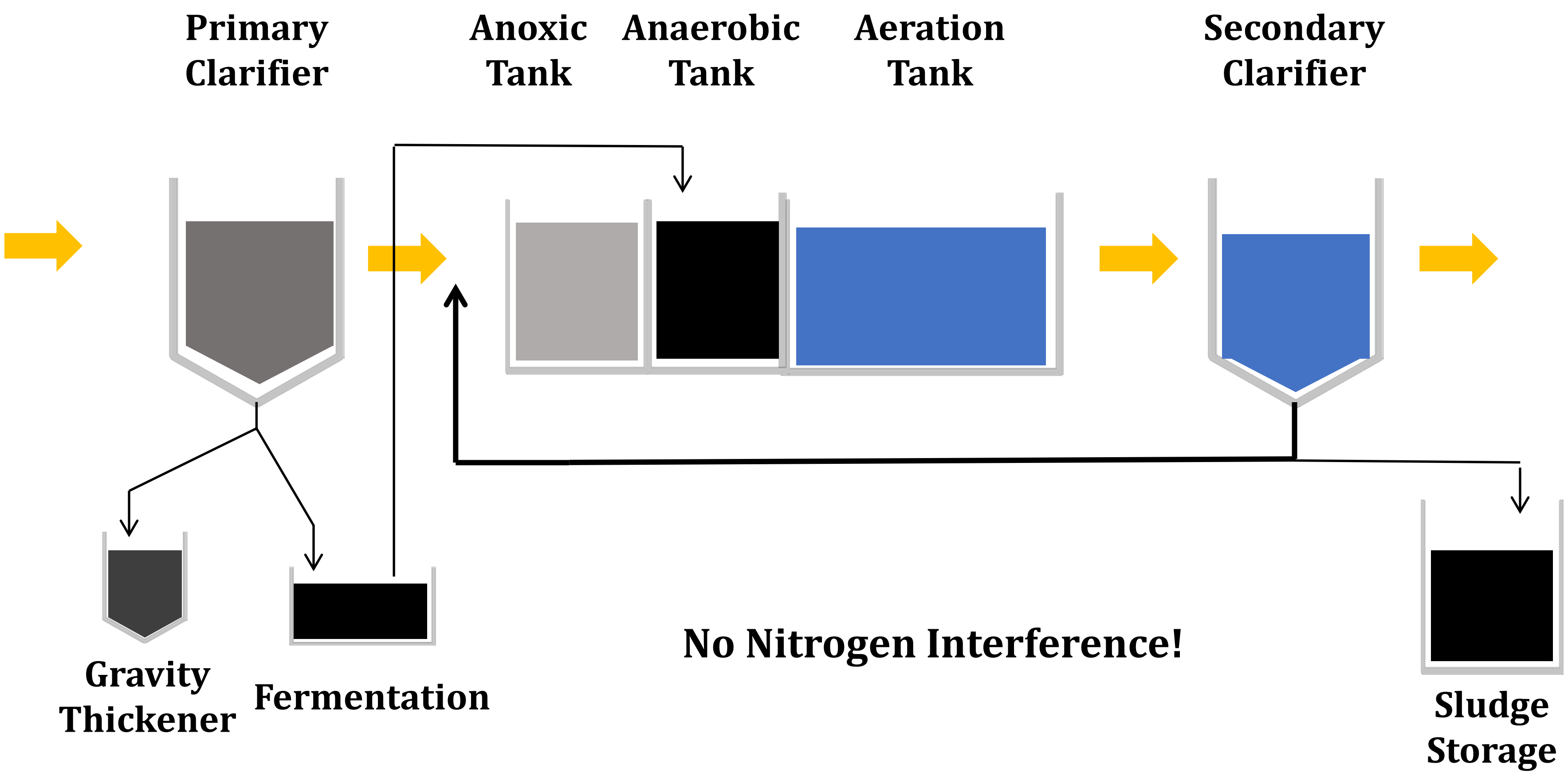
Bio-P Removal: Sidestream Fermentation Process



Nitrogen Interference:

Nitrate (NO_3) will consume VFAs

Bio-P Removal: Sidestream Fermentation Process



Questions?
Comments?

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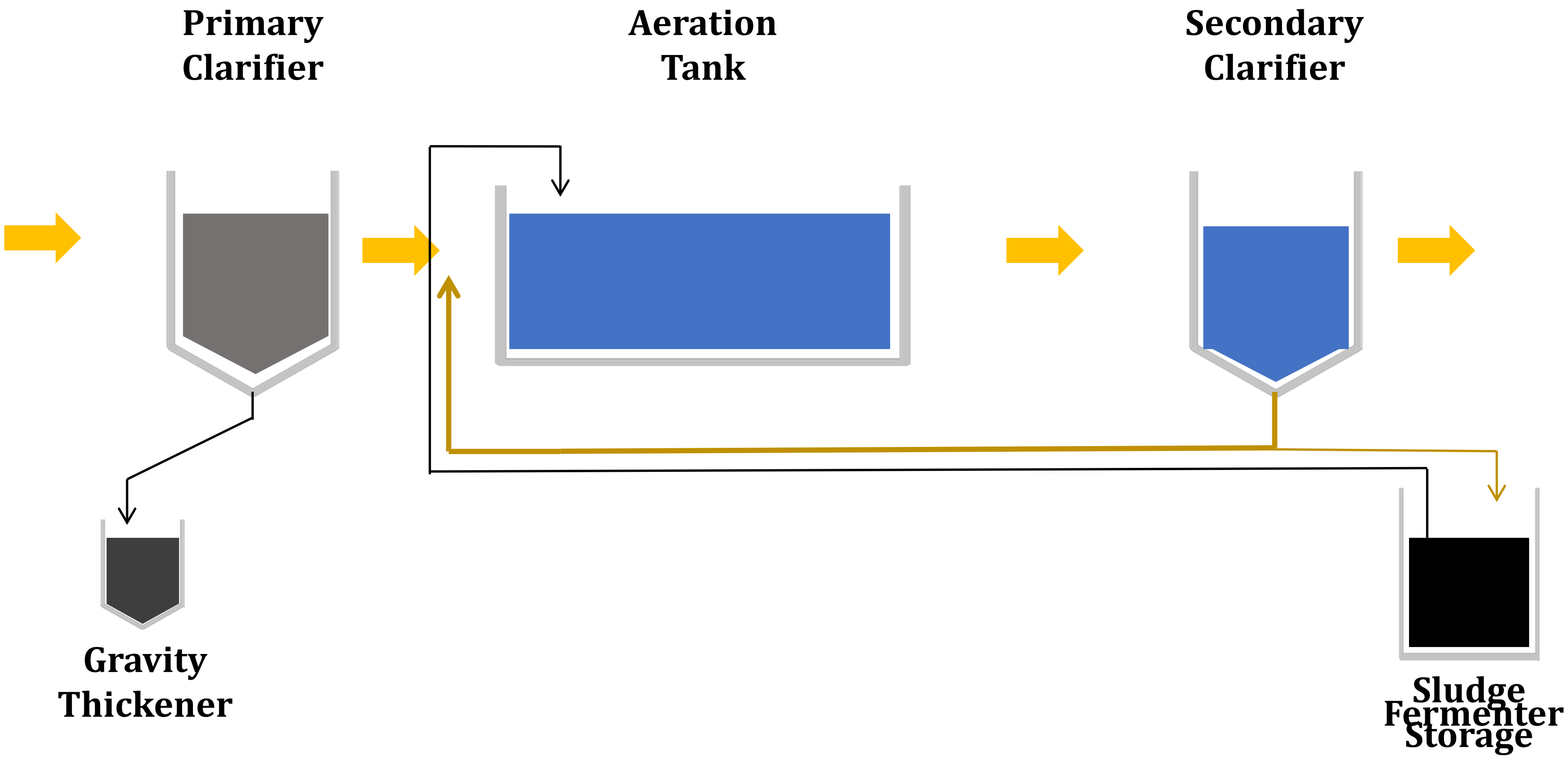
Getting creative …

Biological Phosphorus removal from plants not designed as EBPR (enhanced biological phosphorus removal) facilities

