Energy & Nutrient Optimization

of NC Municipal Wastewater Treatment Plants

February 11, 2021
10:00 - 11:45 AM

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Energy & Nutrient Optimization
of NC Municipal Wastewater Treatment Plants

Today: Overview & Introductions
Biological Nitrogen Removal, Part 1

Feb 18: Nitrogen Removal, Part 2

Feb 25: Activated Sludge, Part 1 - Oxygen Demand and Supply

Mar 4: Activated Sludge, Part 2 - Bio-Tiger Model

Mar 11: Biological Phosphorus Removal, Part 1

Mar 18: Biological Phosphorus Review, Part 2

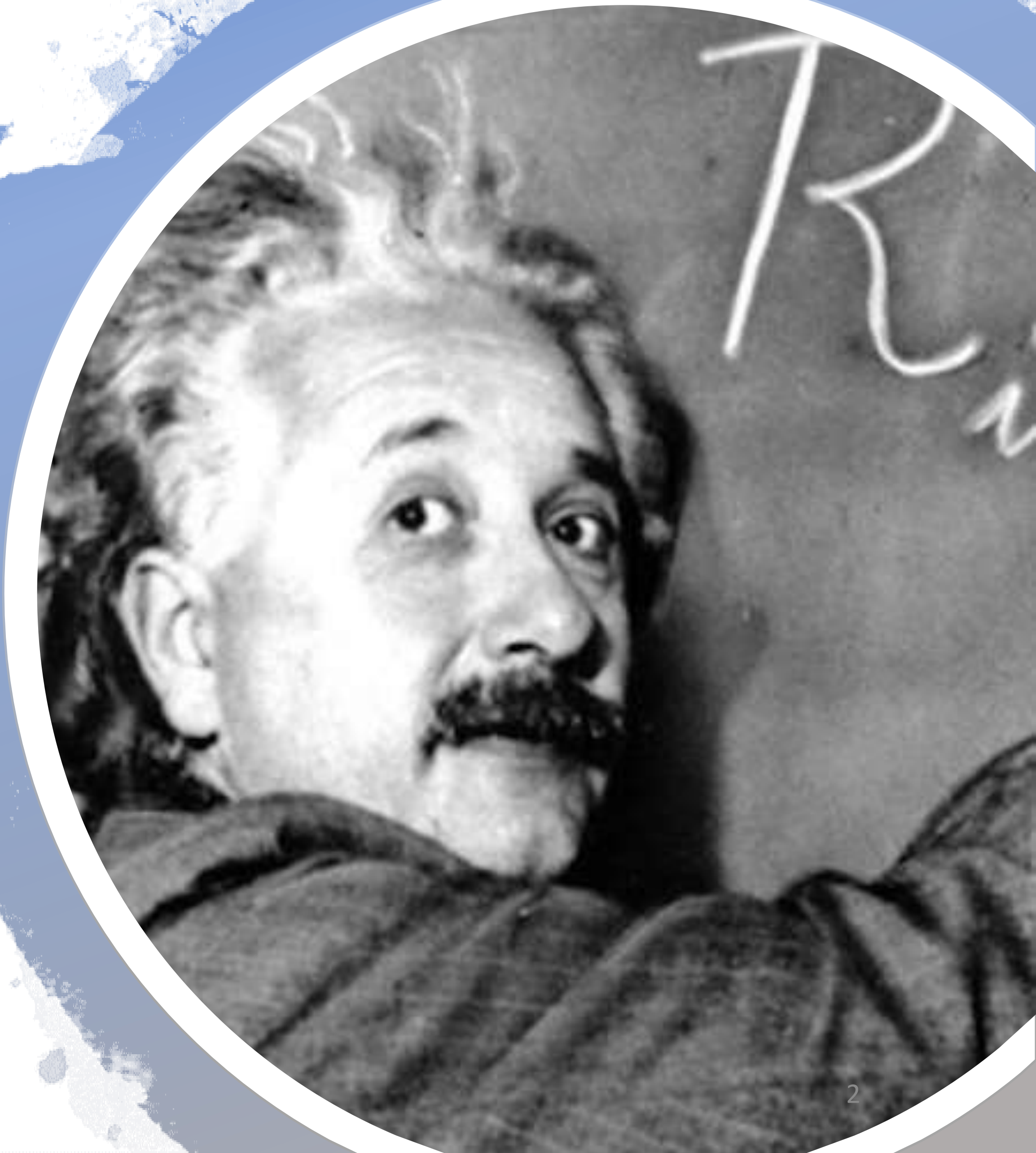
Mar 25: **North Carolina Case Studies**, Part 1

Apr 8: **North Carolina Case Studies**, Part 2

Apr 15: Energy Management, Part 1

Apr 22: Energy Management, Part 2

Apr 29: **North Carolina Case Studies**, Part 3



Why North Carolina operators should care about Nitrogen Removal

From North Carolina's 2019 ***Nutrient Criteria Development Plan***

Development and adoption of nutrient criteria for the following by **2025**:

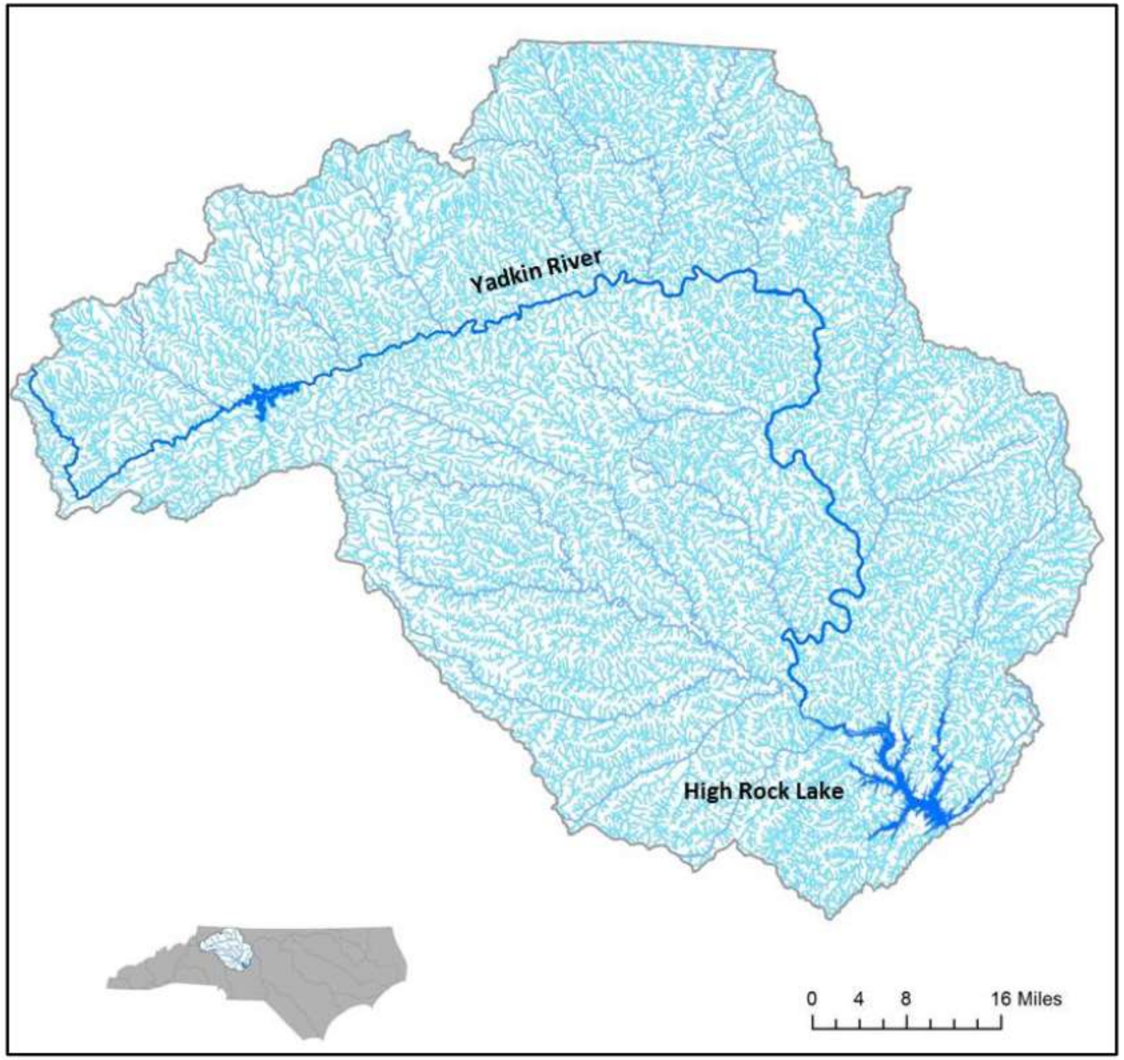
High Rock Lake / Yadkin River Basin

Albemarle Sound / Chowan River Basin

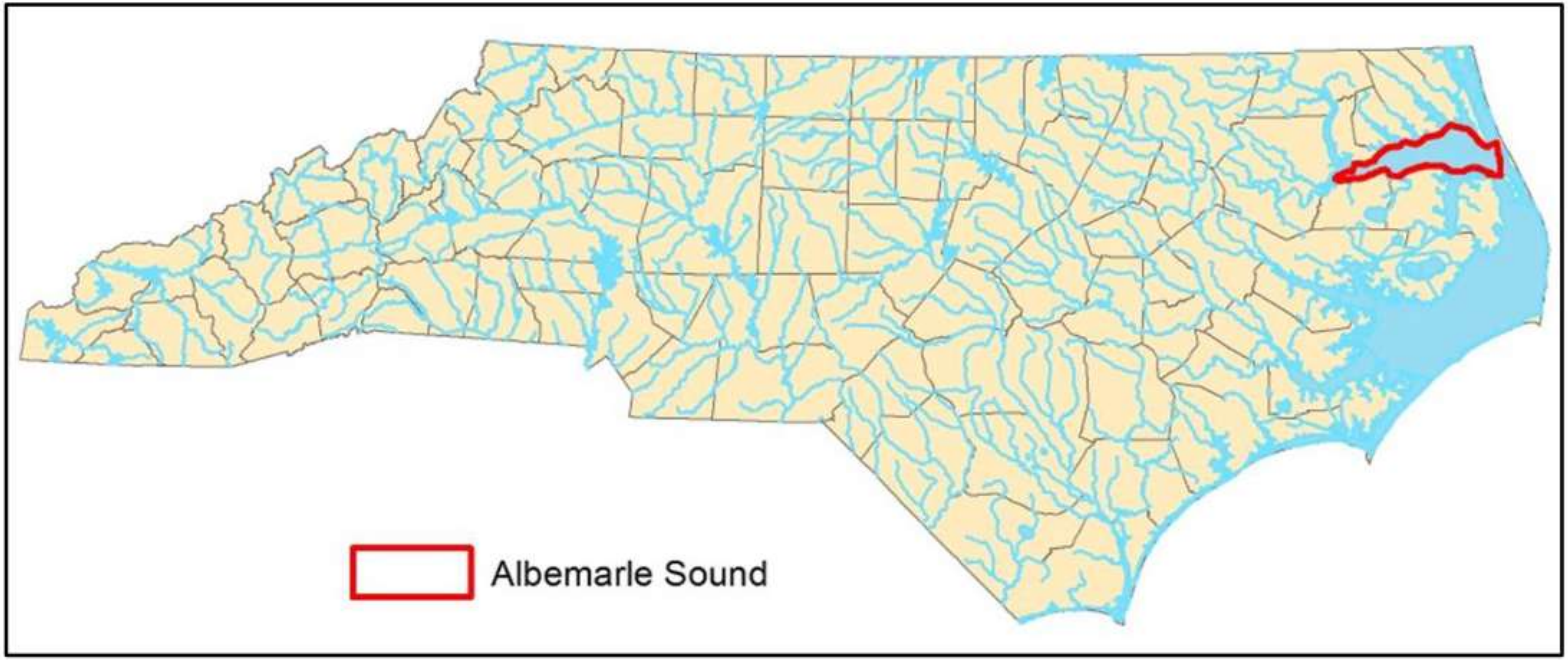
Central portion of the Cape Fear River

Adoption of nutrient criteria **statewide by 2029**

High Rock Lake / Yadkin River Basin



Albemarle Sound / Chowan River Basin



Central Portion of Cape Fear River

Introducing a new way of thinking:

Facility upgrades aren’t the only way to get phosphorus removal…

Empowered operators achieve amazing results!

Change day-to-day operations to
create ideal habitats for bacteria to remove phosphorus

Connecticut
Colchester-East Hampton
East Haddam
Groton
New Canaan
New Hartford
Plainfield North
Plainfield Village
Suffield
Windham

Iowa
Eldora

Kansas
Andover
Basehor
Chanute
Chisholm Creek
Derby
Eudora
Garden Plain
Goddard
Great Bend
Halstead
Hiawatha
Holton

Kansas, cont'd
Kingman
Lansing
Lyons
Medicine Lodge
Miami CO - Bucyrus
Miami CO - Walnut Creek
Osawatomie
Pratt
Riley CO - University Park
Rose Hill
Shawnee CO - Sherwood
St. Marys
Spring Hill
Topeka North
Wellington
Wellsville
Wichita Plants 1&2
Winfield

Kentucky
Hopkinsville

Massachusetts
Amherst
Barnstable
Easthampton

Massachusetts, cont'd
Greenfield
Montague
Newburyport
Northfield
Palmer
South Deerfield
South Hadley
Sunderland
Upton
Westfield

Montana
Bigfork
Big Sky
Billings
Boulder
Bozeman
Butte
Chinook
Choteau
Colstrip
Columbia Falls
Conrad
Dillon
East Helena
Forsyth

Montana, cont'd
Gallatin Gateway
Glendive
Great Falls
Hamilton
Hardin
Havre
Helena
Kalispell
Laurel
Lewistown
Libby
Lolo
Manhattan
Miles City
Missoula
Stevensville
Wolf Creek

New Hampshire
Keene

South Carolina
Greeneville

Tennessee
Athens
Baileyton
Bartlett
Chattanooga
Collierville
Cookeville
Cowan
Crossville
Harriman
Humboldt
Lafayette
LaFollette
Livingston
Millington
Nashville Dry Creek
Norris
Oak Ridge

Texas
Nottingham MUD (Houston)

