Nitrogen Removal

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wastewater operator

Helena, Montana
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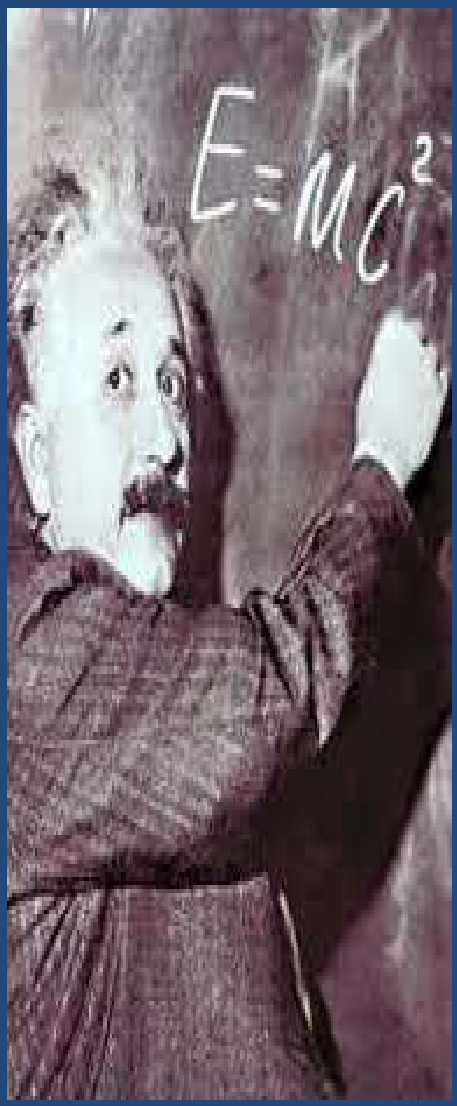
THE WATER PLANET COMPANY

www.cleanwaterops.com

Optimizing wastewater treatment for nutrient removal



<u>Today</u>

Operators Make a Difference !

Nitrogen Removal
- Wastewater
- Habitats
- Design Theory
- Process
- Control

Phosphorus Removal
- Habitats, Theory & Process Control

Why Nutrient Removal is Important to Montana

Case Studies

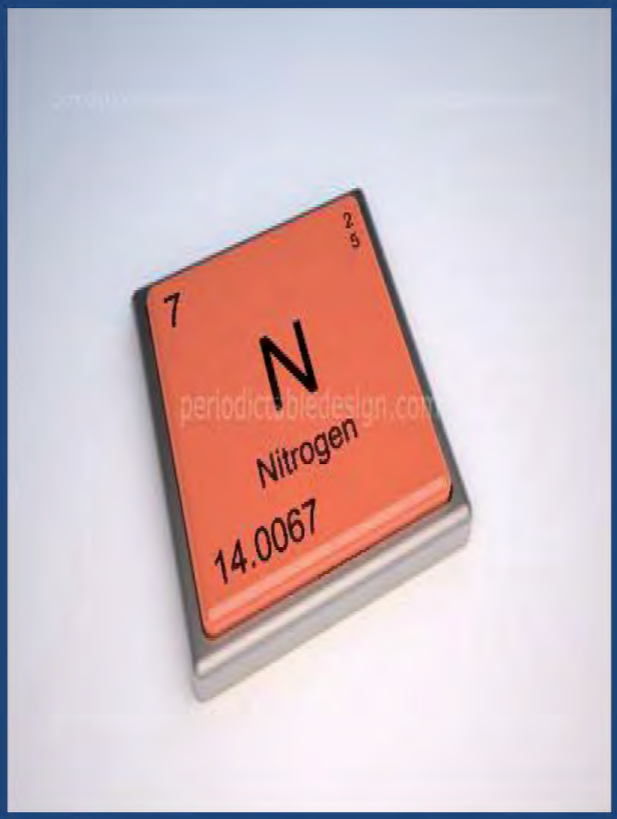
<u>Tomorrow</u>

Cost-Savings / Sludge Reduction Modifications

Review

Group Discussion & Design

Let's begin



Biological Nitrogen Removal

Organic-Nitrogen
(org-N)

Biological Nitrogen Removal

Organic-Nitrogen (org-N)

↓

Ammonia
(NH_4)

Biological Nitrogen Removal

Organic-Nitrogen (org-N)

↓

Ammonia (NH_4)

↓

Nitrate (NO_3)