Home Grown Sidestream Fermenter



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S
B
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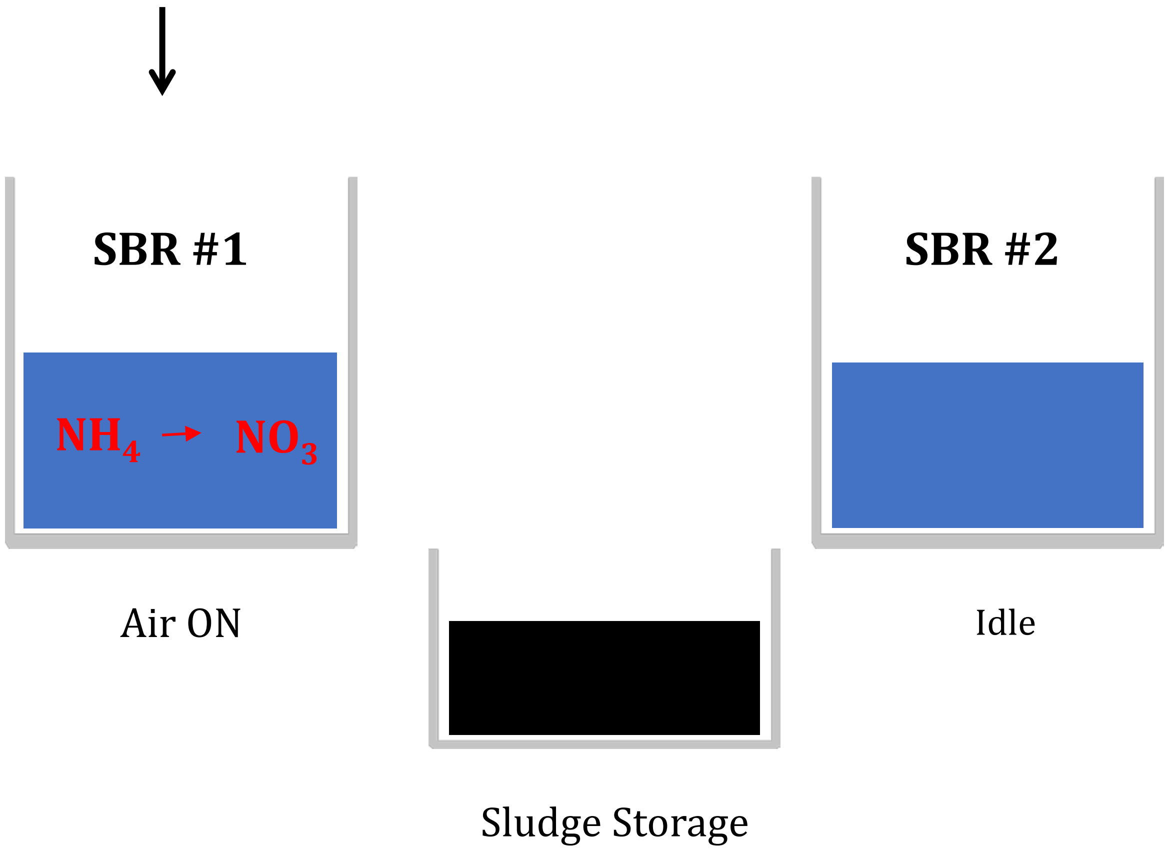
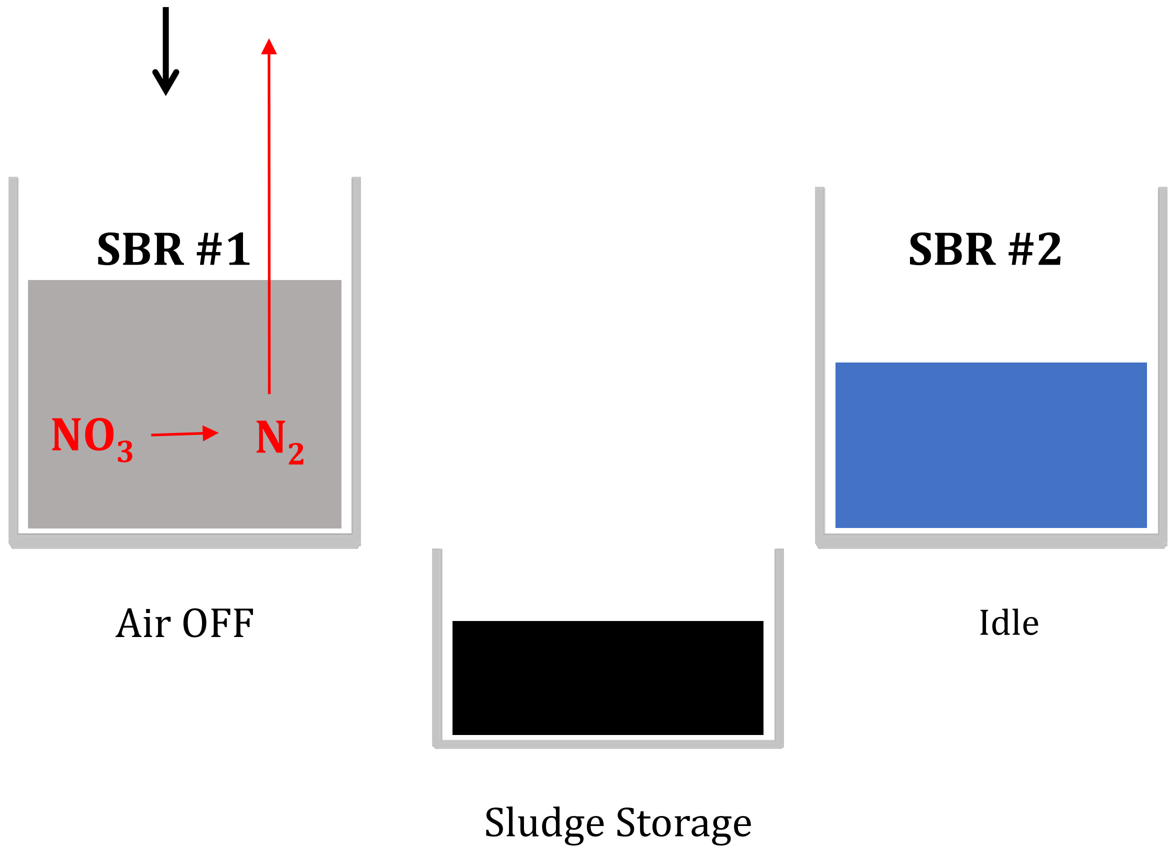
Sequencing Batch Reactors

Designed for Nitrogen Removal
Most not designed for Phosphorus Removal

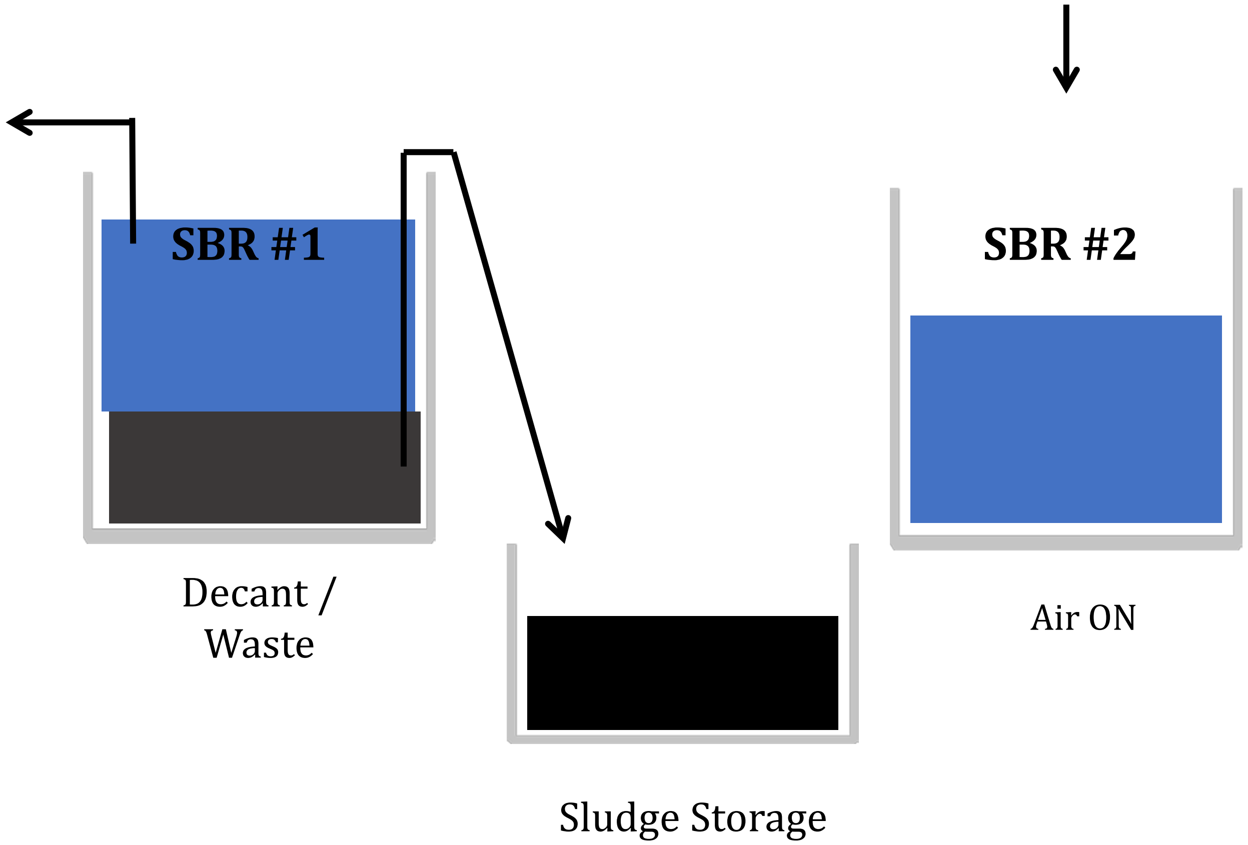
Sequencing Batch Reactor (SBR)
Side View
Ammonia (NH_4) Removal: Nitrification



Sequencing Batch Reactor (SBR)
Side View
Nitrate (NO_3) Removal: Denitrification



Sequencing Batch Reactor (SBR)
Side View
Settle, Decant & Waste Sludge



Establish cycle times that are long enough to provide optimal habitats.

And, short enough to allow all of the flow to be nitrified and denitrified.

Optimizing SBR operations - Nitrogen Removal

Too short

Will not reach +100 mV for Ammonia (NH_4) Removal.

Will not reach -100 mV for Nitrate (NO_3) Removal.

Note: Temperature and BOD affect Air OFF cycle.

Too long

Wastewater will pass through tank before all Ammonia (NH_4) converted to Nitrate (NO_3).

And, before all Nitrate (NO_3) is converted to Nitrogen Gas (N_2).

Just right

Good habitats …

ORP of +100 mV for 60 minutes

And, ORP of -100 mV for 30 minutes.

Questions?
Comments?