Virginia
Strasburg

Wyoming
Laramie

Gauging your N-smarts


Case Study
research
case
subject
circumstan
studies
criteria
sampling
based
information
object
cases
knowledge
multiple
established
typology
may
focus
thus
Outlier
theory-testing
evidence
historical
approach
become
retrospective
whether
local
study
researchers
data
exploratory
theory-building
theoretical
single
selecting
frame
researcher
in-depth
key
qualitative
quantitative
offer
event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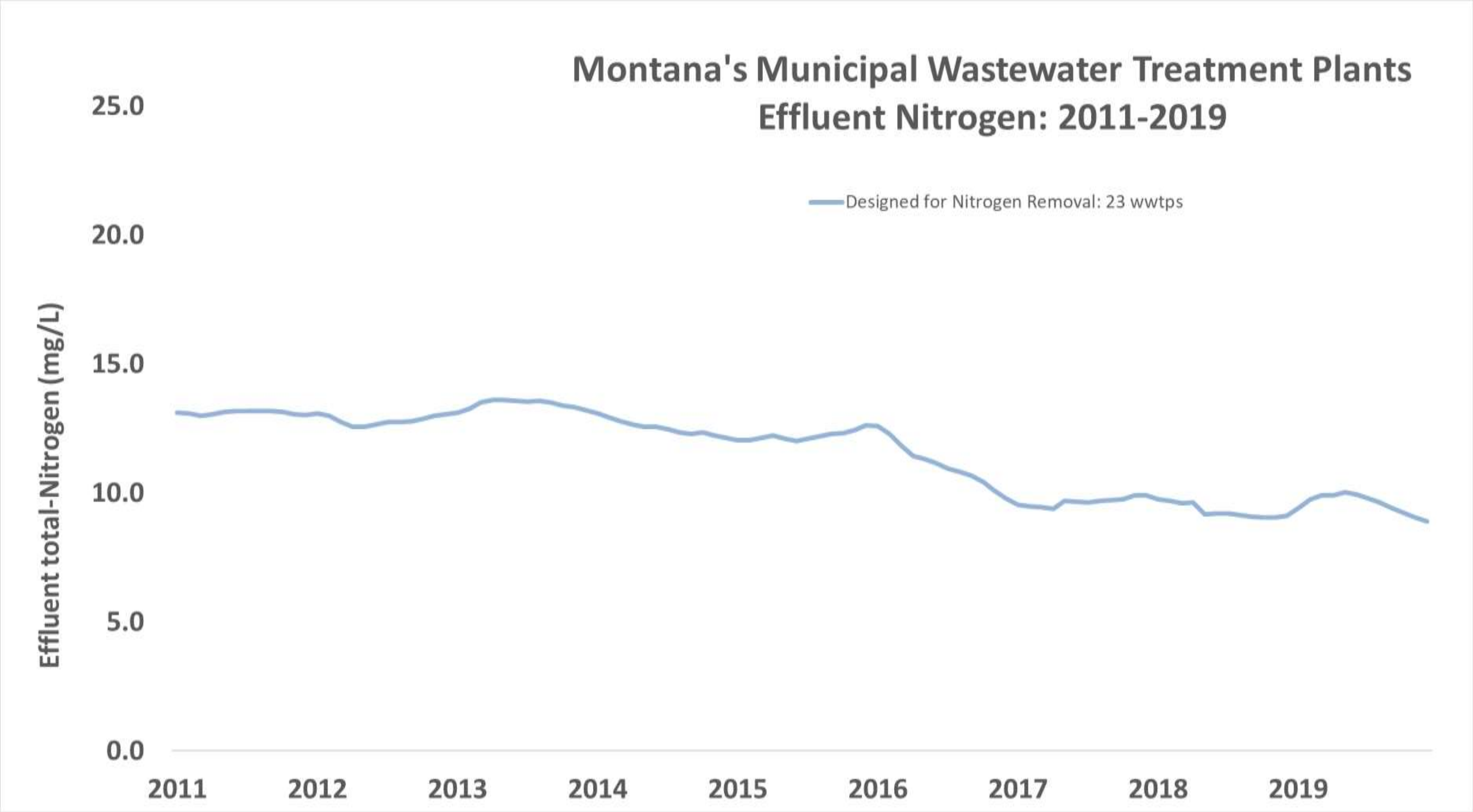
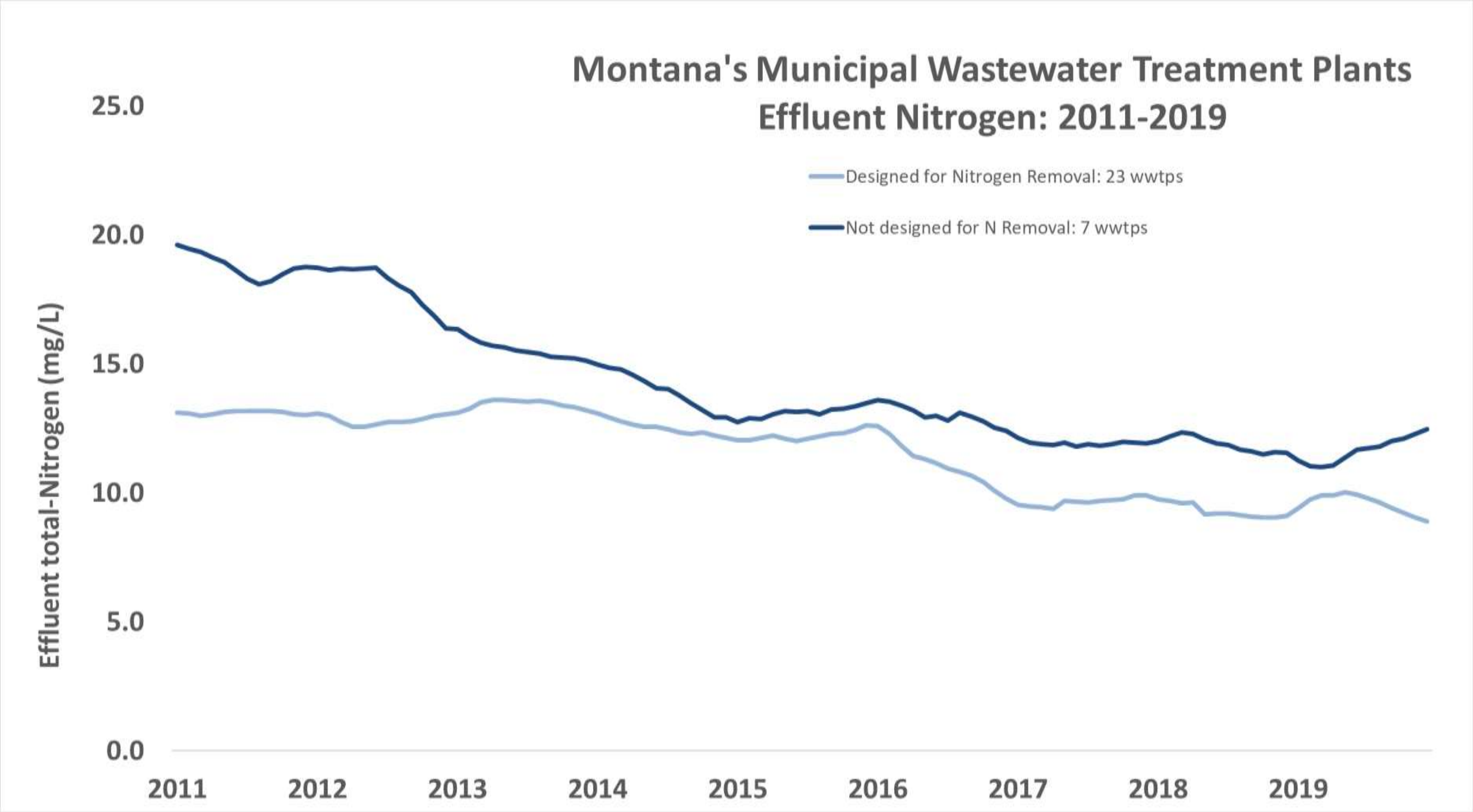
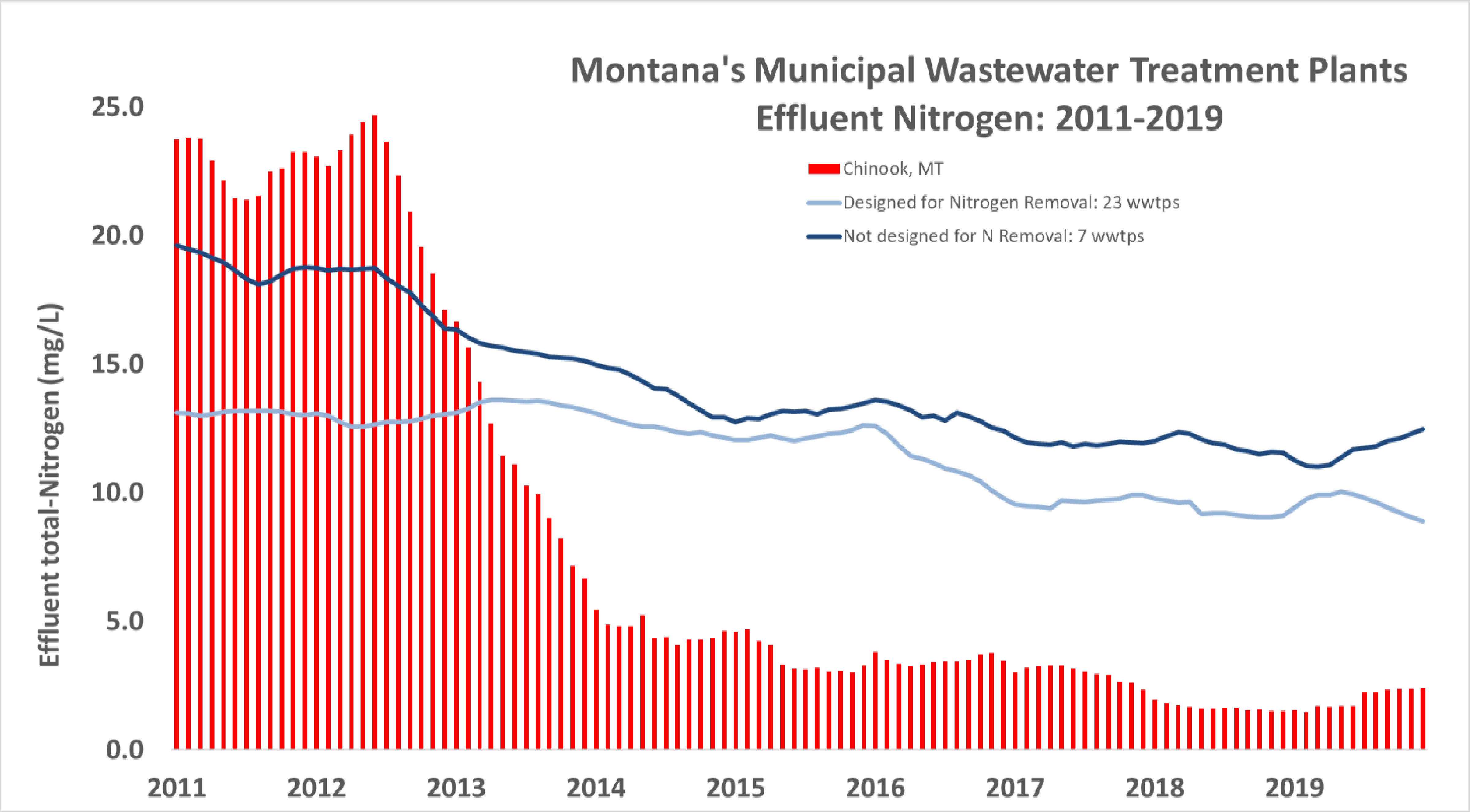
NA


Montana's Municipal Wastewater Treatment Plants
Effluent Nitrogen: 2011-2019
Designed for Nitrogen Removal: 23 wwtps
Effluent total-Nitrogen (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019



Montana's Municipal Wastewater Treatment Plants
Effluent Nitrogen: 2011-2019
Designed for Nitrogen Removal: 23 wwtps
Not designed for N Removal: 7 wwtps
Effluent total-Nitrogen (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019

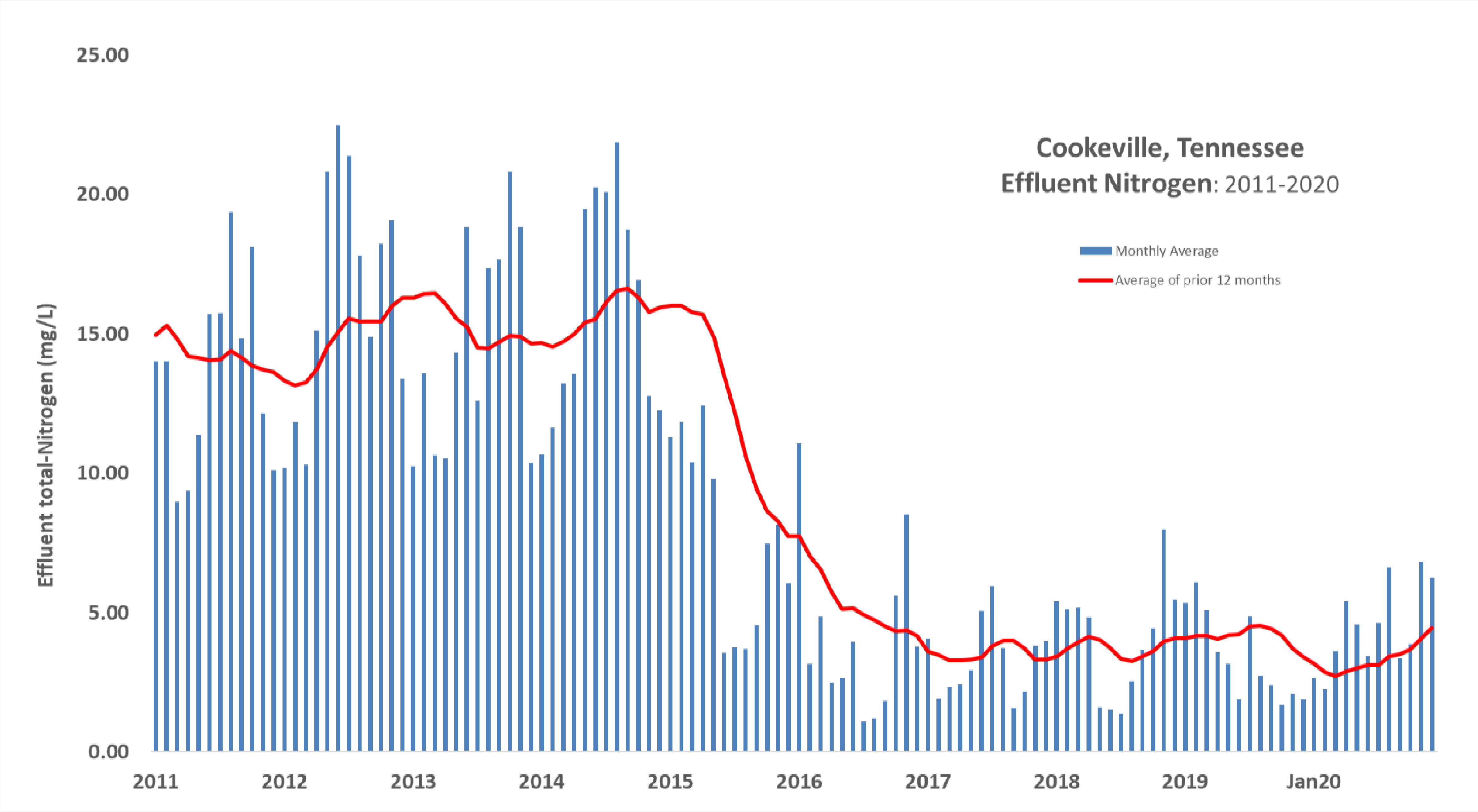

Montana's Municipal Wastewater Treatment Plants
Effluent Nitrogen: 2011-2019
Chinook, MT
Designed for Nitrogen Removal: 23 wwtps
Not designed for N Removal: 7 wwtps
Effluent total-Nitrogen (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019


TENNESSEE

Cookeville, Tennessee Population: 33,500 15 MGD design flow


Cookeville


TREATMENT PLANT OPERATOR
tpo
IN MY WORDS:
Treatment innovations
for small communities | 22
TECH TALK:
A new approach
to flood protection | 14
From Learner
to Mentor
MICHELE HIGDON SAYS THANKS
FOR HER SUCCESS BY GIVING BACK
AS A VOLUNTEER
PLANT
PROFICIENCIES