Ammonia Removal - Nitrification: Bacteria Convert Ammonia to Nitrate

Biological Nitrogen Removal

Organic-Nitrogen (org-N)

↓

Ammonia (NH_4)

↓

Nitrate (NO_3)

↓

Nitrogen Gas (N_2)

Ammonia Removal - Nitrification:
Bacteria Convert Ammonia to Nitrate

Nitrate Removal - Denitrification:
Bacteria Convert Nitrate to Nitrogen Gas

Re-Engineering O&M for Nitrogen Removal

Figure out what
the bugs
need to prosper

Deliv
er

Nitrogen Removal – Step 1
Nitrification: Ammonia
(NH_4) removal

Ammonia Removal - Nitrification

Create a Habitat to motivate and support Bacteria that remove Ammonia (NH_4)

- Dissolved Oxygen (DO)
- +100 ORP
- Low BOD
- High MLSS (High MCRT / SRT; Low F:M)
- Alkalinity to keep pH from dropping
- Time (HRT)

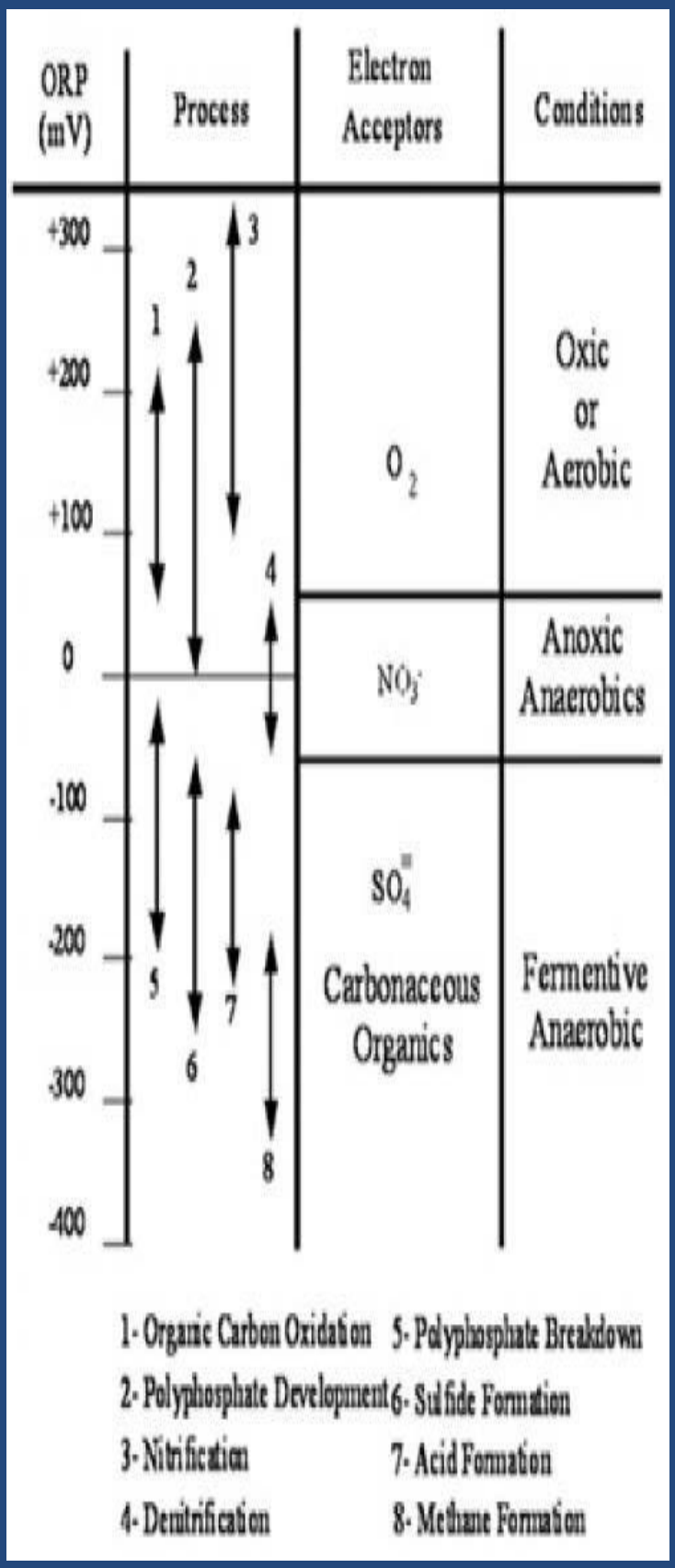
pH & Alkalinity

DO & ORP (oxygen reduction potential)