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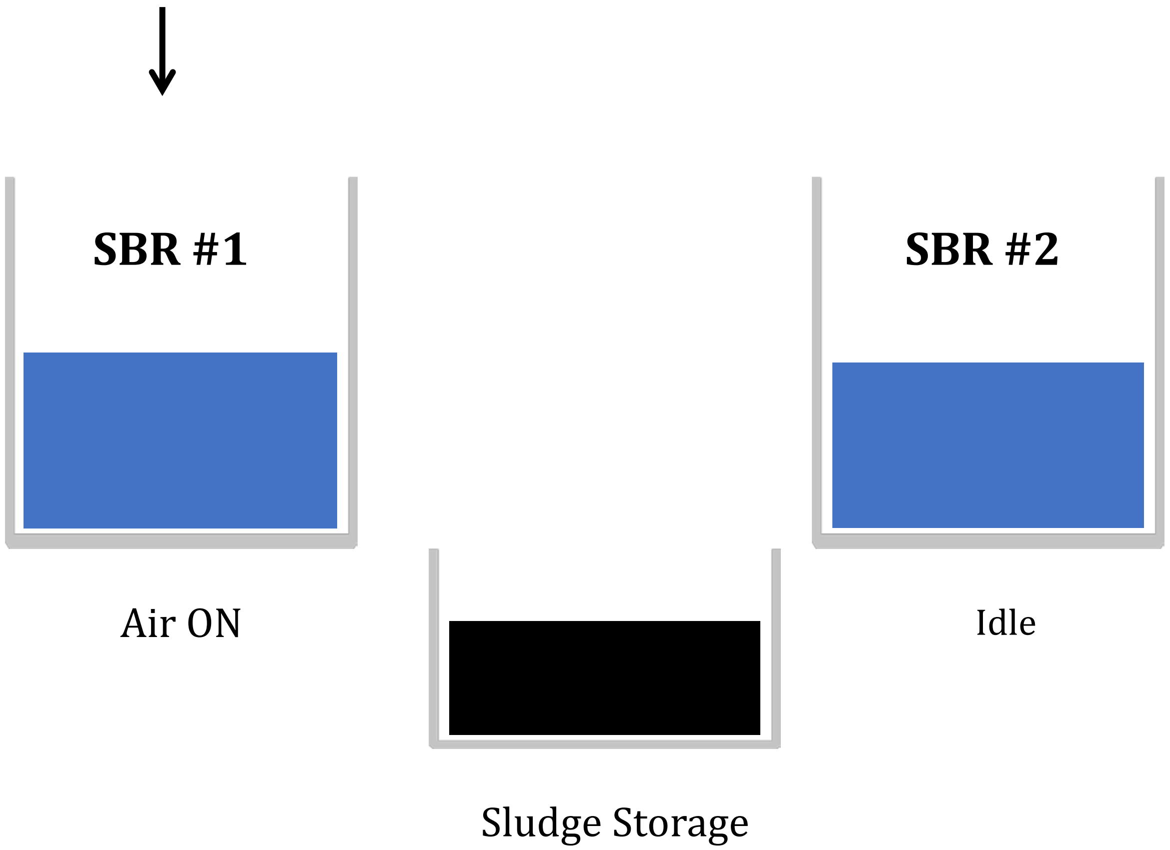
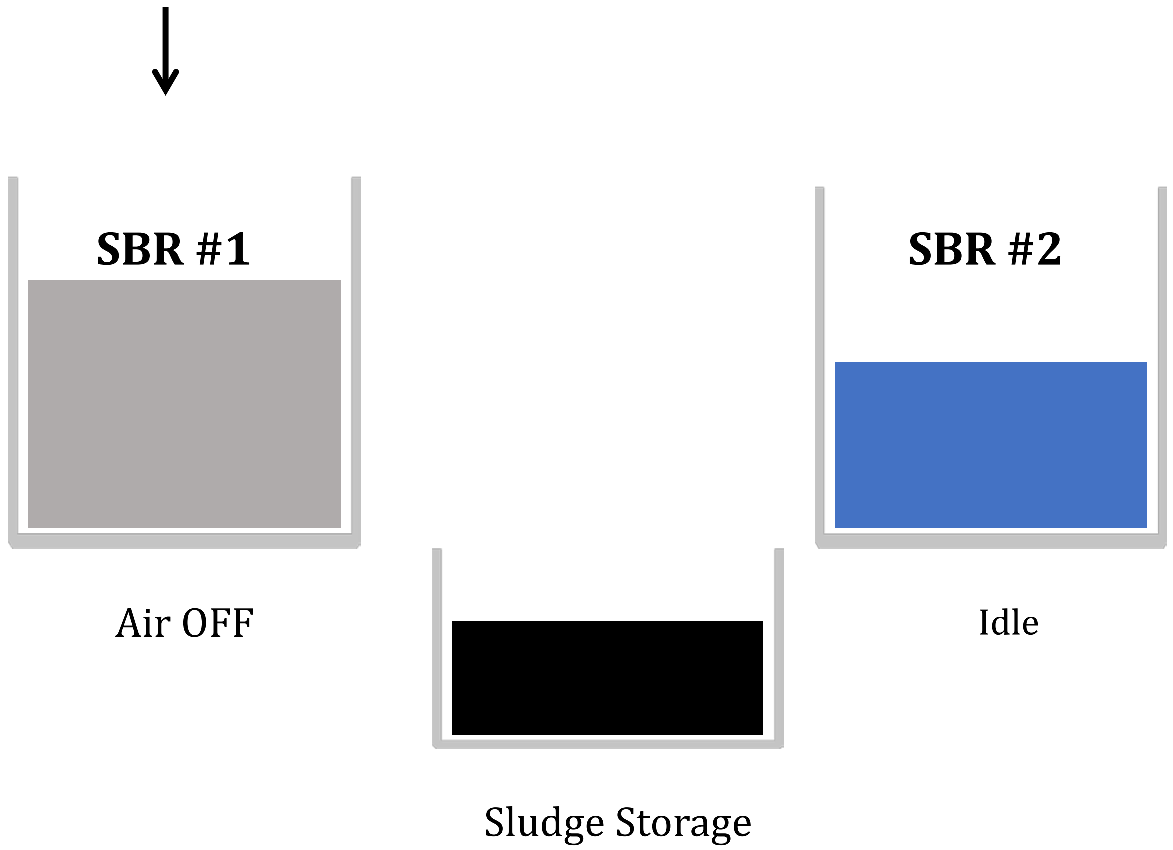
Where are you?


BREAK TIME
memegenerator.net

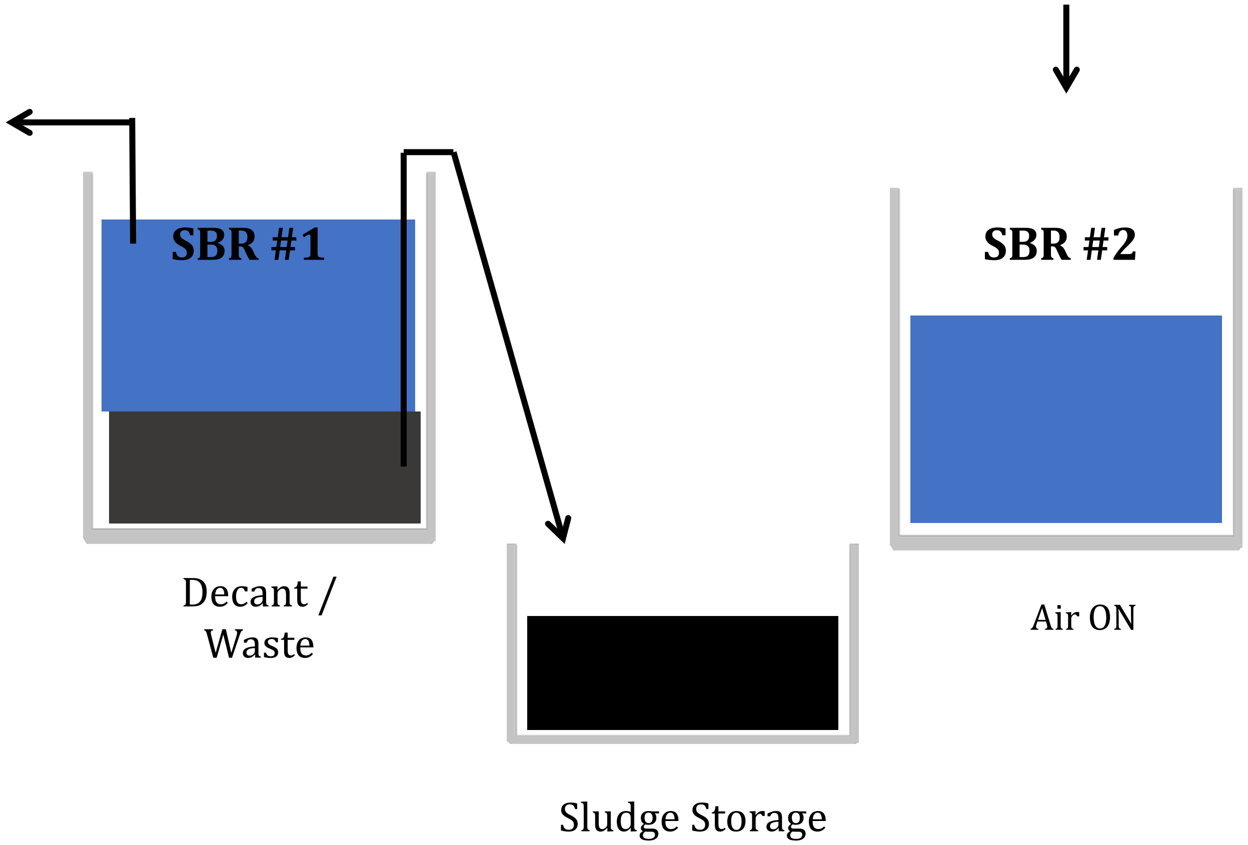
Sequencing Batch Reactor (SBR)
Side View
Ammonia (NH_4) Removal: Nitrification



Sequencing Batch Reactor (SBR)
Side View
Nitrate (NO_3) Removal: Denitrification



Sequencing Batch Reactor (SBR)
Side View
Settle, Decant & Waste Sludge



Getting Phosphorus Removal out of SBRs

Mainstream

Extend air-off cycle to drop ORP to -200 mV

Turn off mixing to create anaerobic blanket during part of air-off cycles

Proceed with caution: don’t let plant go septic!

Getting Phosphorus Removal out of SBRs

<u>Mainstream</u>

Extend air-off cycle to drop ORP to -200 mV

Turn off mixing to create anaerobic blanket during part of air-off cycles

Proceed with caution: don’t let plant go septic!