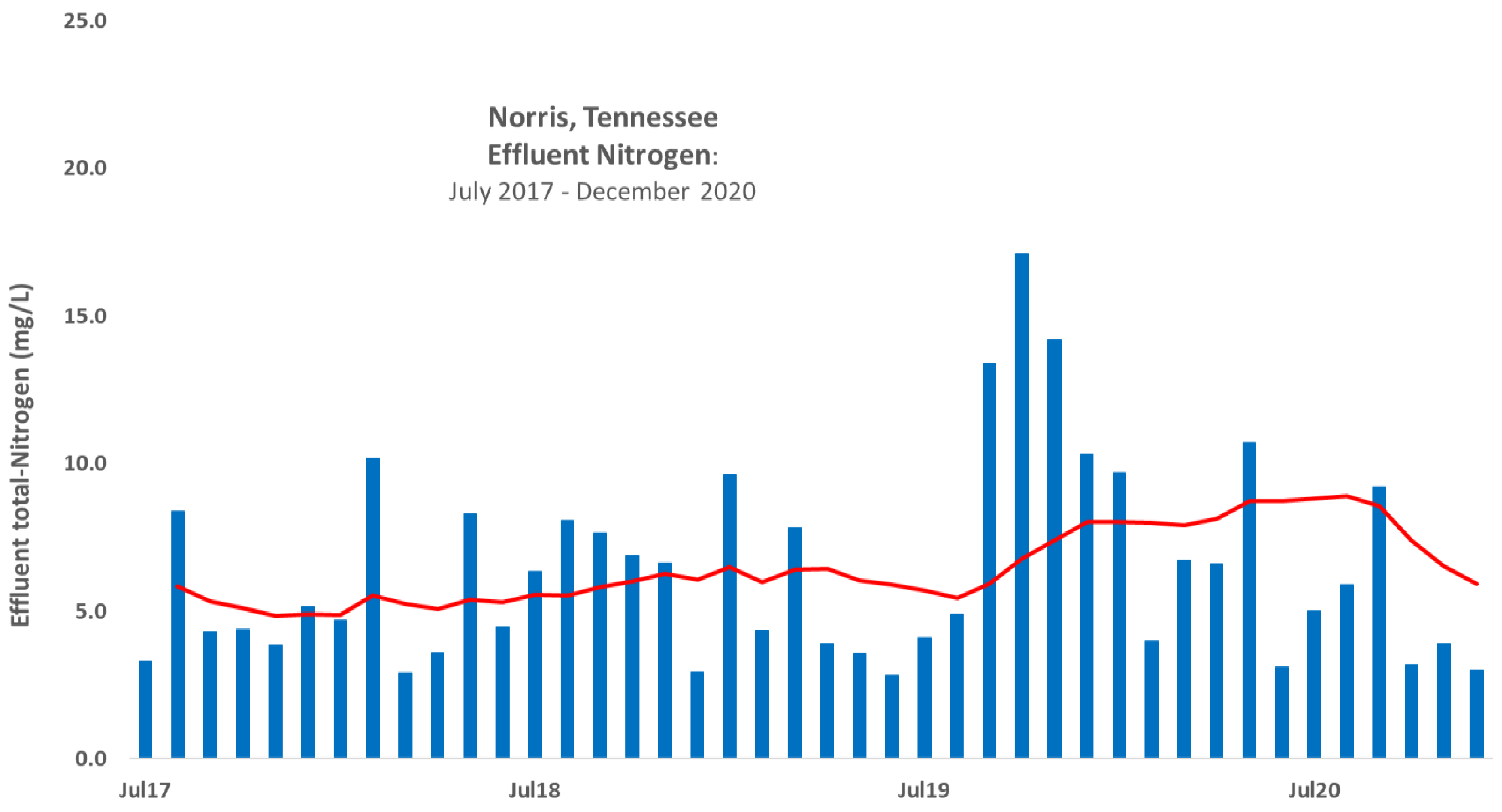


Cookeville, Tennessee
Effluent Nitrogen: 2011-2020
Monthly Average
Average of prior 12 months
Effluent total-Nitrogen (mg/L)
25.00
20.00
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
Jan20

Norris, Tennessee Population: 1,450 0.2 MGD design flow

GOVERNOR'S ENVIRONMENTAL STEWARDSHIP AWARDS

Norris



Norris, Tennessee
Effluent Nitrogen:
July 2017 - December 2020
Effluent total-Nitrogen (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
Jul17
Jul18
Jul19
Jul20

Harriman, Tennessee | Population: 6,200 | 1.5 MGD design flow

Harriman, Tennessee

Actual Flow (MGD)	Effluent Nitrogen (mg/L)		Effluent Phosphorus (mg/L)	
	Historical Average	After Optimization	Historical Average	After Optimization
1.2	21.5	2.3	2.9	1.4

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Science

Wastewater Science

Alkalinity and pH

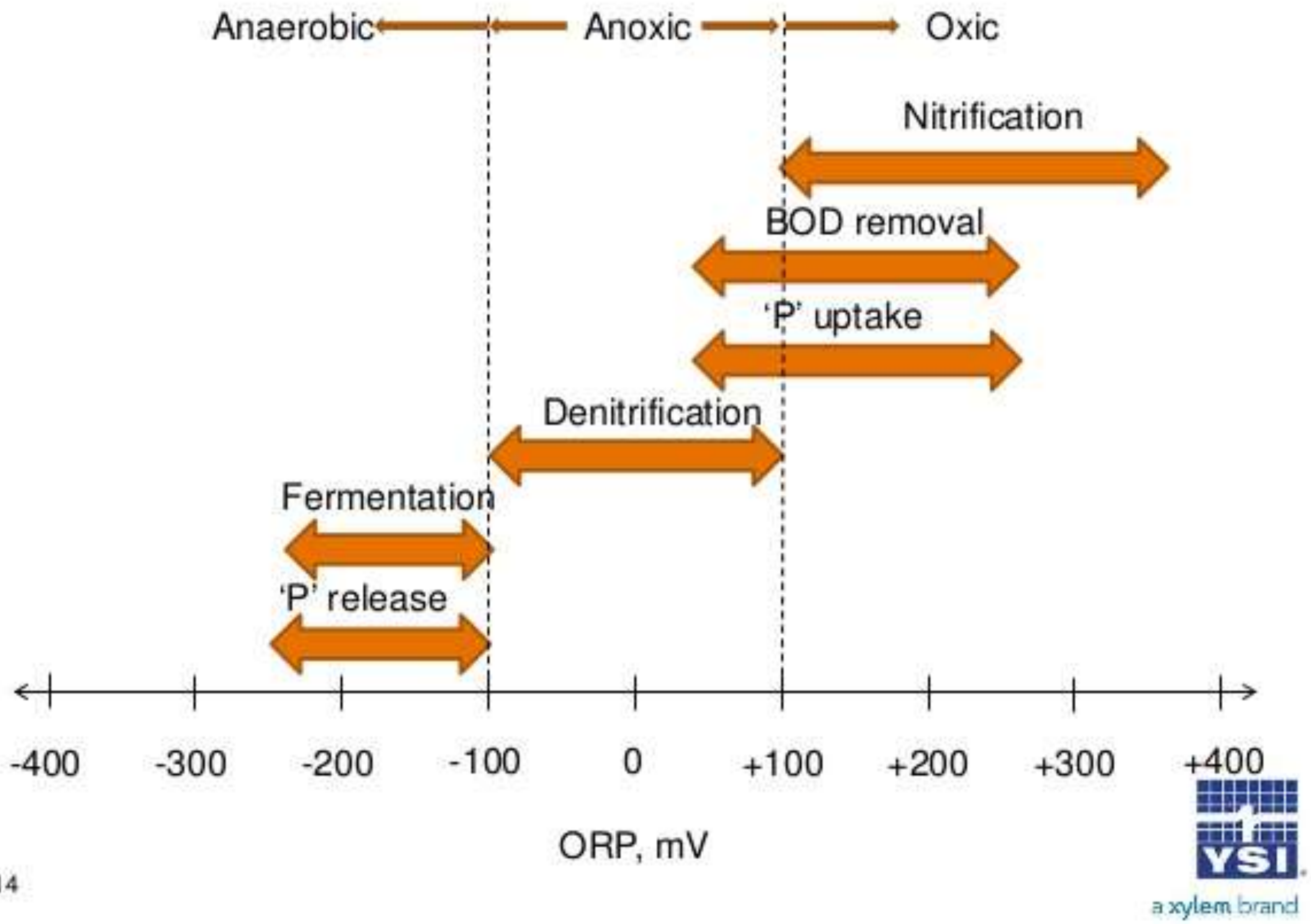
ORP (Oxygen Reduction Potential)

Wastewater Science

DO and ORP

DO (Dissolved Oxygen)

What Does ORP Tell Us About Our Process?



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Nitrogen Limits?

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7

N

Nitrogen

Biological Nitrogen Removal:

Convert LIQUID to GAS …

BOD and TSS Removal:

Convert LIQUID to SOLID …

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

Ammonia (NH_4) is converted to Nitrate (NO_3)

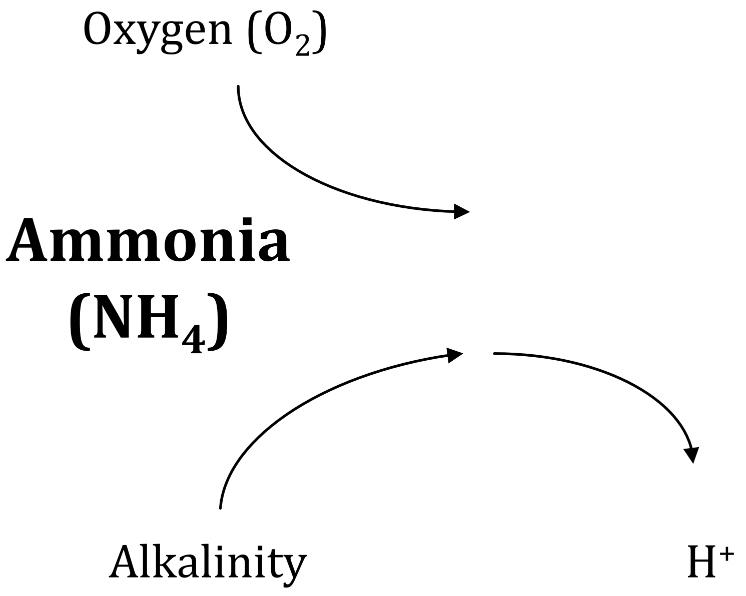
Ammonia
(NH_4)

Ammonia Removal

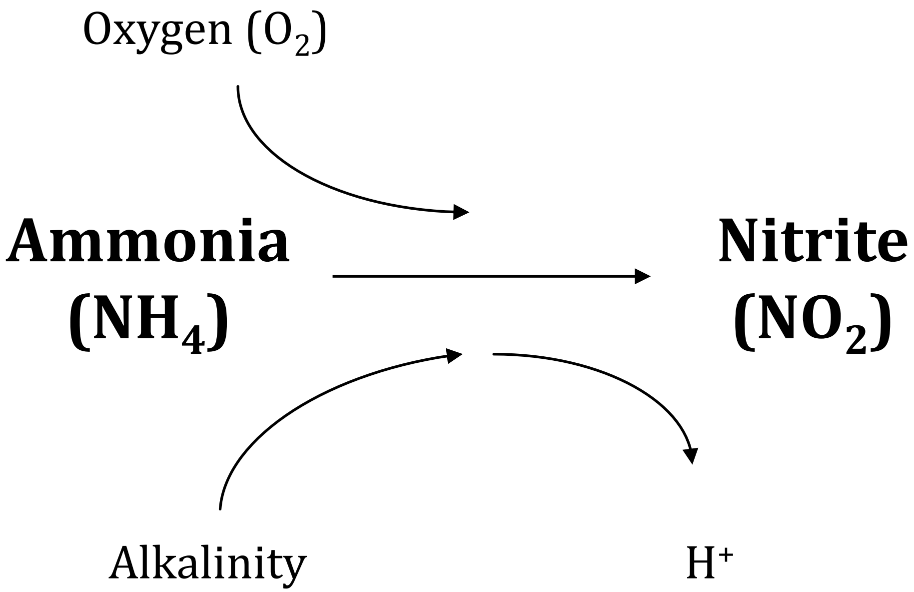
Oxygen (O_2)

Ammonia
(NH_4)

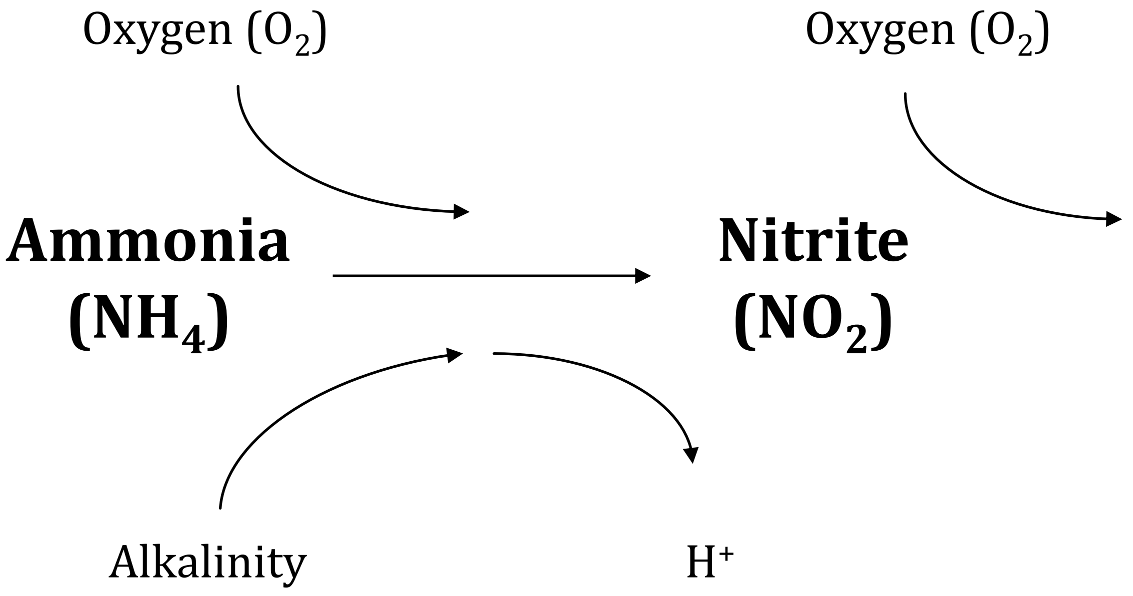
Ammonia Removal



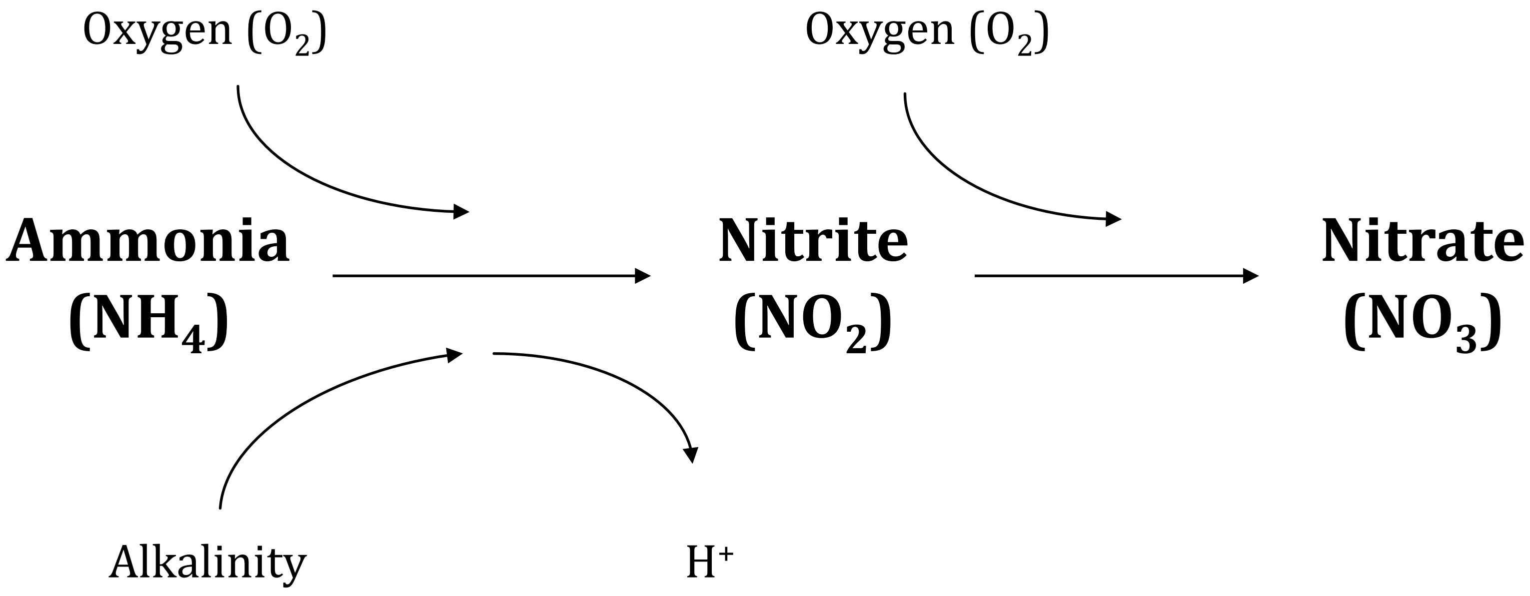
Ammonia Removal



Ammonia Removal



Ammonia Removal



Nitrification:
Ammonia (NH_4) is converted to Nitrate (NO_3)

Oxygen Rich Habitat

MLSS* of 2500+ mg/L (High Sludge Age / MCRT / low F:M)
ORP* of +100 to +150 mV (High DO)
Time* (high HRT … 24 hr, 12 hr, 6 hr)
Low BOD

Consumes Oxygen
Adds acid - Consumes 7 mg/L alkalinity per mg/L of $NH_4 \rightarrow NO_3$

*Approximate, each facility is different.