Low DO
uptake rate

High DO
uptake rate

ORP (Oxygen Reduction Potential)



ORP – "rules of thumb"

3. Ammonia (NH_4) Removal

Nitrification

+100 to +300 mV

4. Nitrate (NO_3) Removal

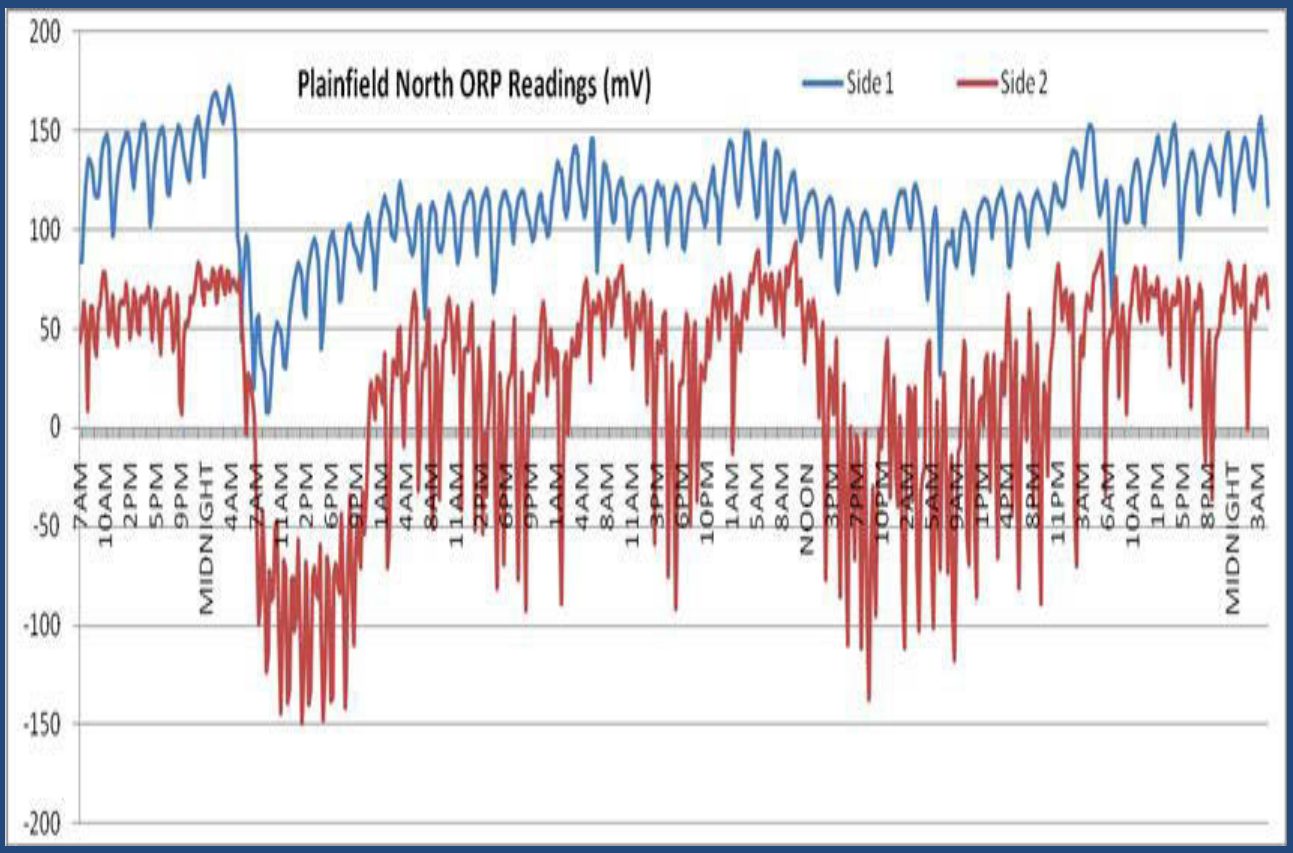
Denitrification

-50 to +50 mV

Grant likes -100 or lower

ORP Readings

Cycling Aeration to create ideal habitats for Ammonia and Nitrate removal



Ammonia (NH_4) Removal

Ammo
nia
(NH_4)

Ammonia (NH_4) Removal

Oxygen

Ammonia
(NH_4)