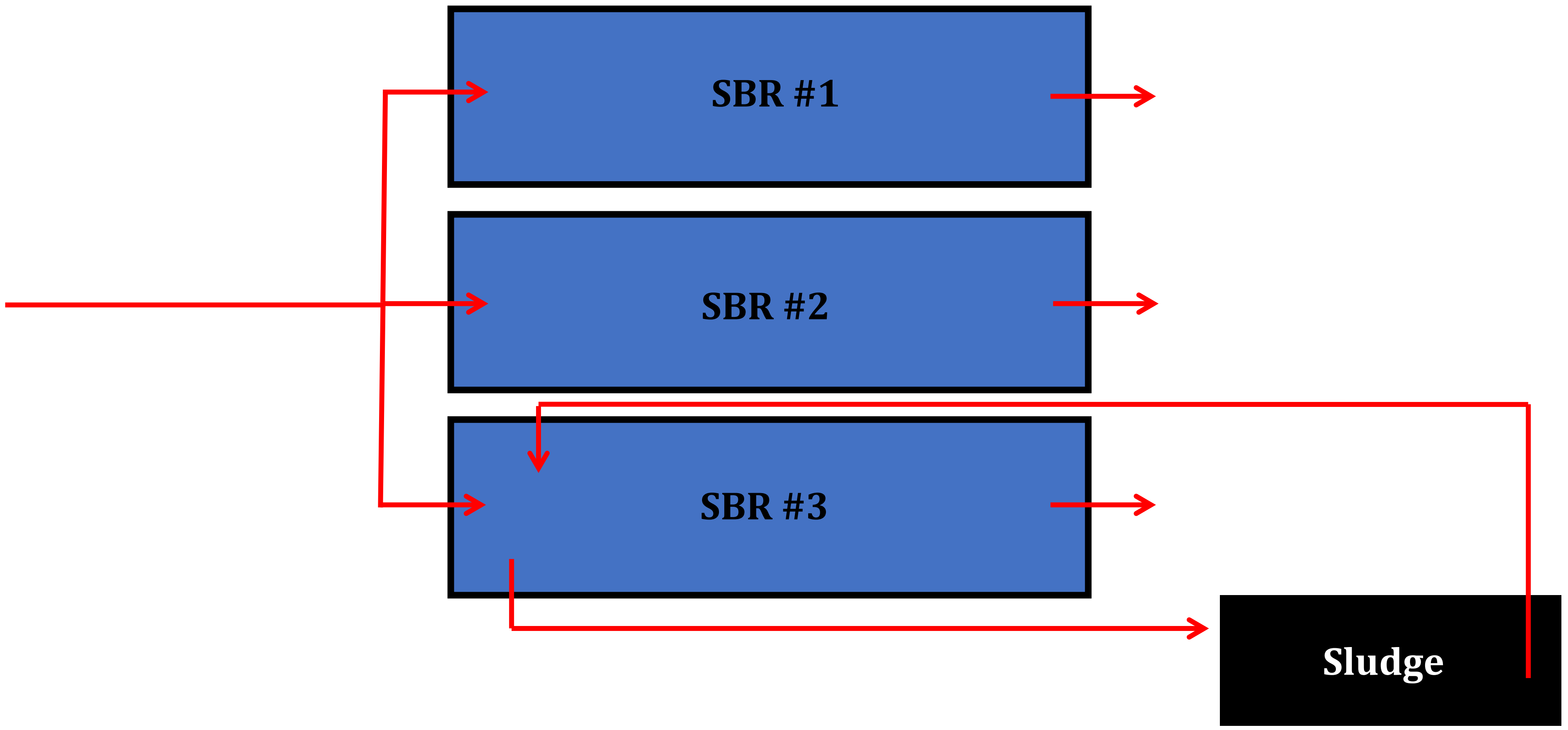
<u>Sidestream</u>

Create sidestream fermenter

Cycle 10% of waste sludge (WAS) through fermenter, hold for 2-10 days, return to SBR

It works!

Sidestream Phosphorus Removal in a Sequencing Batch Reactor (SBR) not designed for Phosphorus Removal TOP VIEW



Questions?
Comments?

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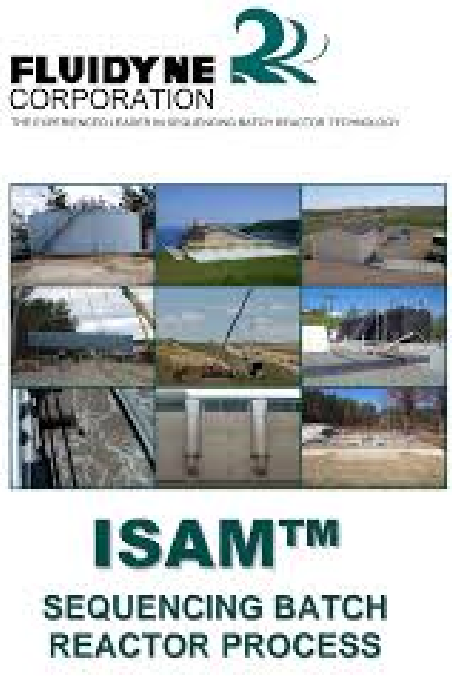
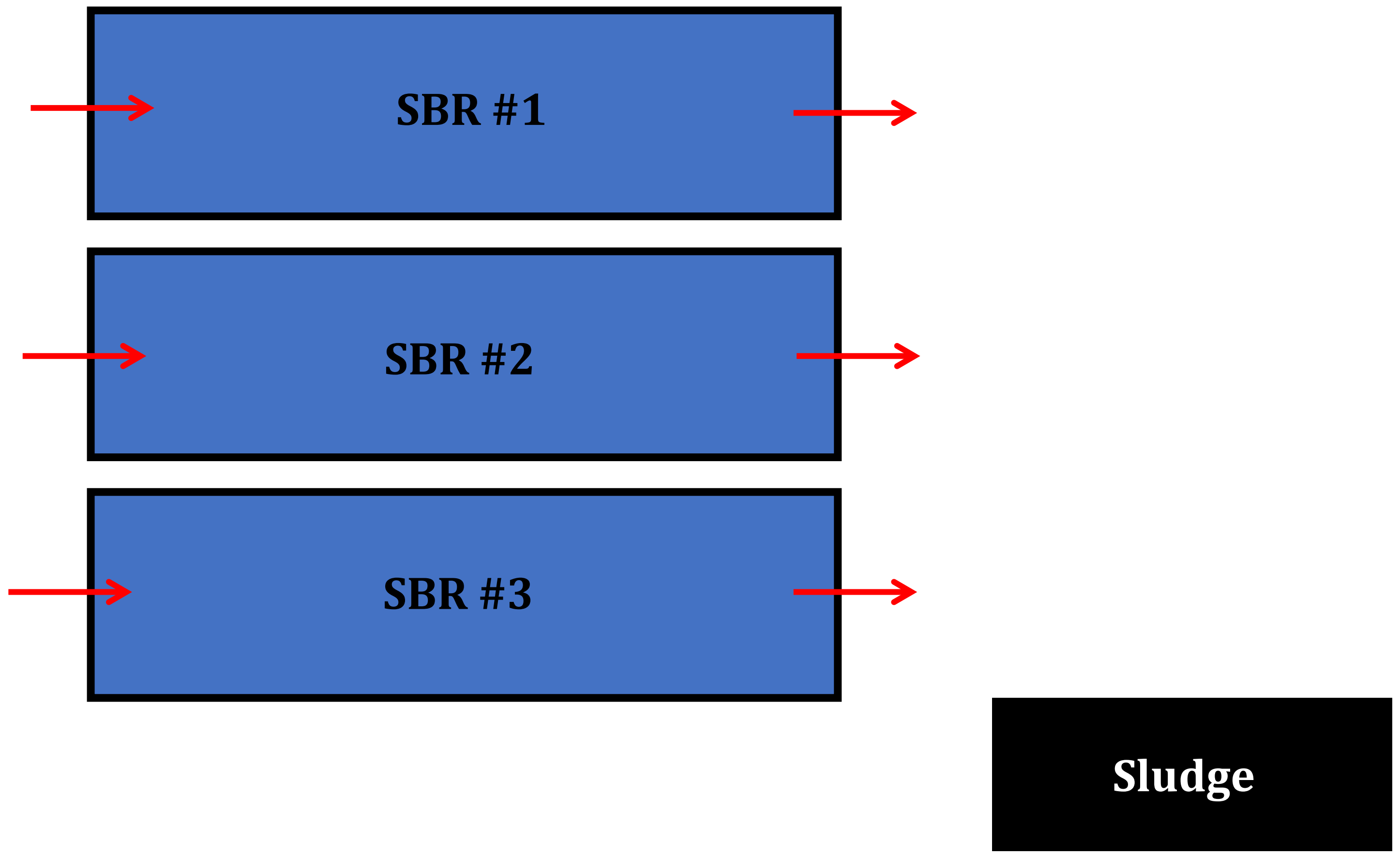
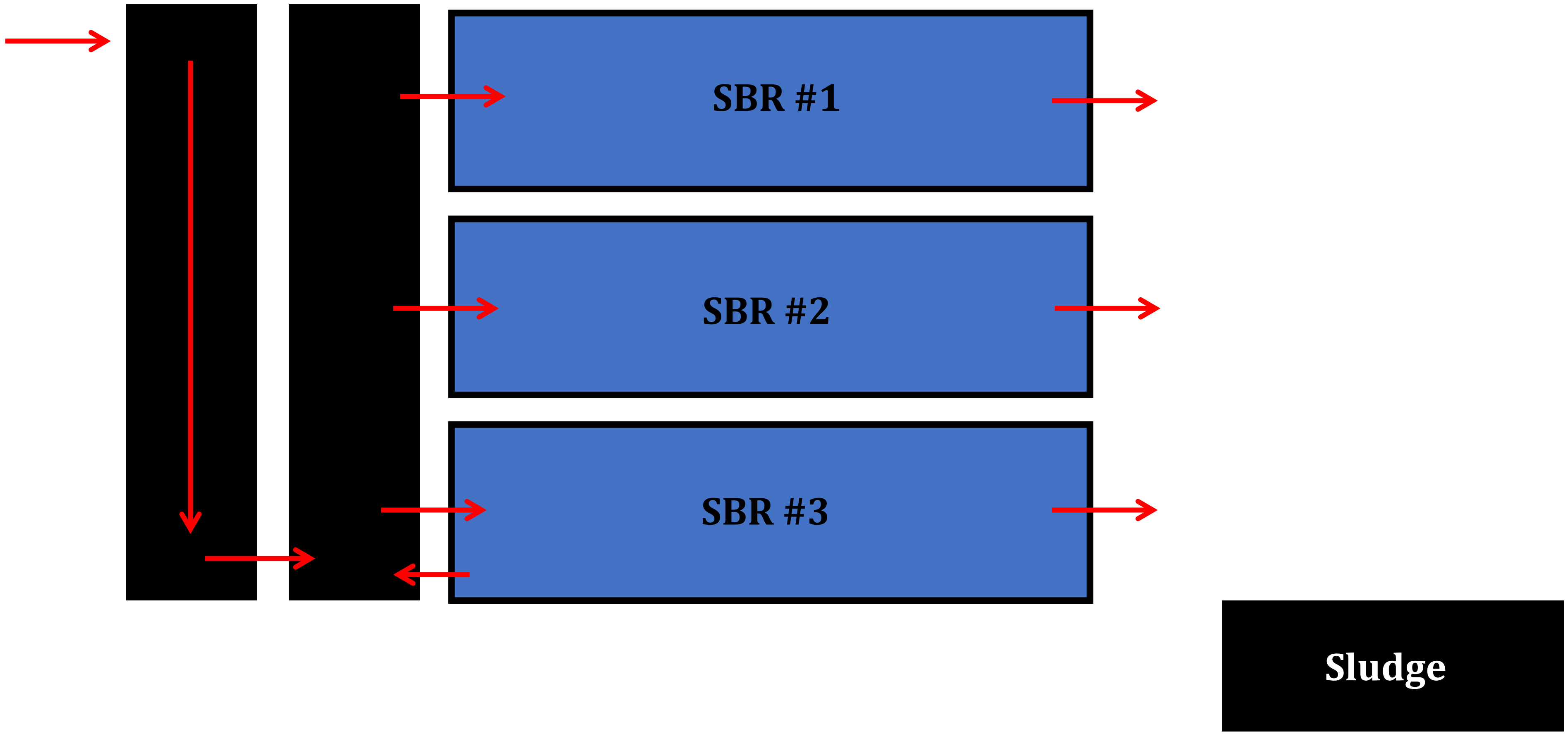
SBR with pre-Anaerobic Zone(s)