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Biological Nitrogen Removal:

Next step:

the Nitrate (NO_3) created during Nitrification …

is converted to Nitrogen Gas (N_2)

Nitrate Removal

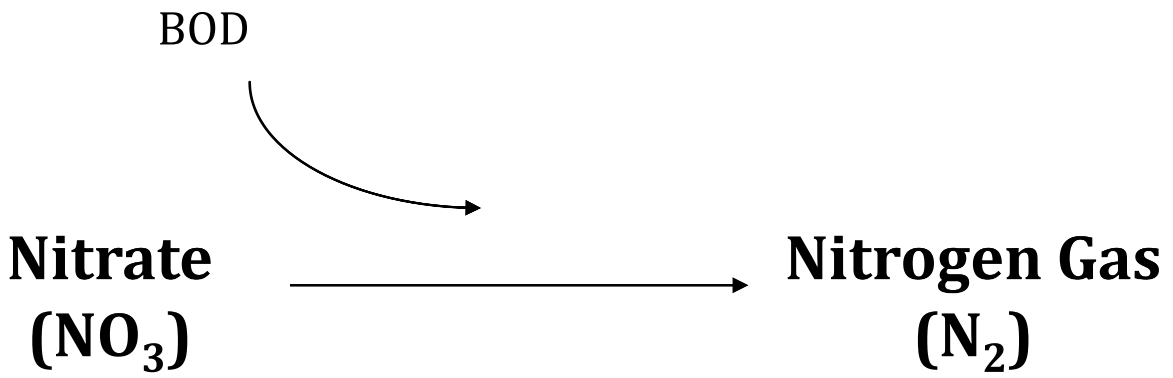
Nitrate
(NO_3)

Nitrate Removal

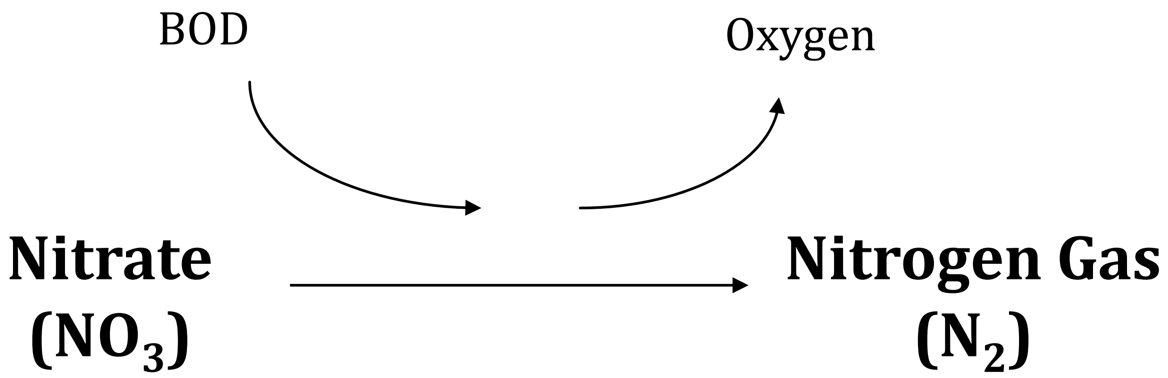
BOD

Nitrate (NO_3)

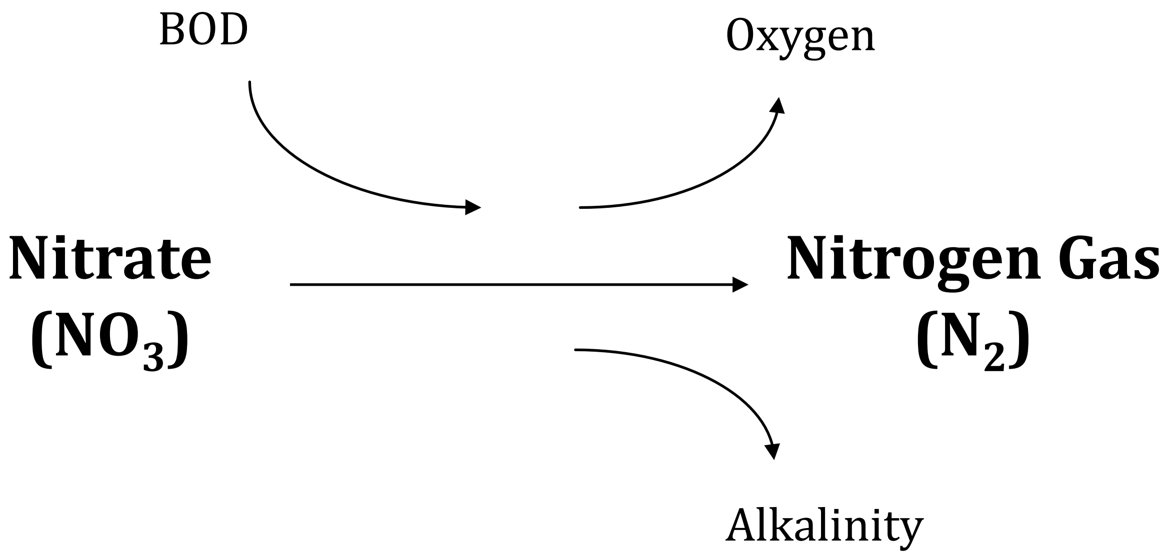
Nitrate Removal



Nitrate Removal



Nitrate Removal



Adds DO (dissolved oxygen)

Consumes BOD

Gives back alkalinity … beneficially raises pH

Denitrification:
Nitrate (NO_3) is converted to Nitrogen Gas (N_2)

Oxygen Poor Habitat

ORP* of -100 mV or less (DO less than 0.3 mg/L)

Surplus BOD* (100-250 mg/L: 5-10 times as much as NO_3)

Retention Time* of 1-2 hours

Gives back Oxygen

Gives back Alkalinity (3.5 mg/L per mg/L of $NO_3 \rightarrow N_2$)

*Approximate, each facility is different.

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**
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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Plant Size

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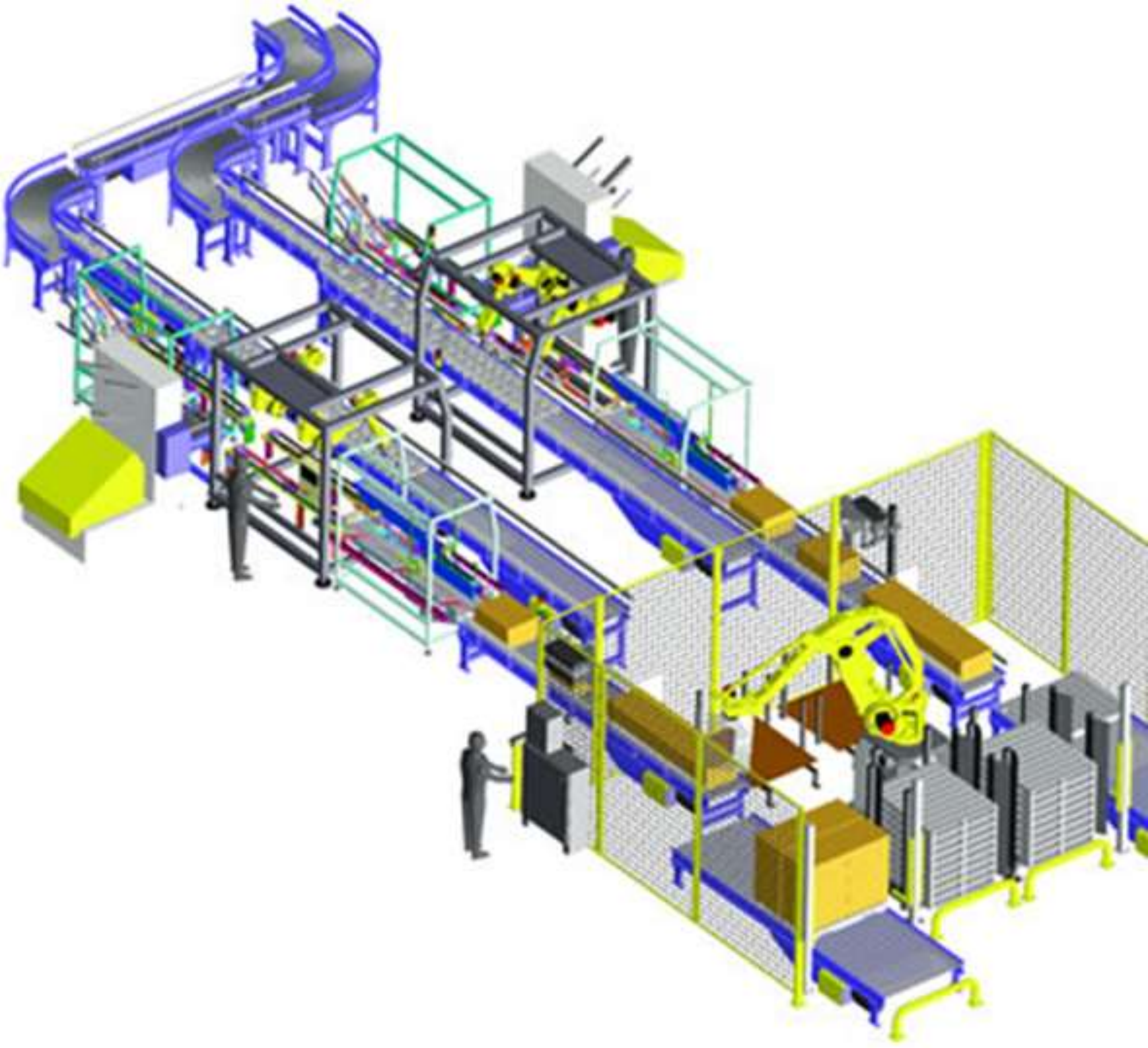
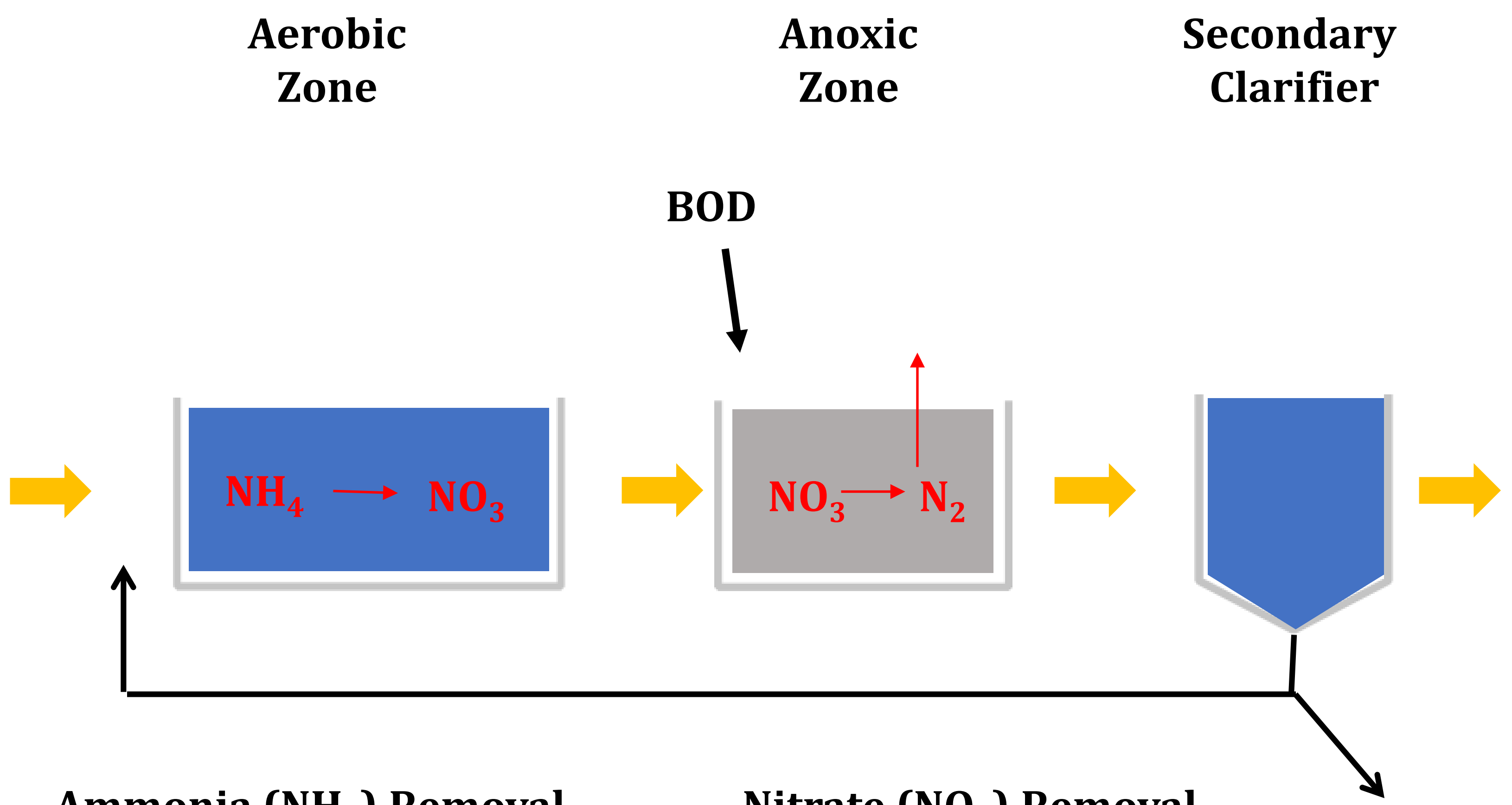
Technology!