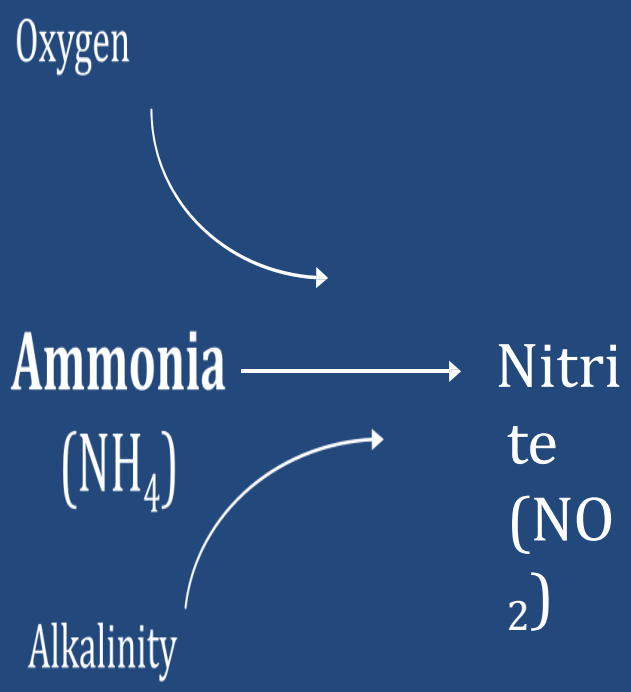
Ammonia (NH_4) Removal

Oxygen

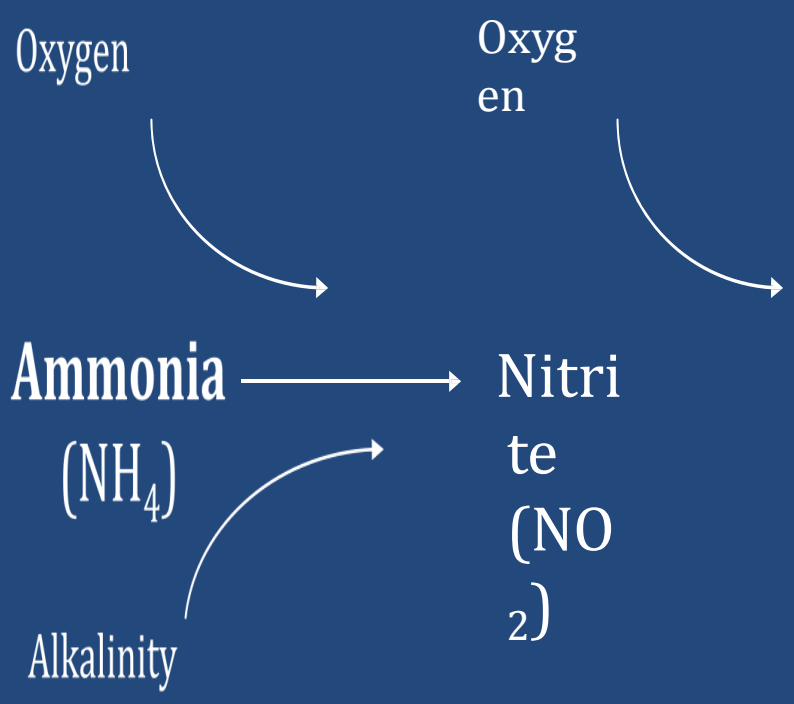
Ammonia
(NH_4)