Sequencing Batch Reactor (SBR) without Pre-Anaerobic Zone
TOP VIEW



Sequencing Batch Reactor (SBR) with Pre-Anaerobic Zone
TOP VIEW



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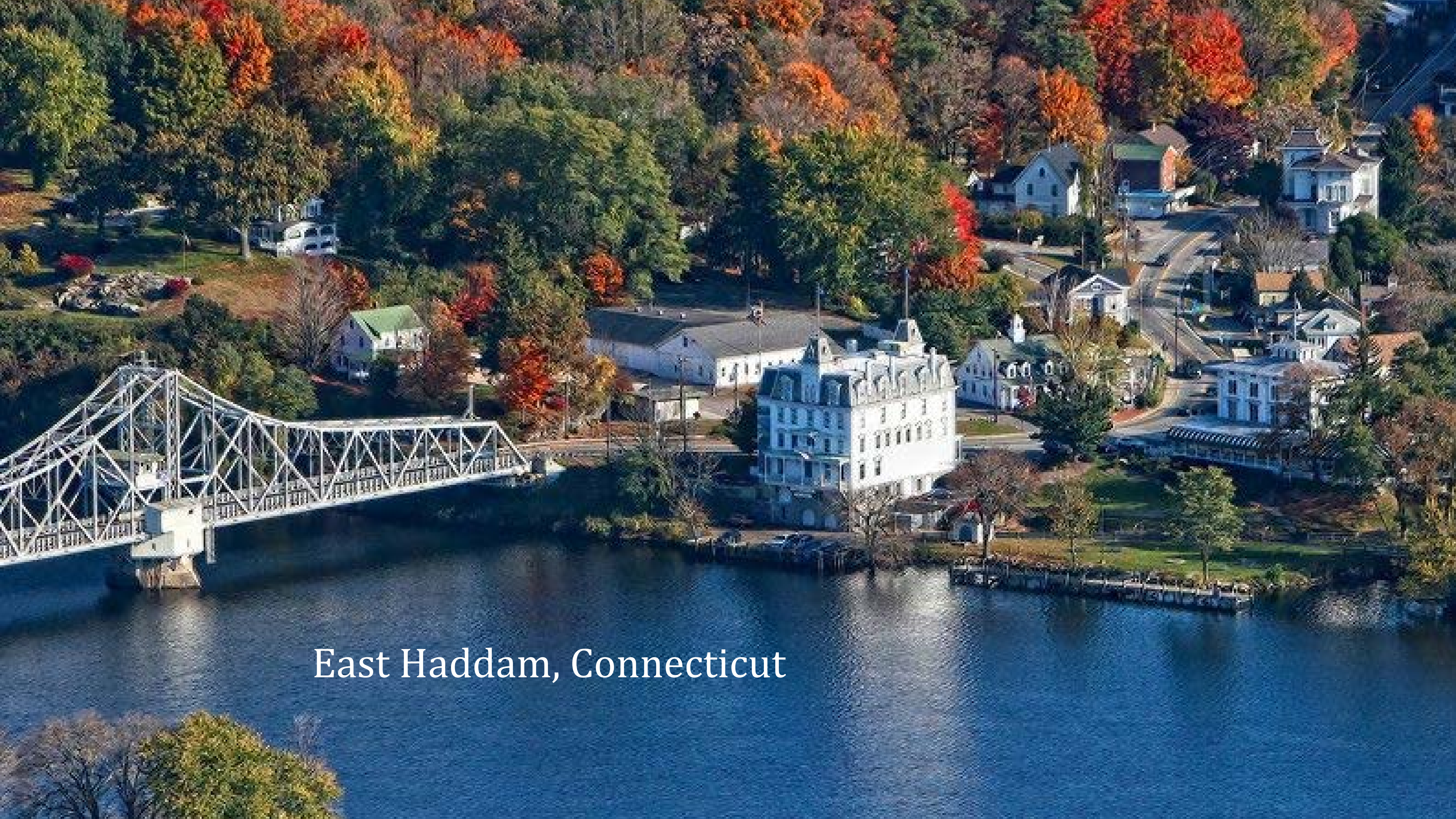
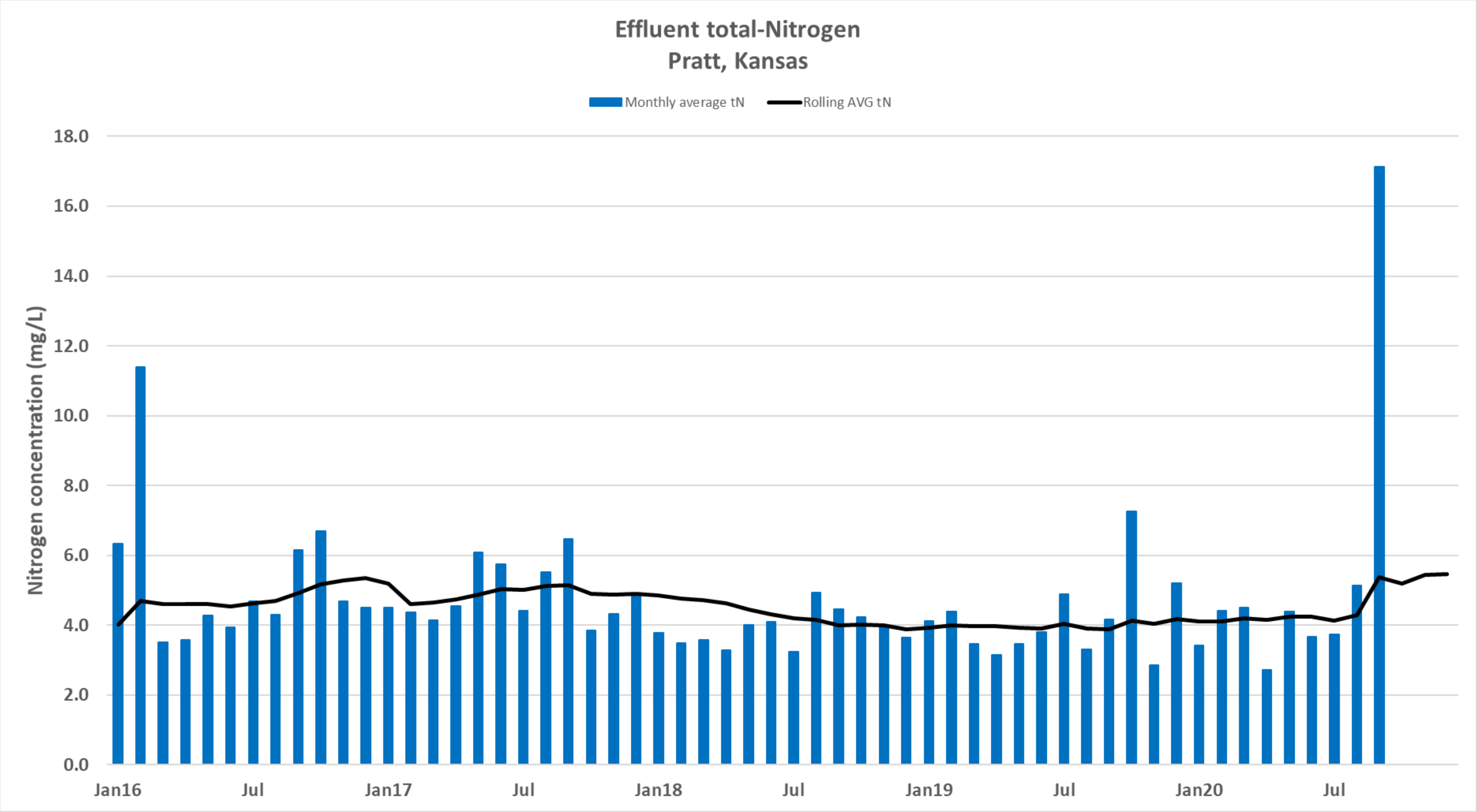
Sequencing Batch Reactors