Post Denitrification

Post-Anoxic Denitrification



Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L

Nitrate (NO_3) Removal

Target NO_3 in Anoxic Tank: 0.5-2 mg/L

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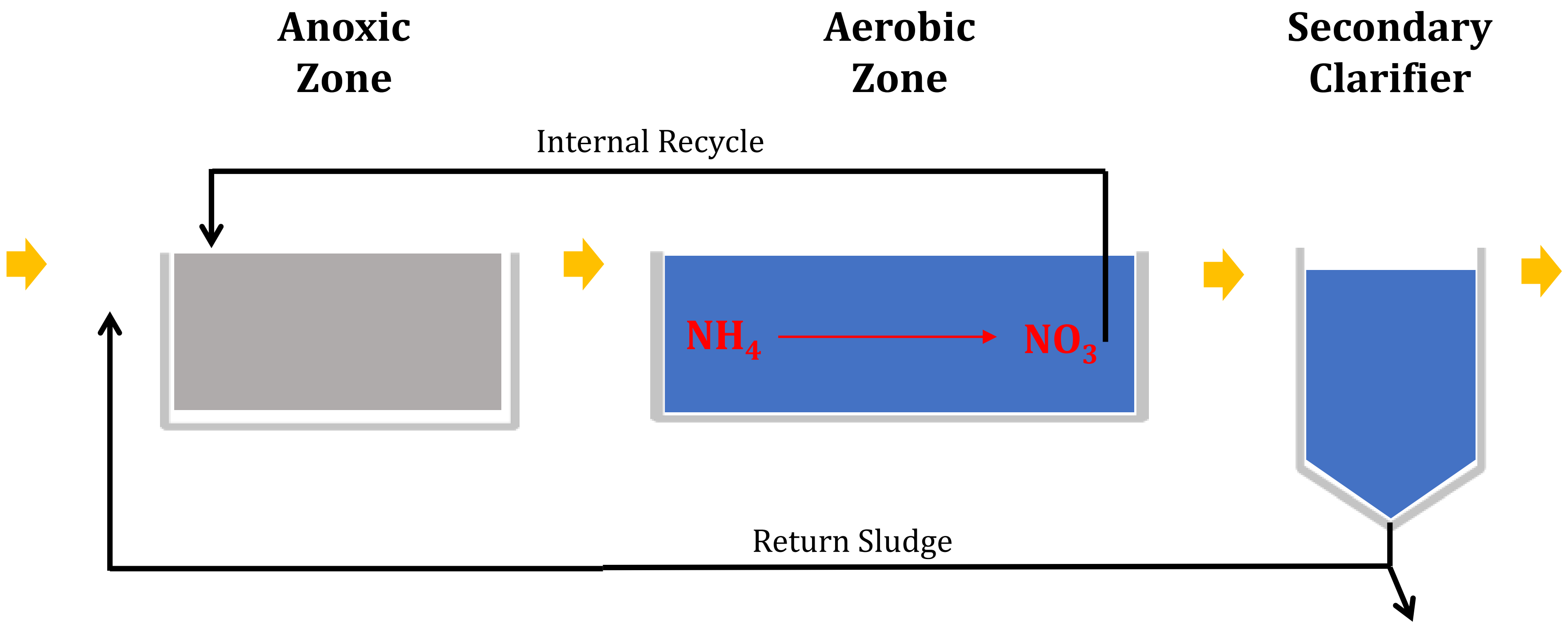
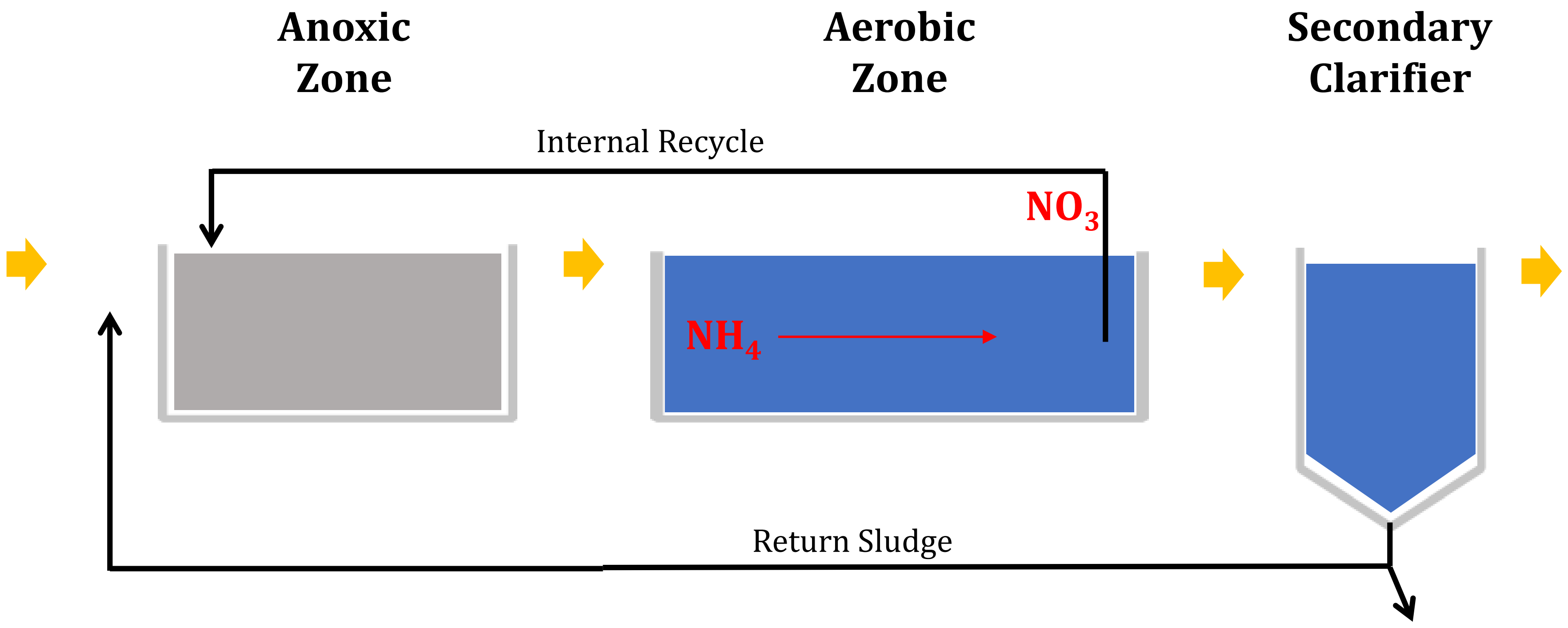
MLE Process
(Modified Ludzack-Ettinger)

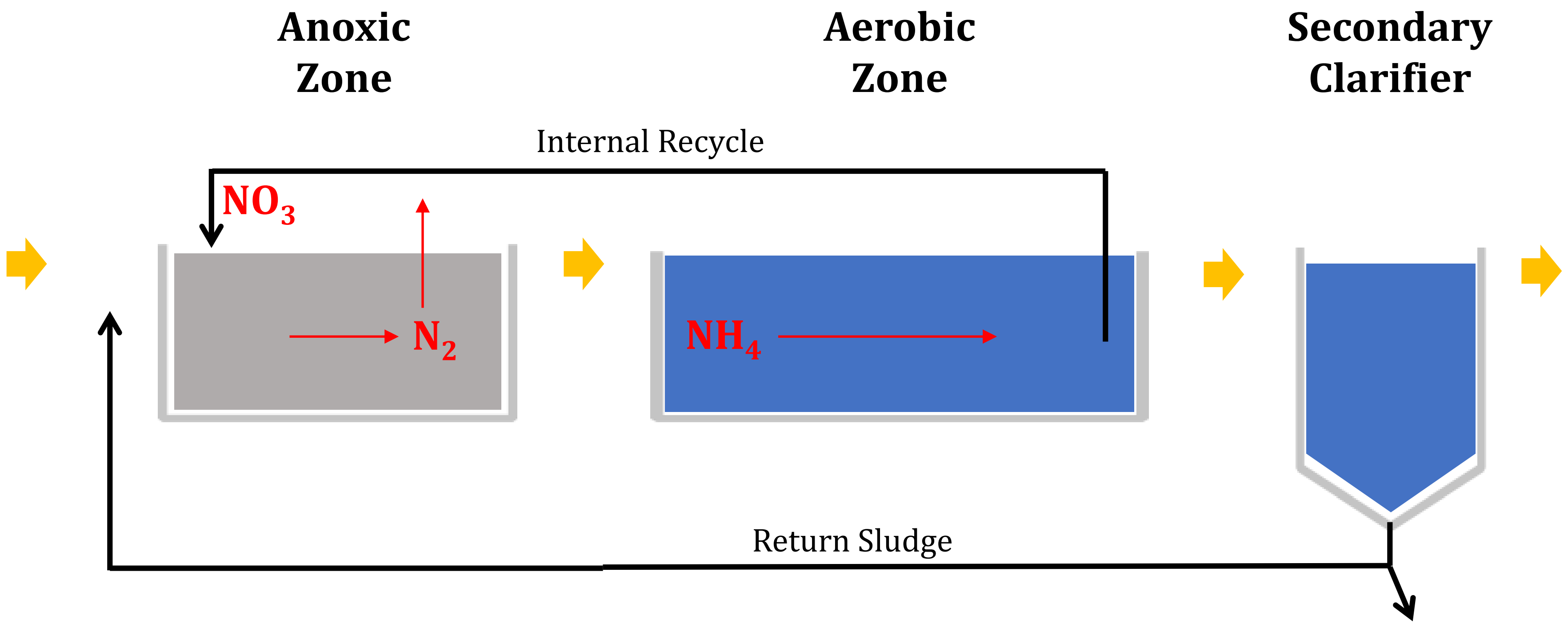
MLE (Modified Ludzack-Ettinger) Process



MLE (Modified Ludzack-Ettinger) Process



MLE (Modified Ludzack-Ettinger) Process



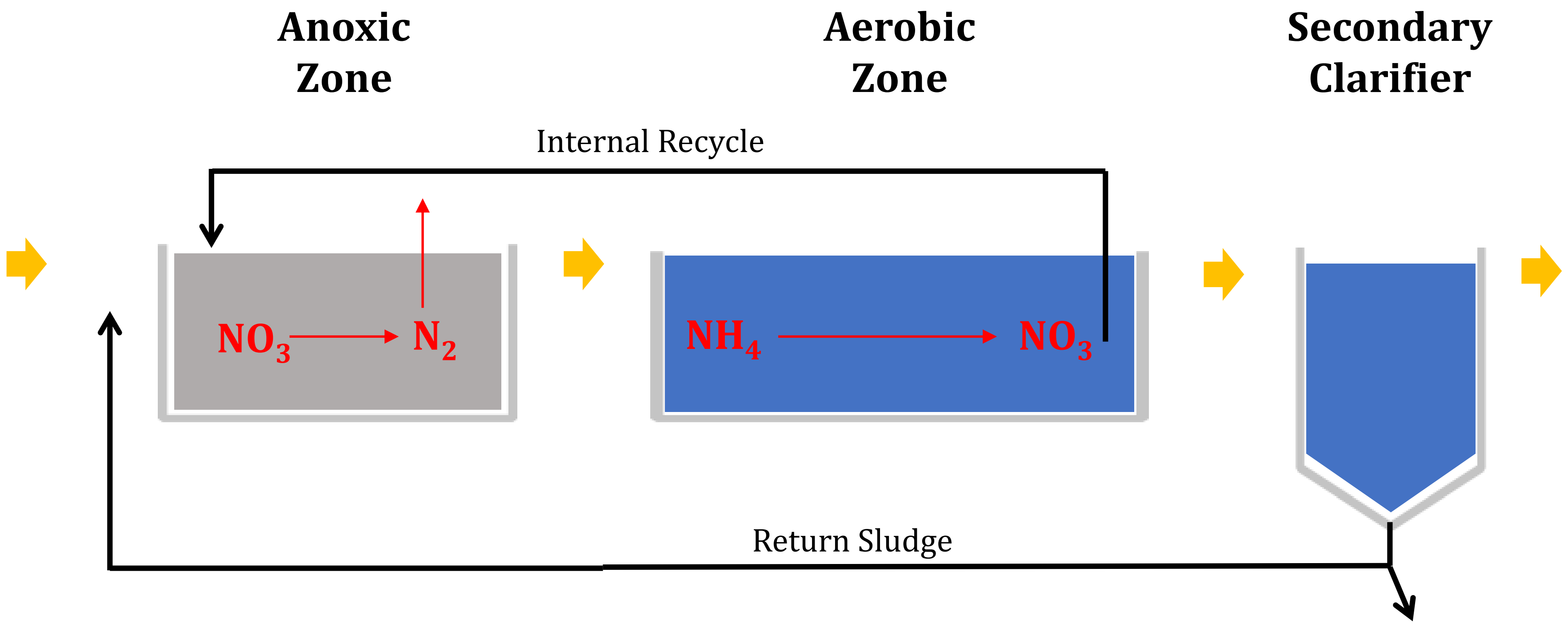
Ammonia (NH_4) Removal

Target: NH_4: 0.5 mg/L

Nitrate (NO_3) Removal

Target NO_3 in Anoxic Tank: 2 mg/L

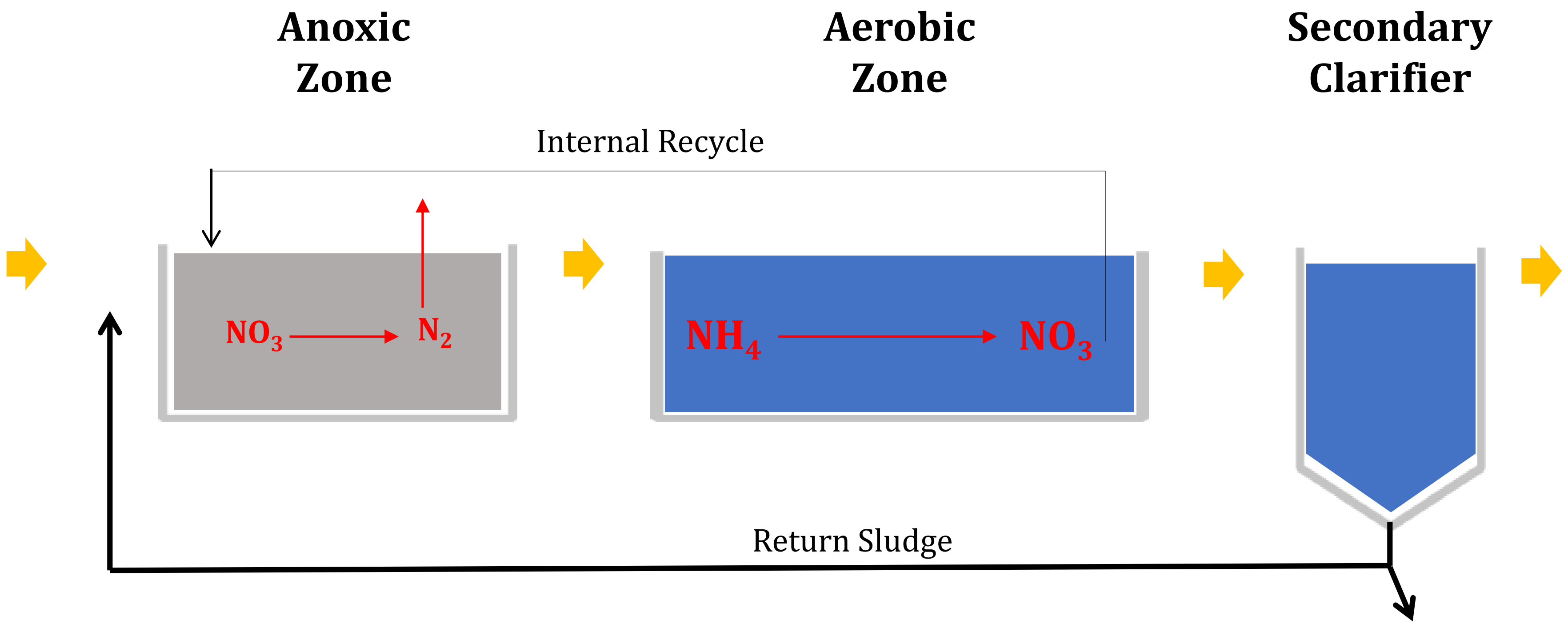
MLE (Modified Ludzack-Ettinger) Process



MLE Process Control:

Proper Internal Recycle Rate; not too much / not too little.
ORP of +100 mV in Aerobic Zone for Ammonia (NH_4) Removal.
ORP of -75 to -150 mV in Anoxic Zone for Nitrate (NO_3) Removal.
Enough BOD to support Nitrate (NO_3) Removal.