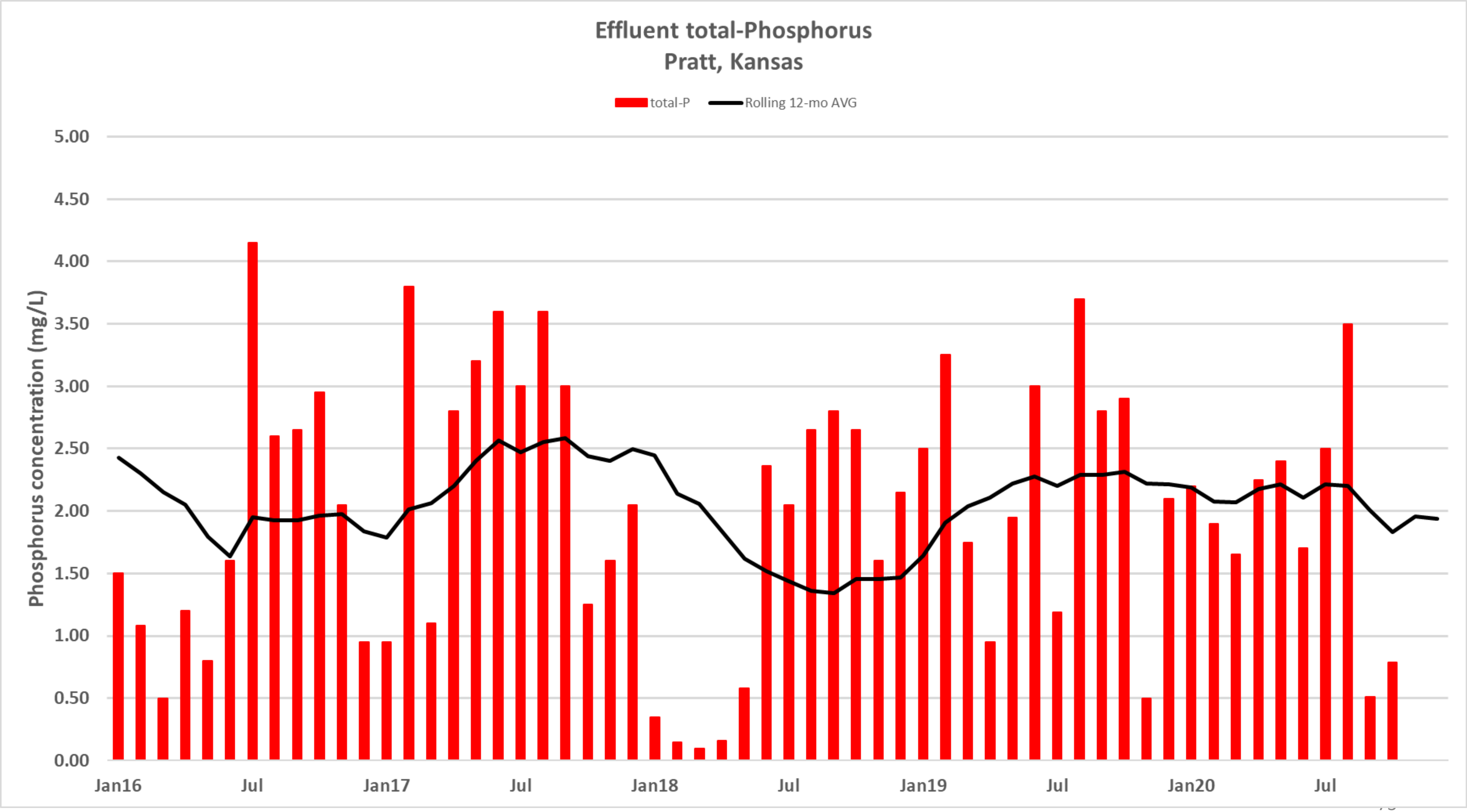
Designed for Nitrogen Removal
Most not designed for Phosphorus Removal

East Haddam, CT
Pratt, KS
Osawatomie, KS


East Haddam, Connecticut

Pratt, Kansas Population: 6,600 1.0 MGD design flow


Effluent total-Nitrogen
Pratt, Kansas
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan16
Jul
Jan17
Jul
Jan18
Jul
Jan19
Jul
Jan20
Jul



Effluent total-Phosphorus
Pratt, Kansas
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan16
Jul
Jan17
Jul
Jan18
Jul
Jan19
Jul
Jan20
Jul

Questions?
Comments?

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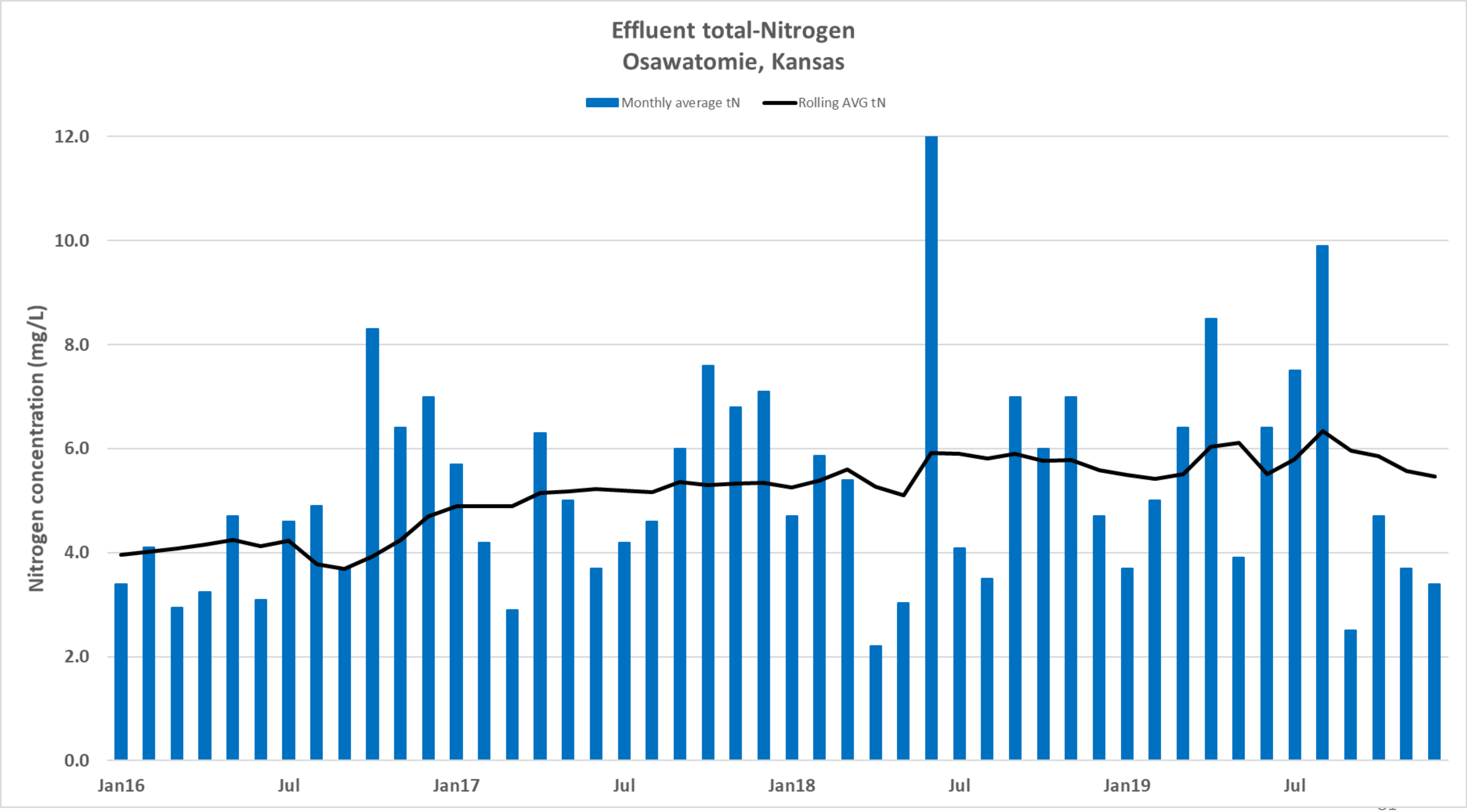
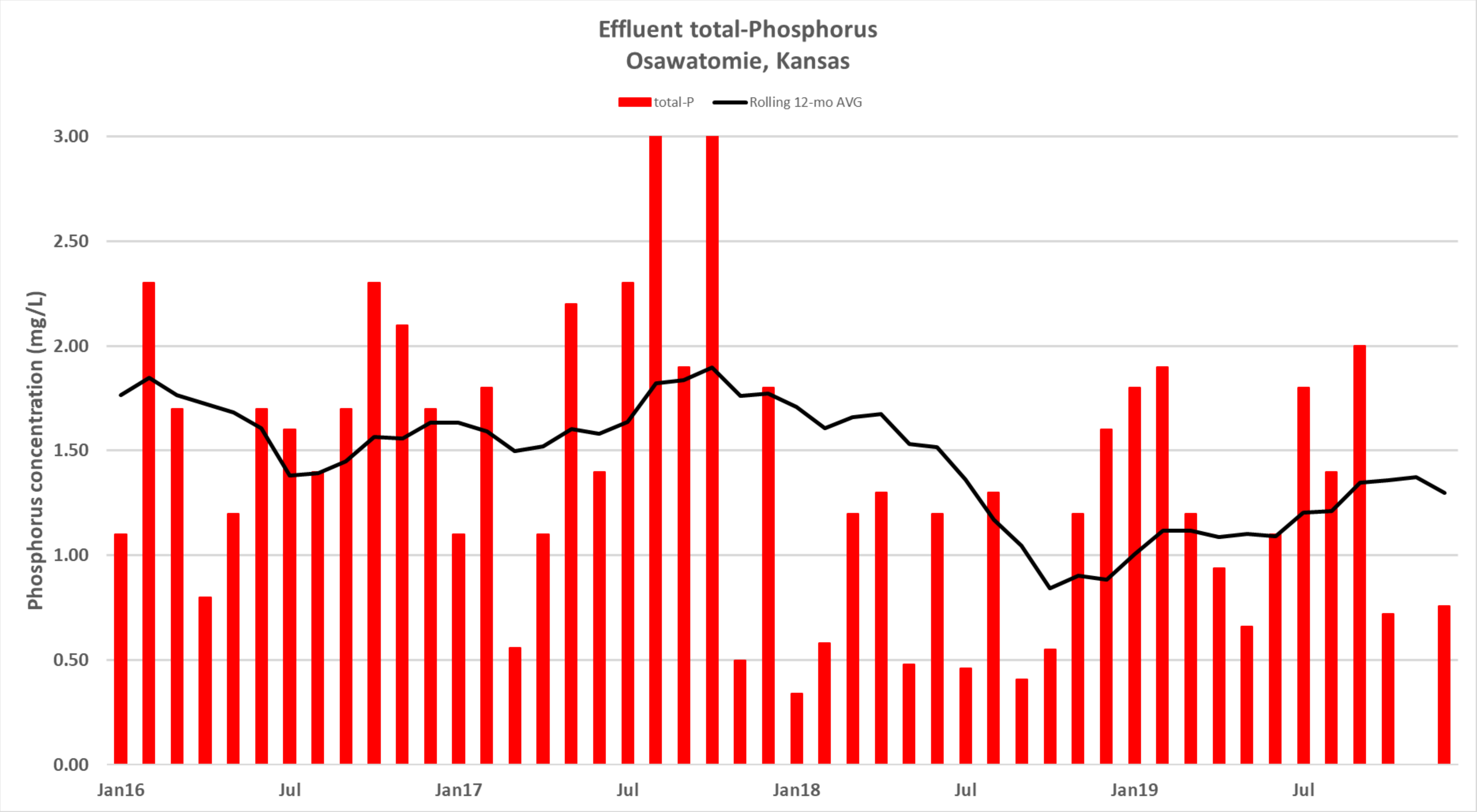
Osawatomie, Kansas
Population: 4,300
MGD design flow