MLE with not enough Internal Recycle



Ammonia (NH_4) Removal

Excellent Aerobic Habitat: ORP +150 mV

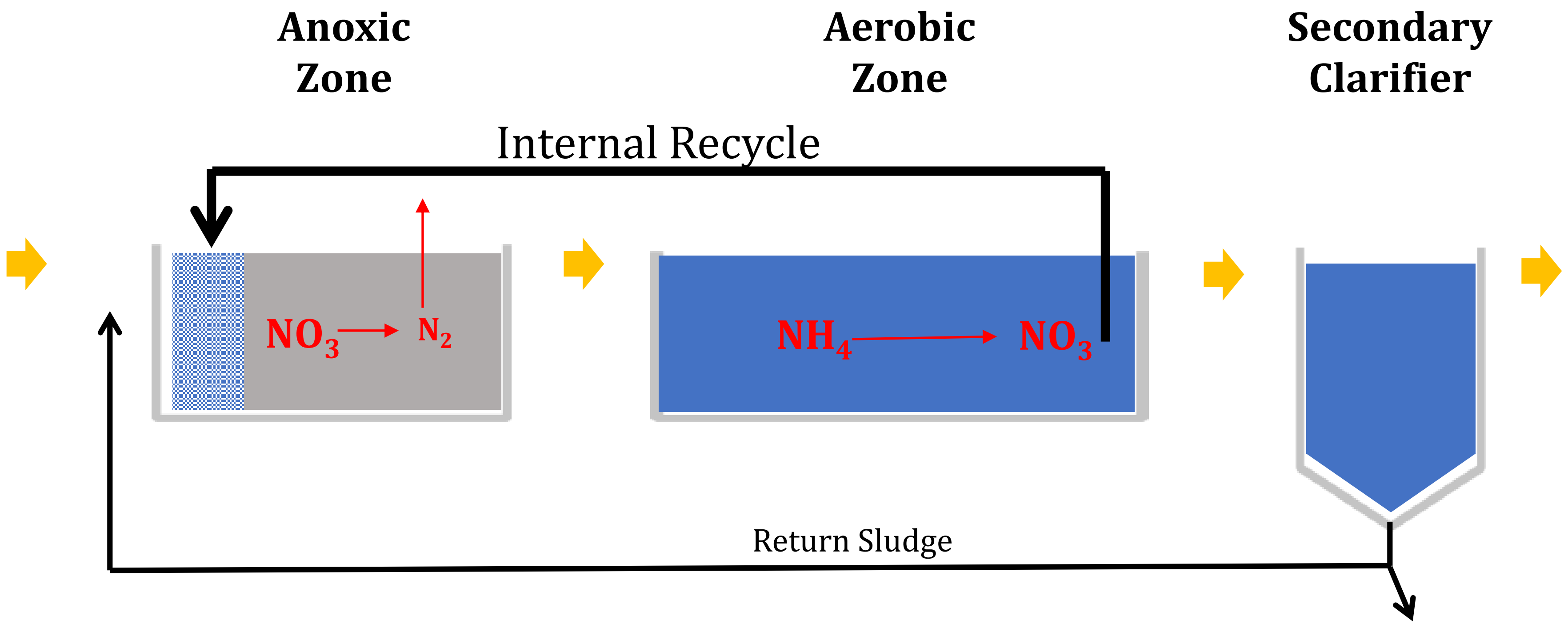
NH_4 < 0.5 mg/L

Nitrate (NO_3) Removal

Great Anoxic Habitat: ORP -150 mV or lower

NO_3 > 4 mg/L because too little NO_3 is returned to Anoxic Zone

MLE with too much Internal Recycle



Ammonia (NH_4) Removal

Good Aerobic Habitat: ORP +100 mV

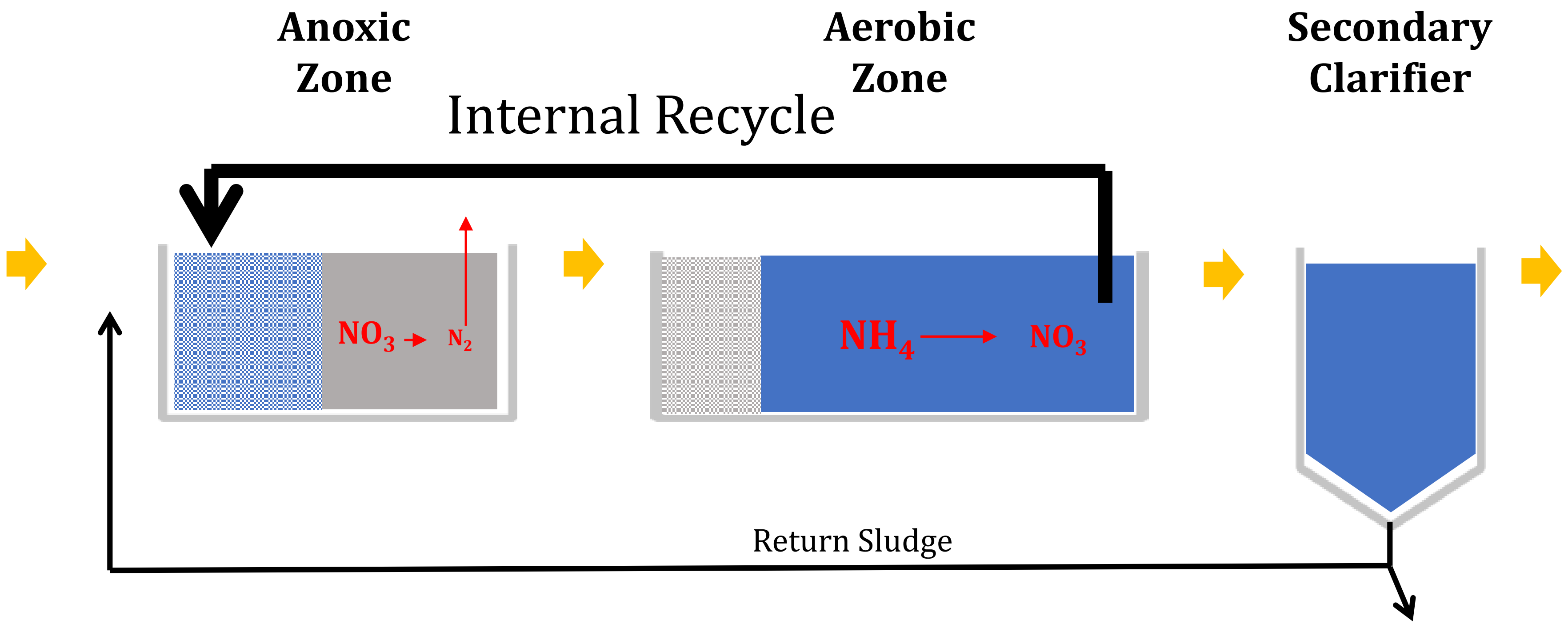
NH_4 < 0.5 mg/L

Nitrate (NO_3) Removal

Stressed Anoxic Habitat: ORP 0 to -100 mV

NO_3 > 4 mg/L: bacteria will not convert Ammonia (NH_4) to Nitrate (NO_3)

MLE with way too much Internal Recycle



Ammonia (NH_4) Removal

Poor Aerobic Habitat: ORP +50 mV

NH_4 > 0.5 mg/L

Nitrate (NO_3) Removal

Poor Anoxic Habitat: ORP 0 mV or higher

NO_3 > 4 mg/L

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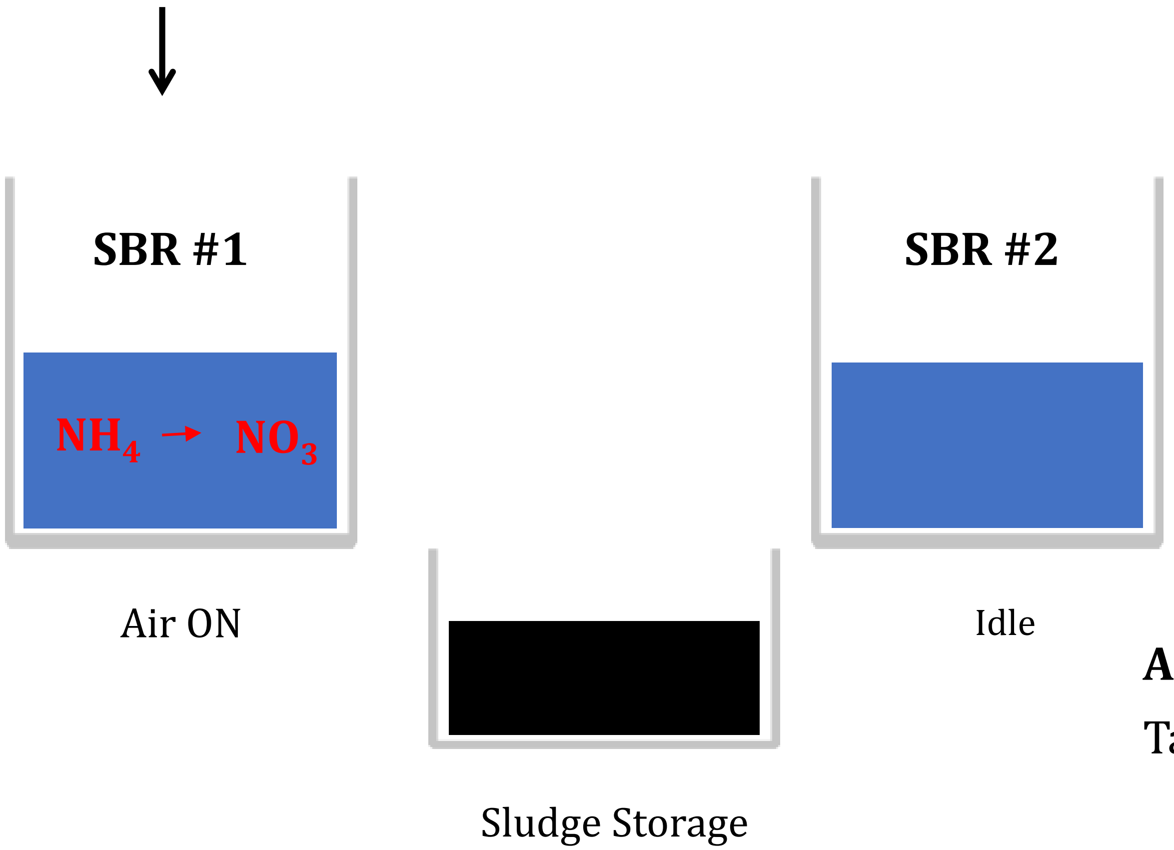
Sequencing Batch Reactor

SBR

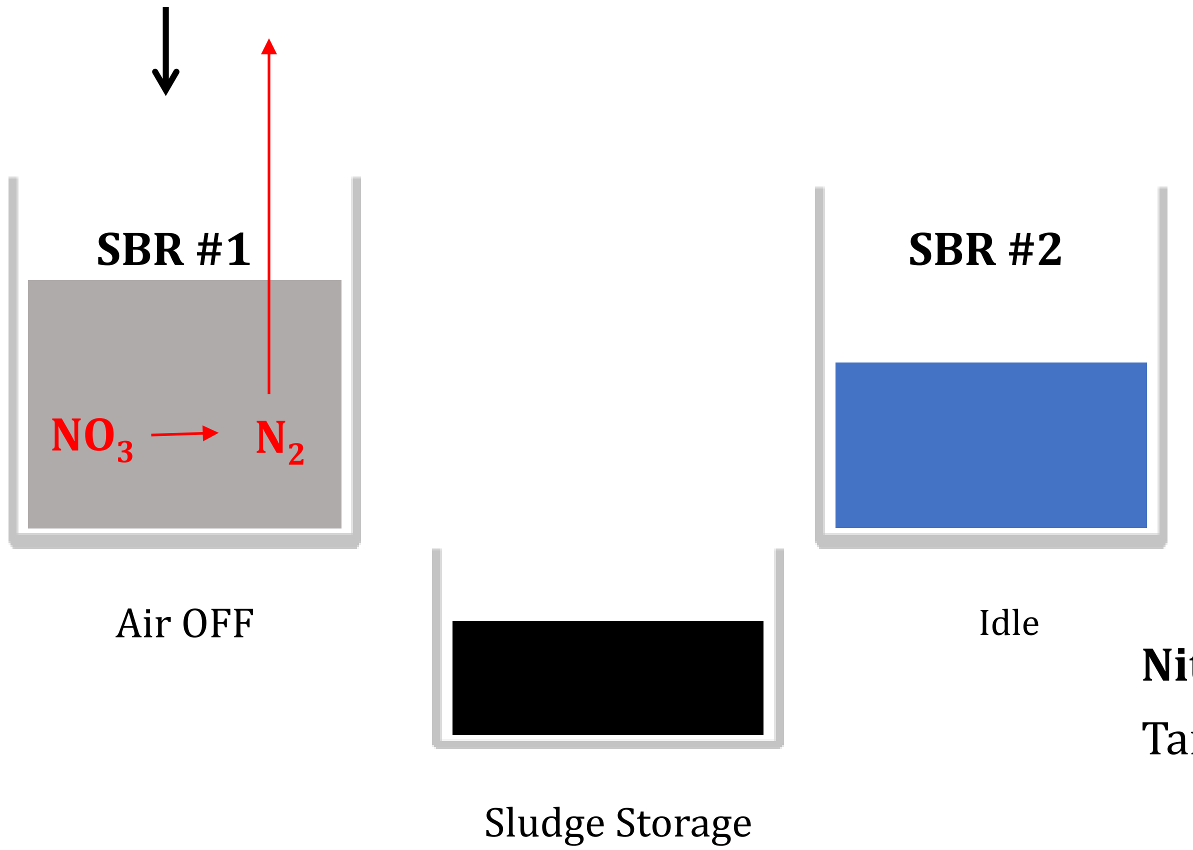
Sequencing Batch Reactor (SBR)
Ammonia (NH_4) Removal: Nitrification



Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L

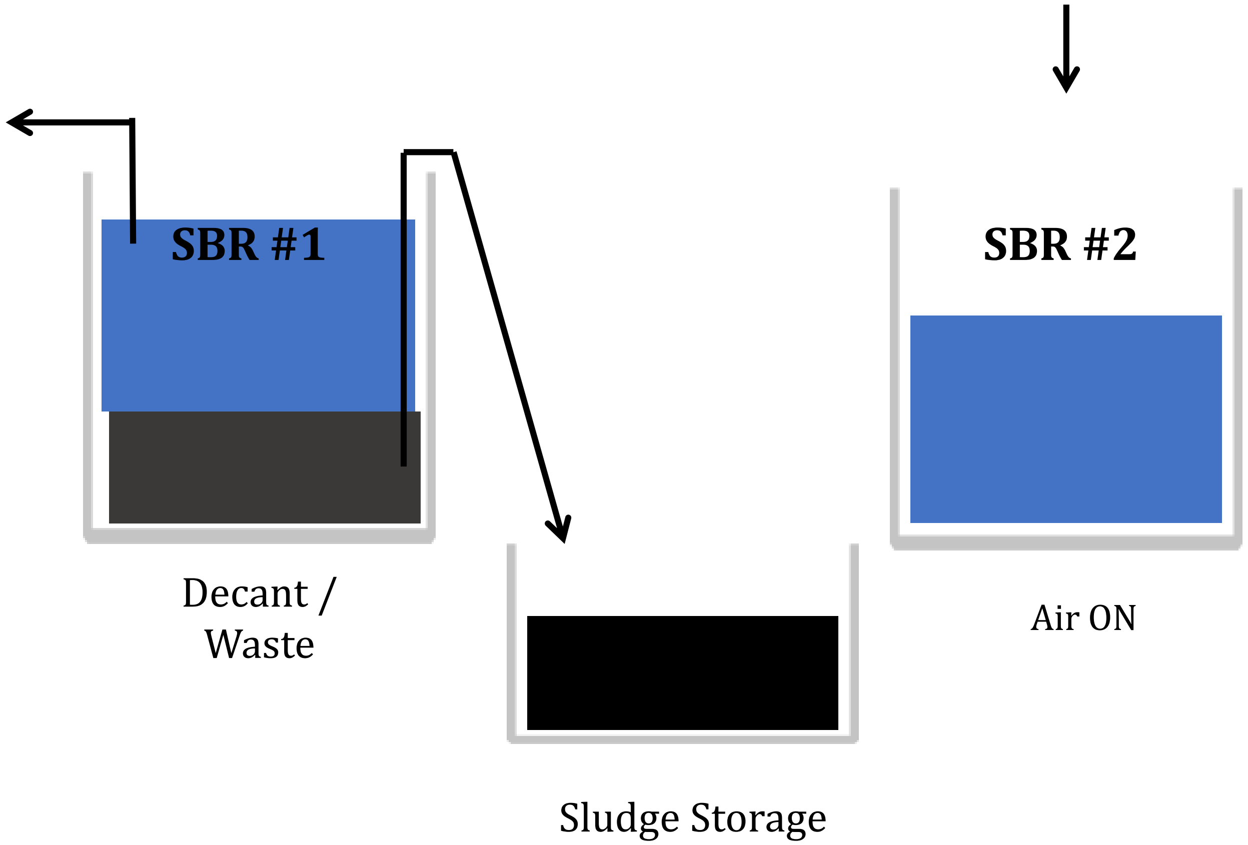
Sequencing Batch Reactor (SBR)
Nitrate (NO_3) Removal: Denitrification



Nitrate (NO_3) Removal

Target: $NO_3 < 4$ mg/L

Sequencing Batch Reactor (SBR)
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 cycle time

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.

Bonus: Changing conditions will serve as a selector.

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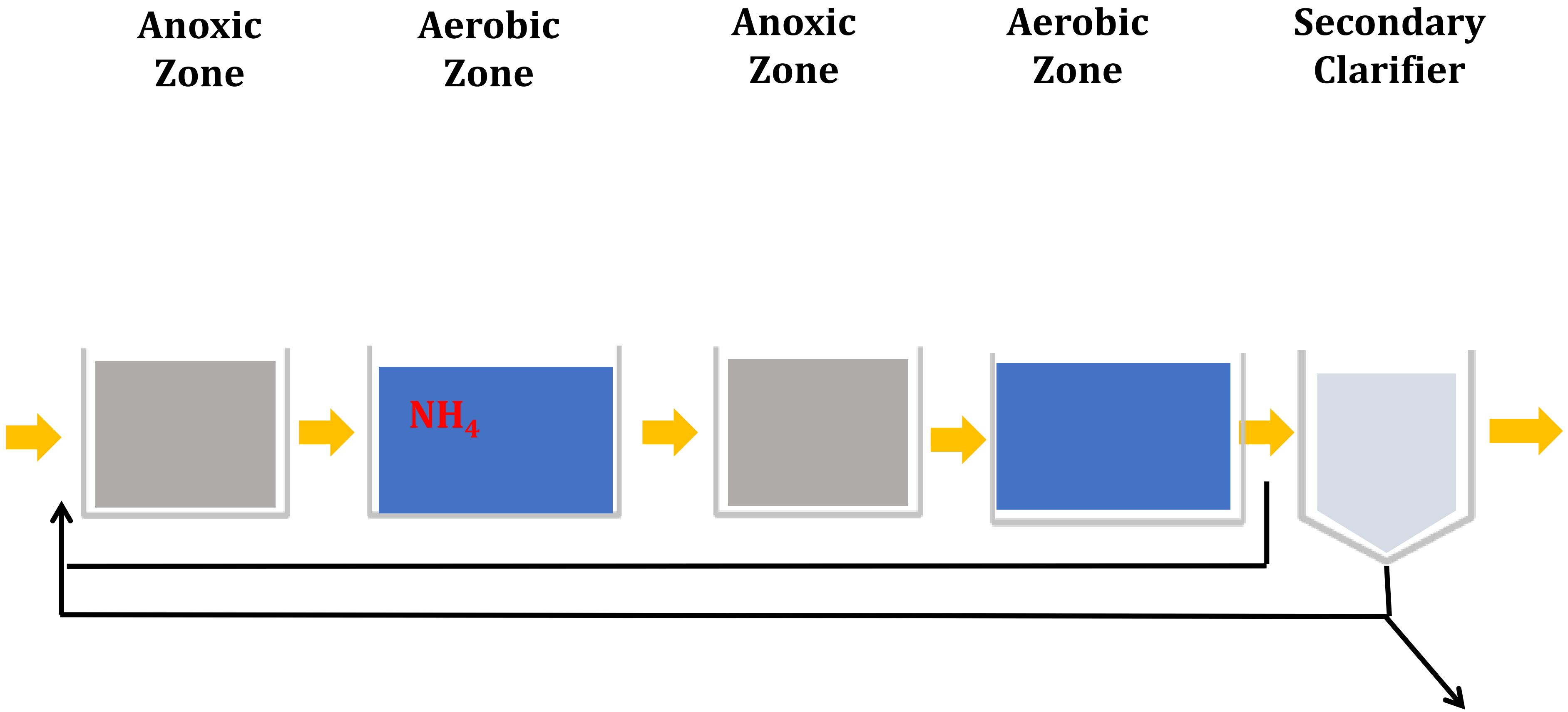
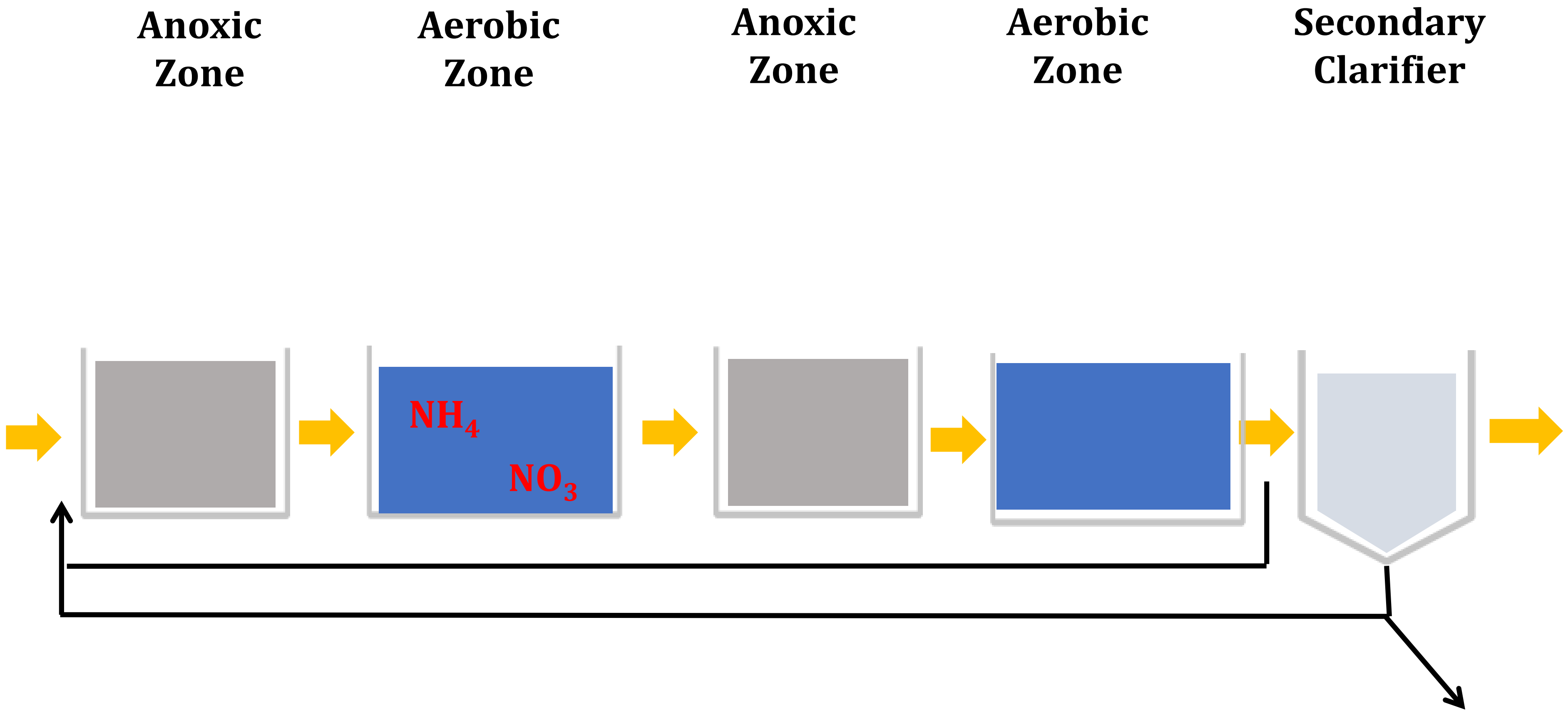
Oxidation Ditch

Oxidation Ditch



Oxidation Ditch



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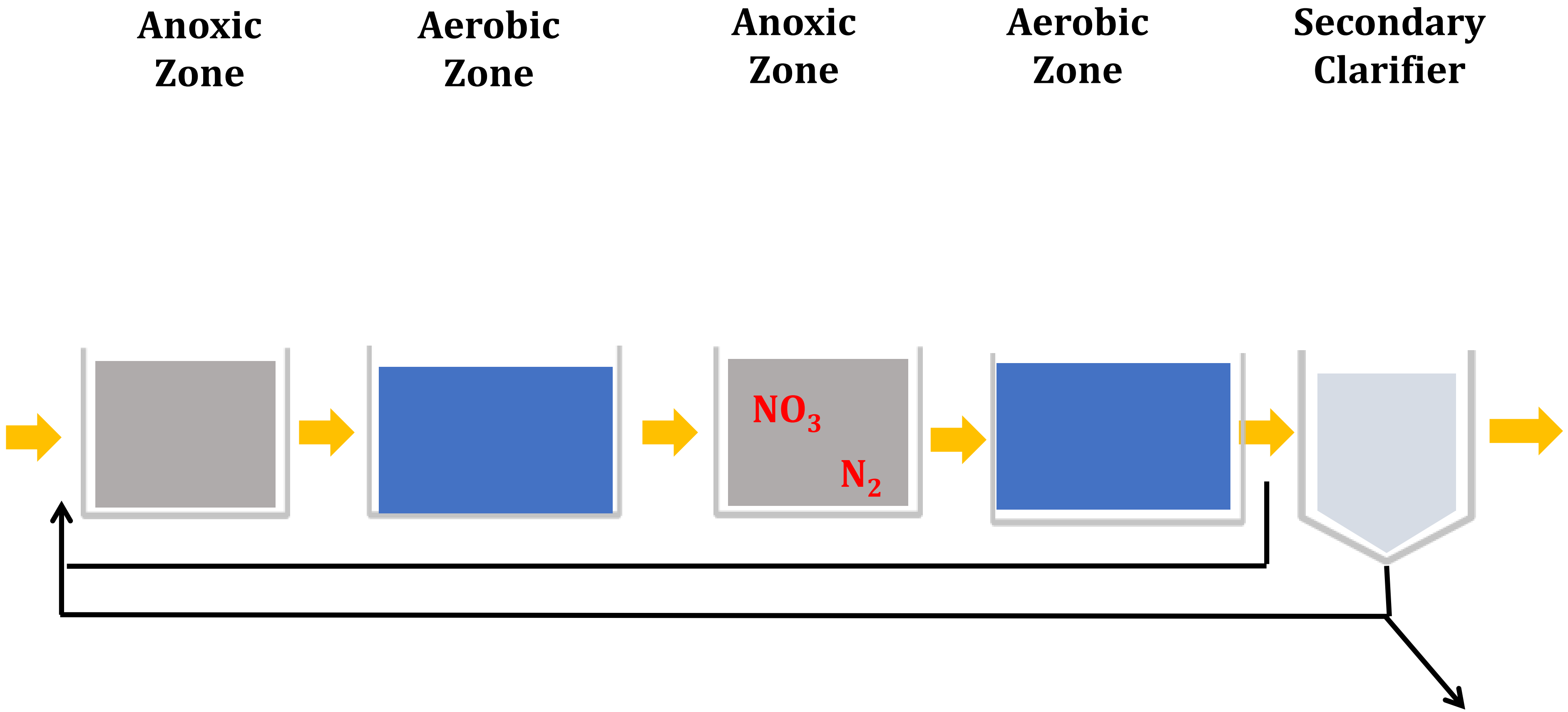
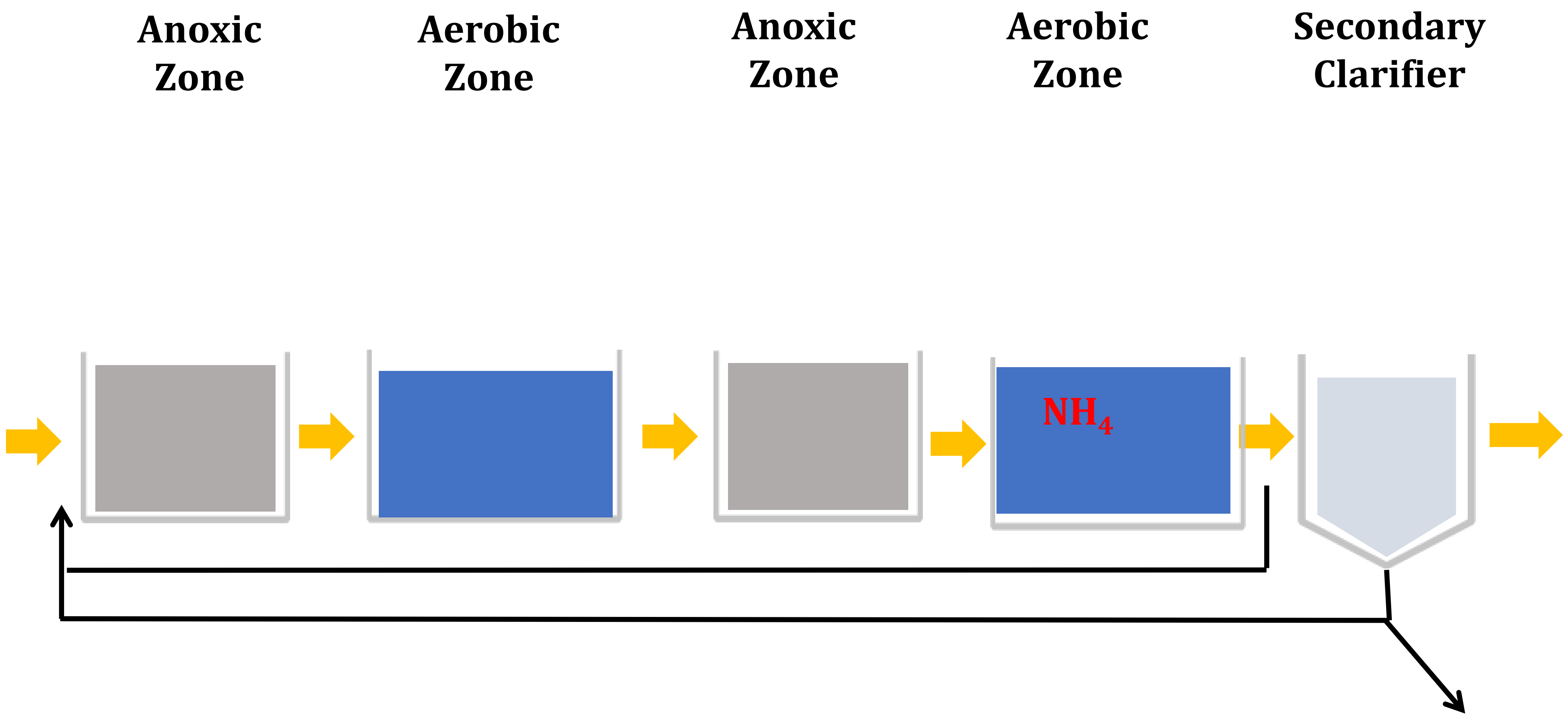