Effluent total-Nitrogen
Osawatomie, Kansas
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan16
Jul
Jan17
Jul
Jan18
Jul
Jan19
Jul


Effluent total-Phosphorus
Osawatomie, Kansas
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan16
Jul
Jan17
Jul
Jan18
Jul
Jan19
Jul

Questions?
Comments?

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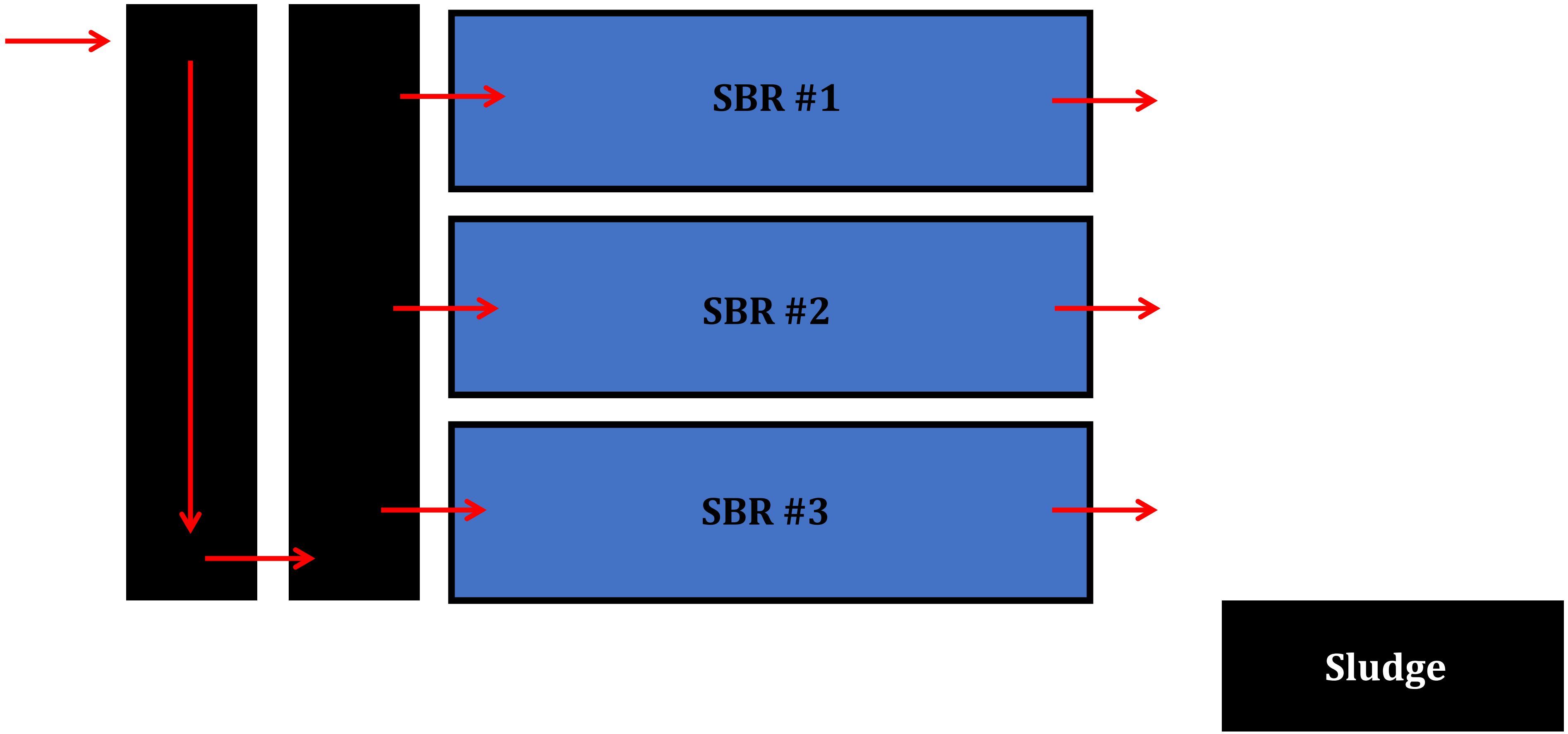
Sequencing Batch Reactors

Designed for Nitrogen and Phosphorus Removal
(Pre-Anaerobic Tank)

Eldora, Iowa

Sequencing Batch Reactor (SBR) with Pre-Anaerobic Zone
TOP VIEW



Questions?
Comments?

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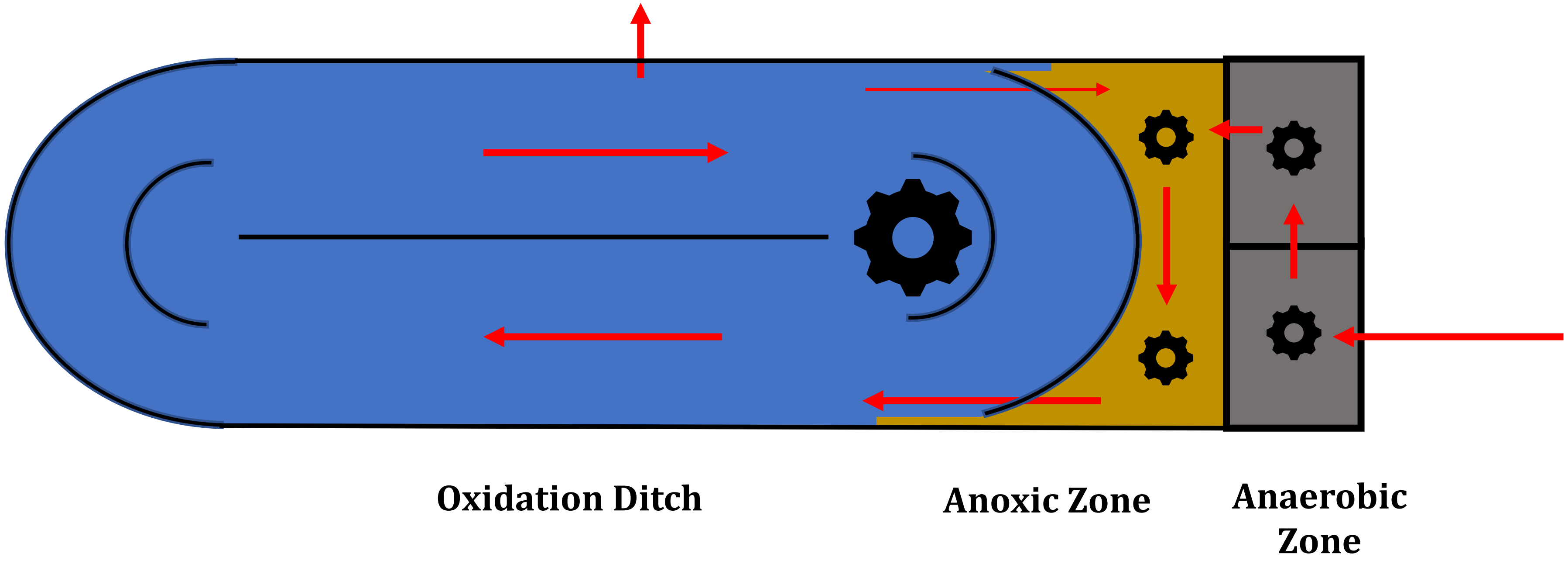
Rate your SBR knowledge