Oxidation Ditch



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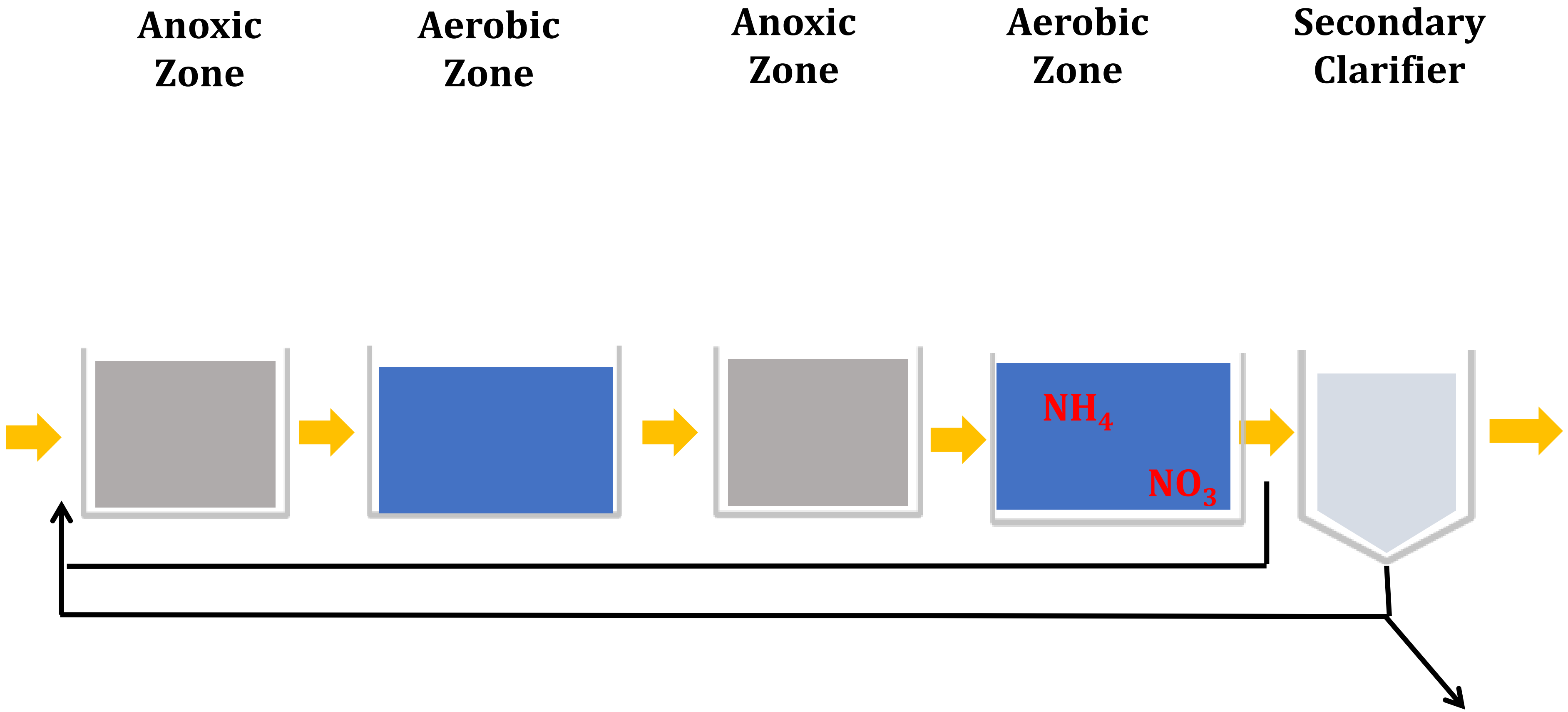
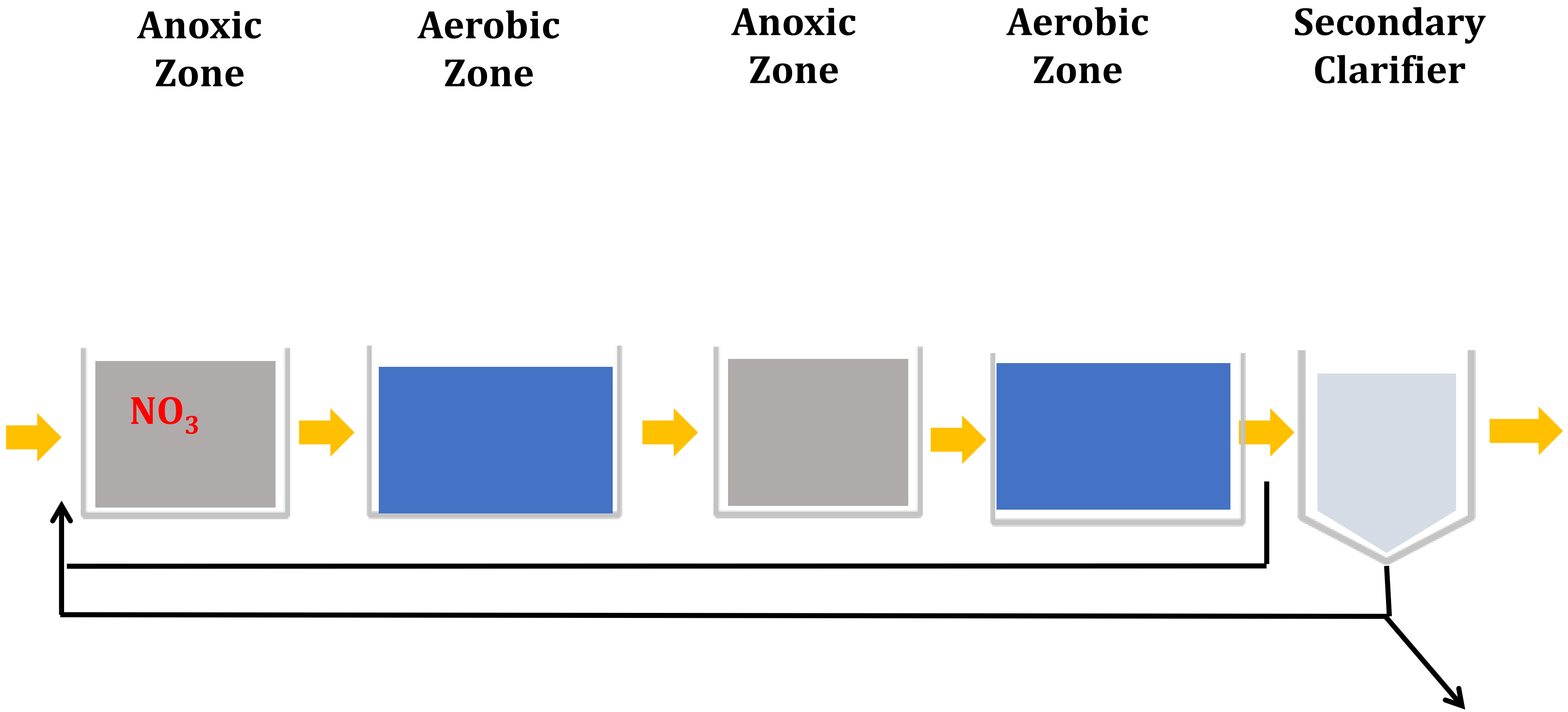
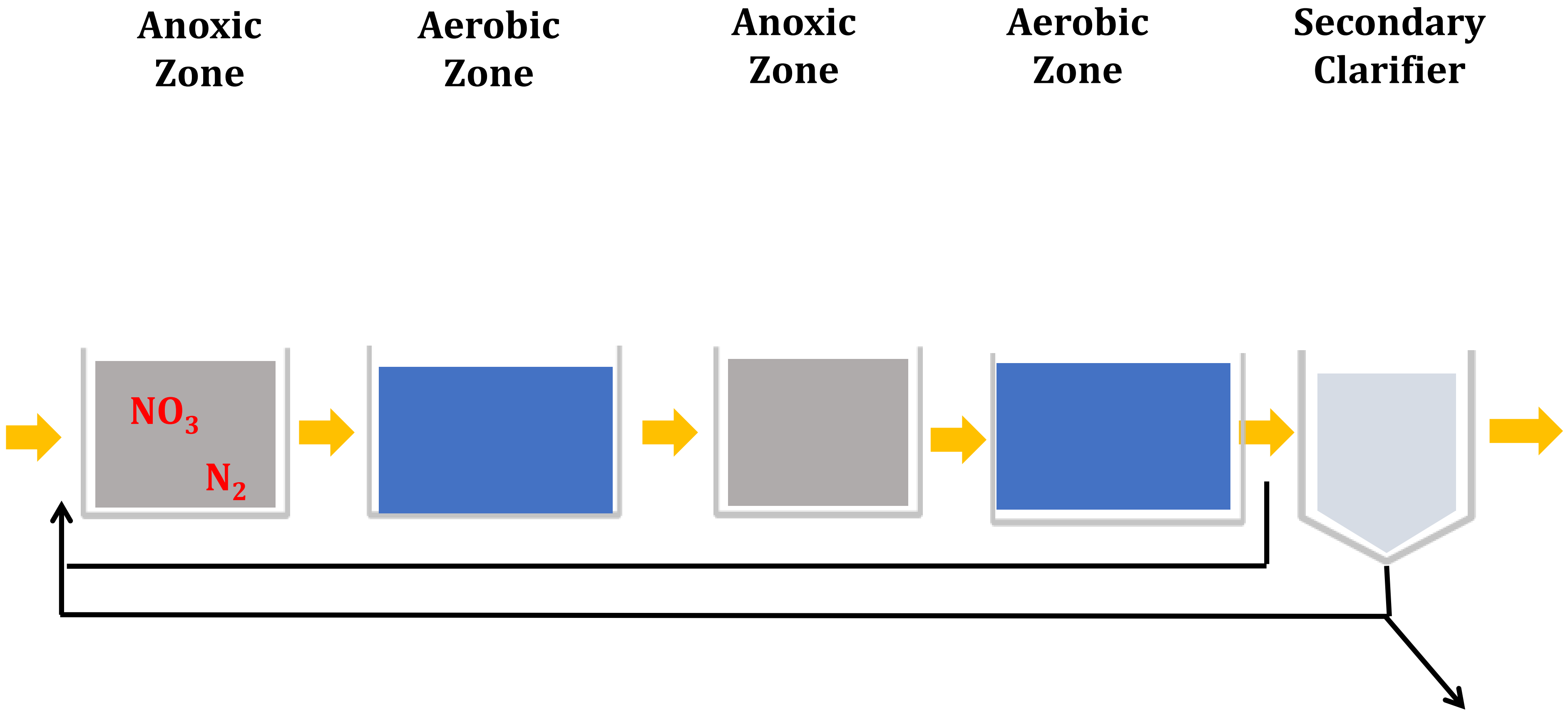


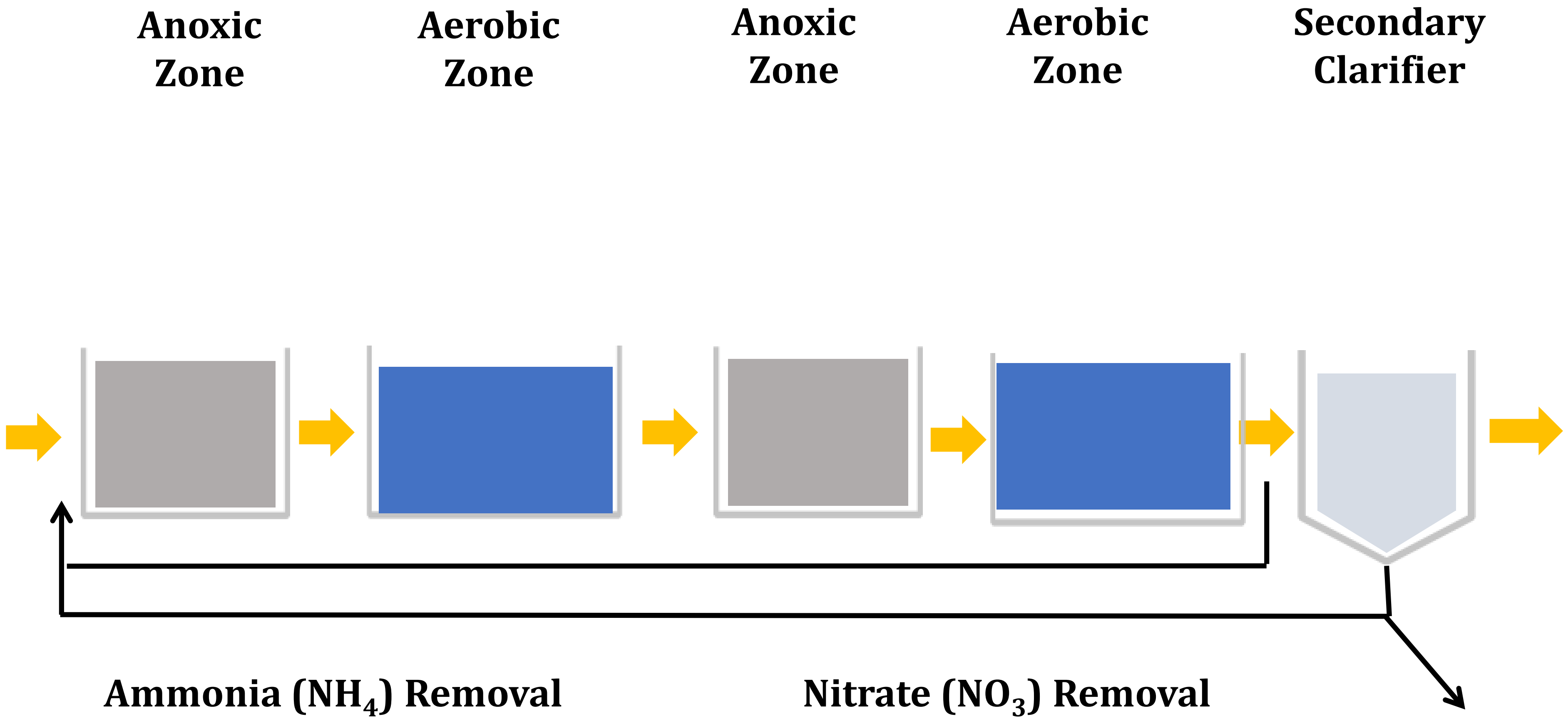
Oxidation Ditch



Oxidation Ditch



Oxidation Ditch



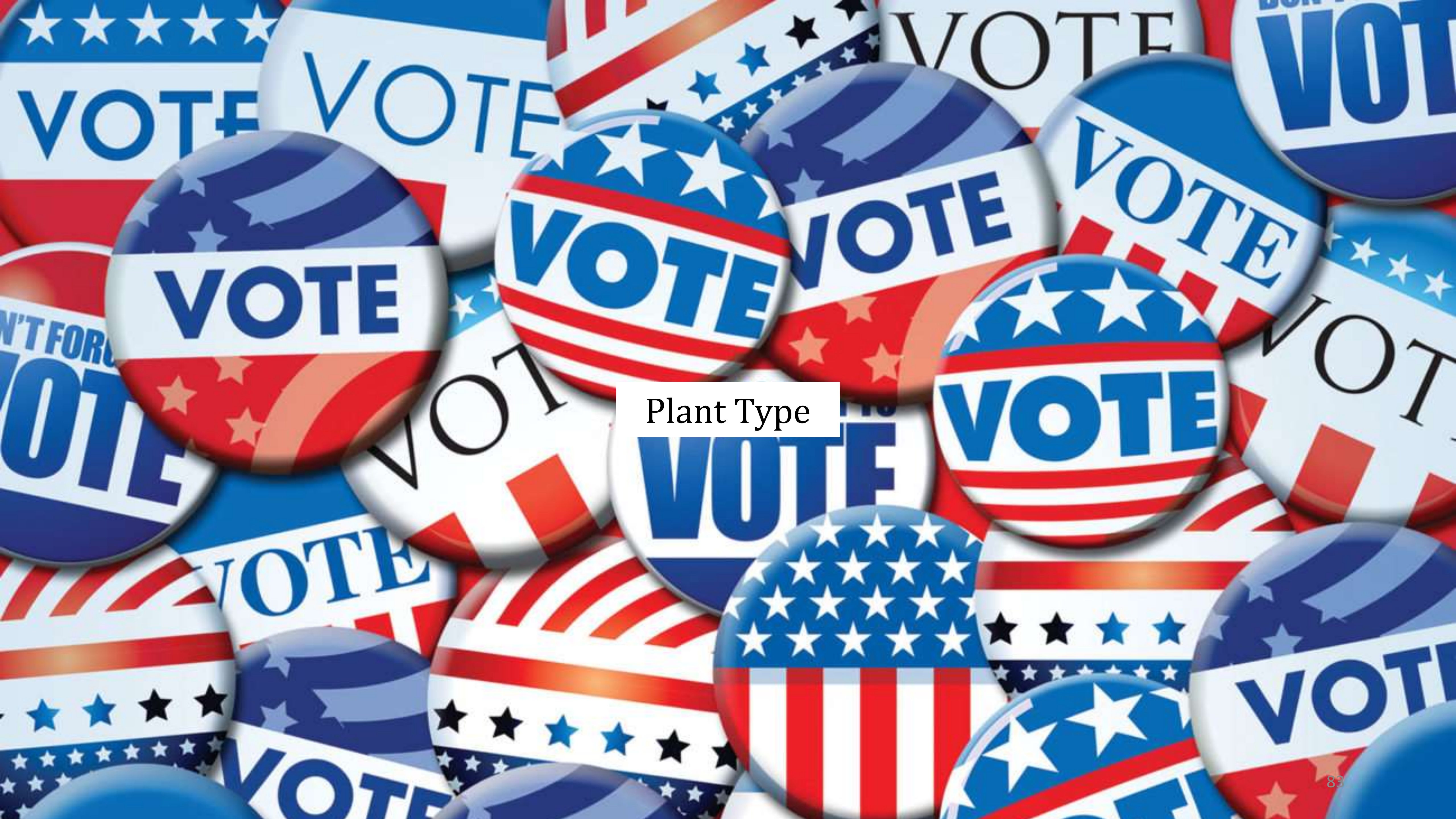
Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L

Nitrate (NO_3) Removal

Target: NO_3 of 1-4 mg/L

Plant Type



Acknowledgements

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Larry Moore, PhD
MONTANA
Paul Lavigne (MDEQ Retired), Pete Boettcher (MDEQ), Josh Vial (MDEQ), Eric Miller (Chinook), Keith Taut (Conrad) & Mark Fitzwater (Helena)
TENNESSEE
Karina Bynum (TDEC), Sherry Wang (TDEC), George Garden (TDEC), Jenny Dodd (TDEC), Brett Ward (UT-MTAS), Dewayne Culpepper (TAUD), Tony Wilkerson (Norris) & Doug Snelson (Norris), Ronnie Kelly (Cookeville), Tom Graham (Cookeville) & John Buford (Cookeville)

… and, many more!

Next Week's Webinar
Nitrogen Removal, Part 2

Thursday, February 18
10:00 - 11:45 AM

Activated Sludge *(2/25 & 3/4)*
Phosphorus Removal *(3/11 & 3/18)*
NC Case Studies *(3/25,4/8 & 4/29)*
Energy Management *(4/15 7 4/22)*

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Volunteers needed for Case Study sessions!

Grant Weaver
g.weaver@cleanwaterops.com

Questions
Comments
Discussion