Oxidation Ditch Review

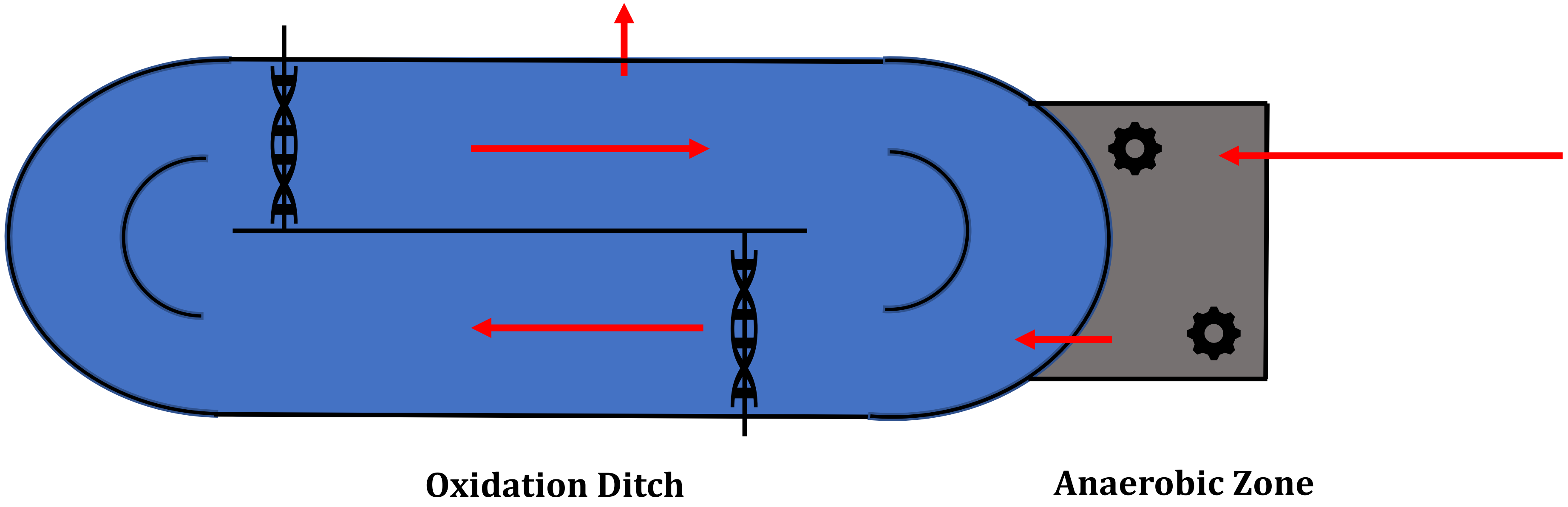
Survey Question (soon):
Which Oxidation Ditch is yours?

Orbal Oxidation Ditch

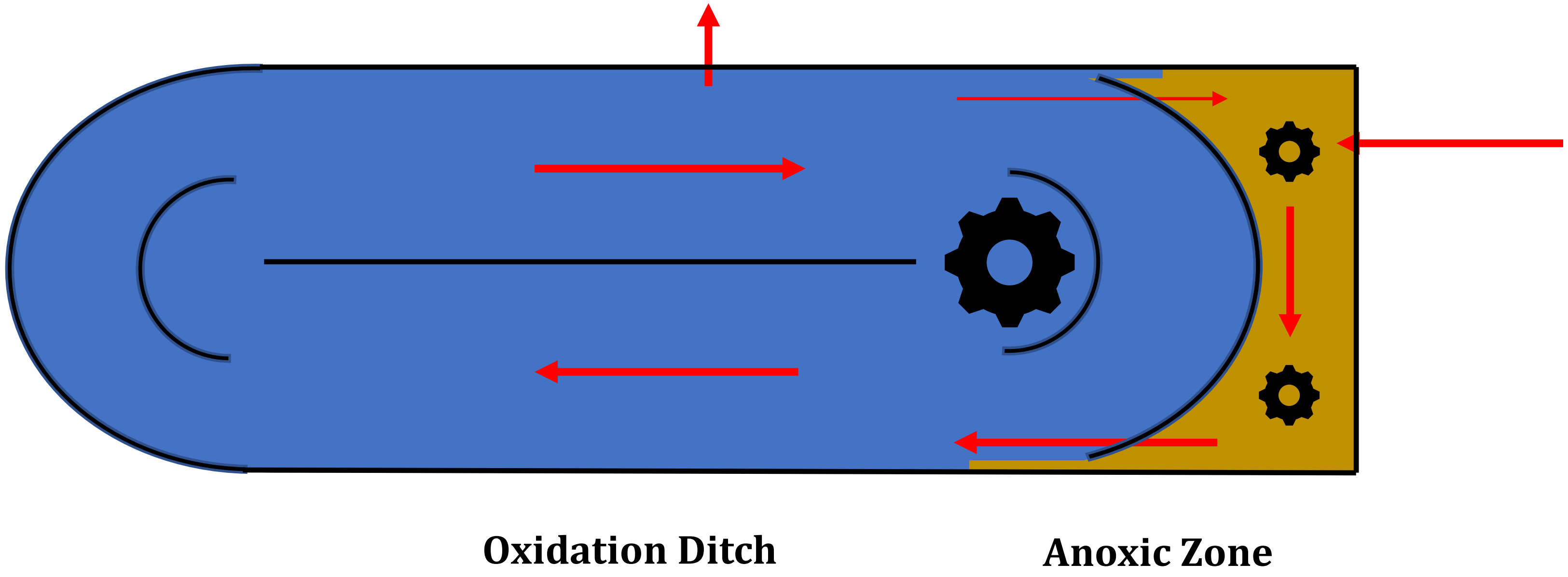
Oxidation Ditch with Anaerobic and Anoxic Zone



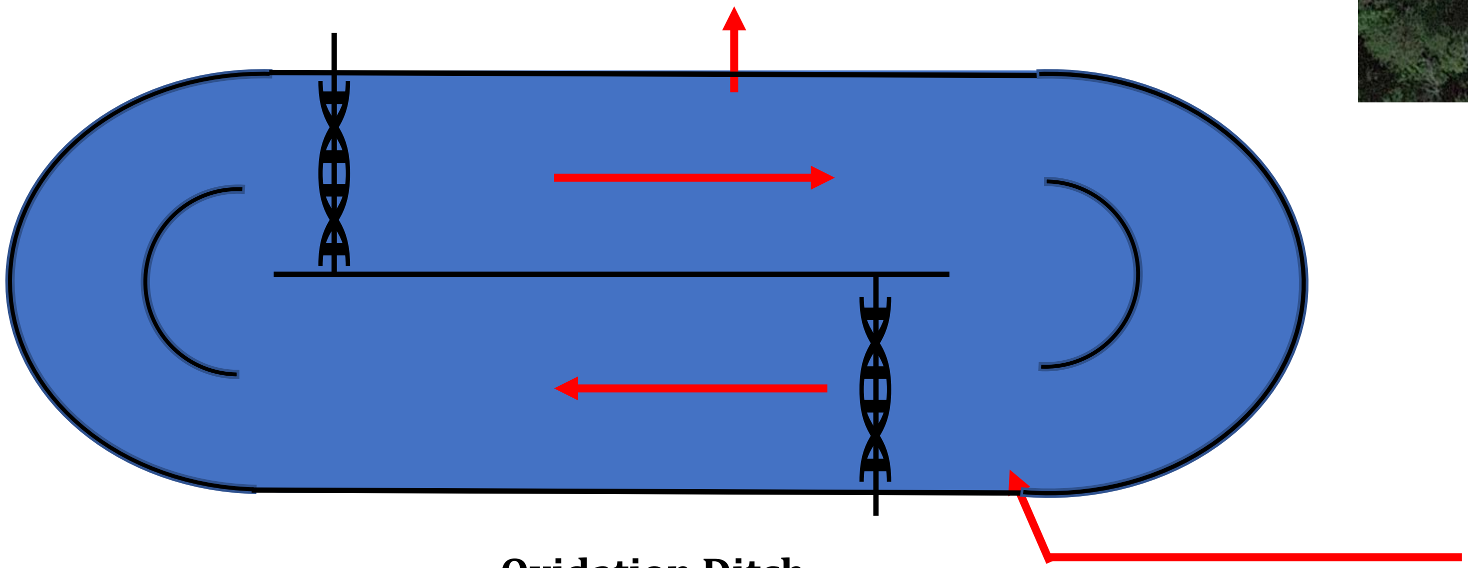
Oxidation Ditch with Anaerobic Zone



Oxidation Ditch with Anoxic Zone



Oxidation Ditch with no Anoxic Zone and no Anaerobic Zone



Oxidation Ditch

Which Oxidation Ditch is Yours?

Acknowledgements

MONTANA Paul LaVigne (DEQ retired) … Pete Boettcher (DEQ) … Josh Viall (DEQ) … Eric Miller (Chinook) … Keith Thaut (Conrad) … Mark Fitzwater (Helena) …

TENNESSEE Karina Bynum (TDEC) … Sherry Wang (TDEC) … George Garden (TDEC) … Jen Dodd (TDEC) … Tom Graham (Cookeville) … John Buford (Cookeville) … Greg Hayes (Athens) … Russell Coleman (Athens) … Tony Wilkerson (Norris) … Doug Snelson (Norris) … Nick Cowan (LaFollette)

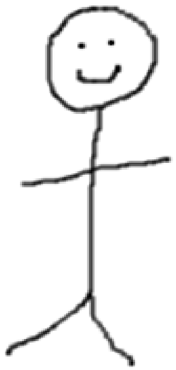
KANSAS Tom Stiles (KDHE) … Rod Geisler (KDHE retired) … Shelly Shores-Miller (KDHE) … Bruce Hurt (Osawatomie) … Jeff Shanline (Pratt) … James Gaunt (Great Bend) … April Batt (Great Bend) … Reuben Martin (Great Bend) … Jason Cauley (Great Bend)

IOWA Kelly Haskin (Eldora) …

EPA Paul Shriner (HQ) … Tony Tripp (HQ) … Tina Laidlaw (R8) … Craig Hesterlee (R4) … Brendon Held (R4) … Timothy Elkins (R5) … David Pfeifer (R5) … Sydney Weiss (R5)

WISCONSIN Matthew Claucherty (DNR) … Amy Garbe (DNR) … Laura Dietrich (DNR)

ERG Lori Weiss … Tessa Roscoe … Morgan Collins



… and, many more!

Optimizing Phosphorus Removal in Conventional and Extended Aeration WWTPs: Case Studies

Wednesday, March 10

10:00 - 11:45 AM Central Time

March 17: What We've Learned and Brainstorming P Removal Opportunities at Your Plants

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Comments & Questions