Alkalinity

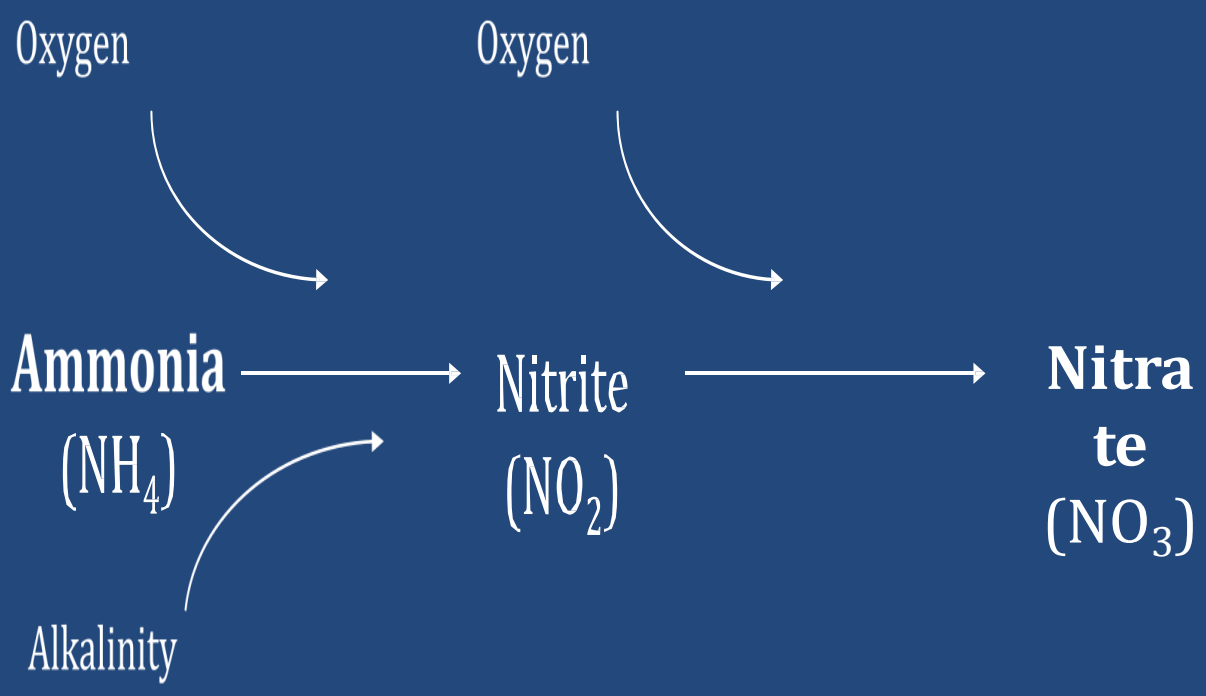
Ammonia (NH_4) Removal



Ammonia (NH_4) Removal



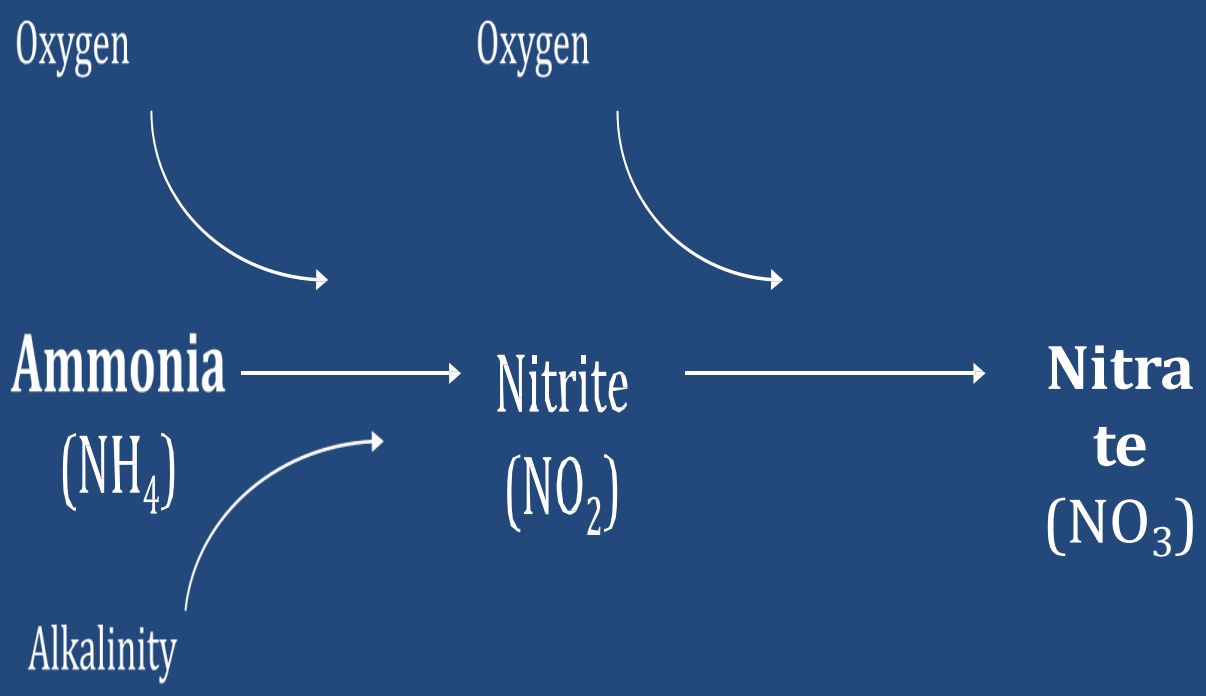
Ammonia (NH_4) Removal



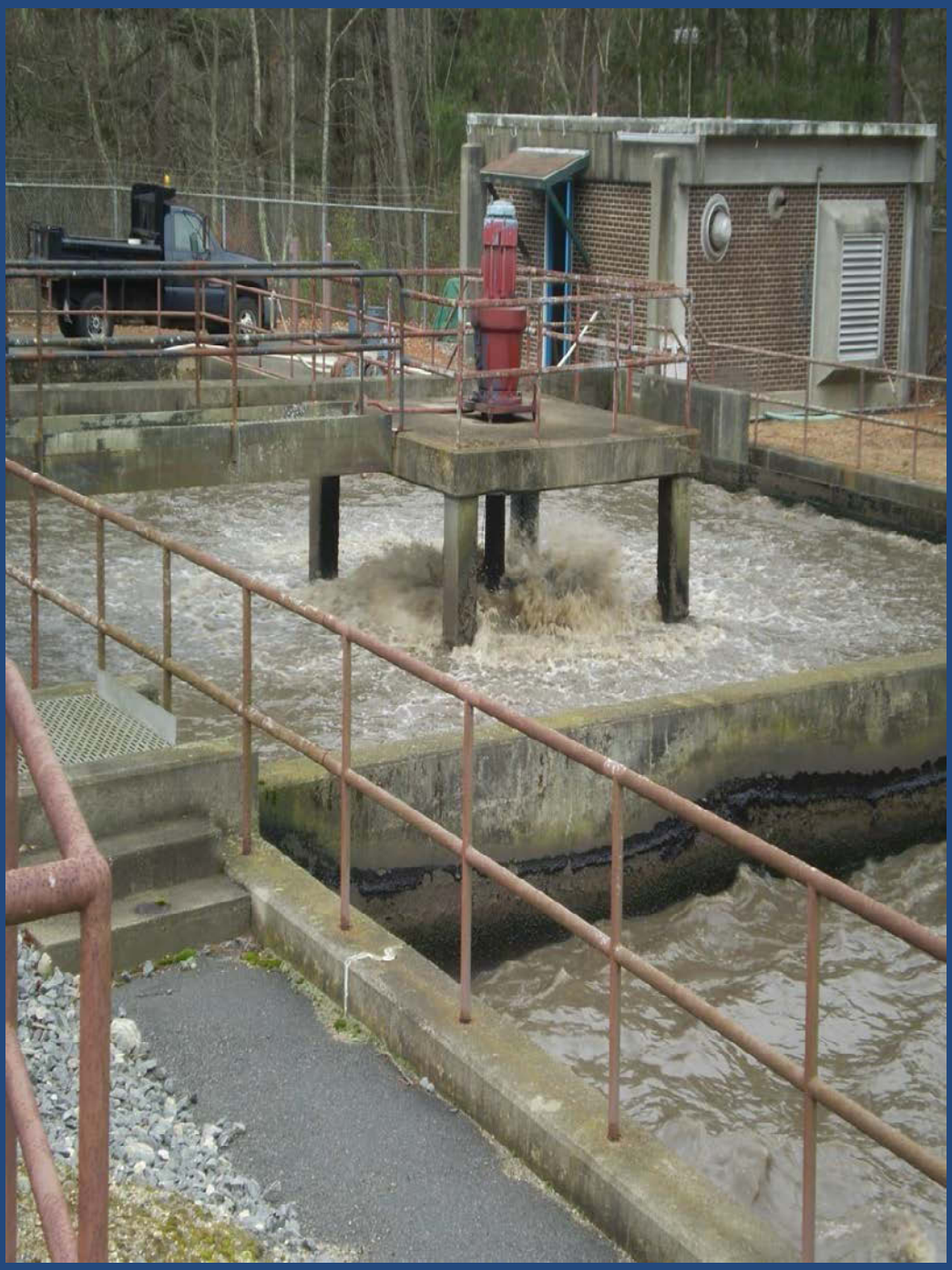
Ammonia (NH_4) Removal

Nitrification Habitat

- High DO / ORP
- Low BOD
- Plenty of Alkalinity High Sludge Age
- Long Retention time



Ammonia Removal – What bacteria want

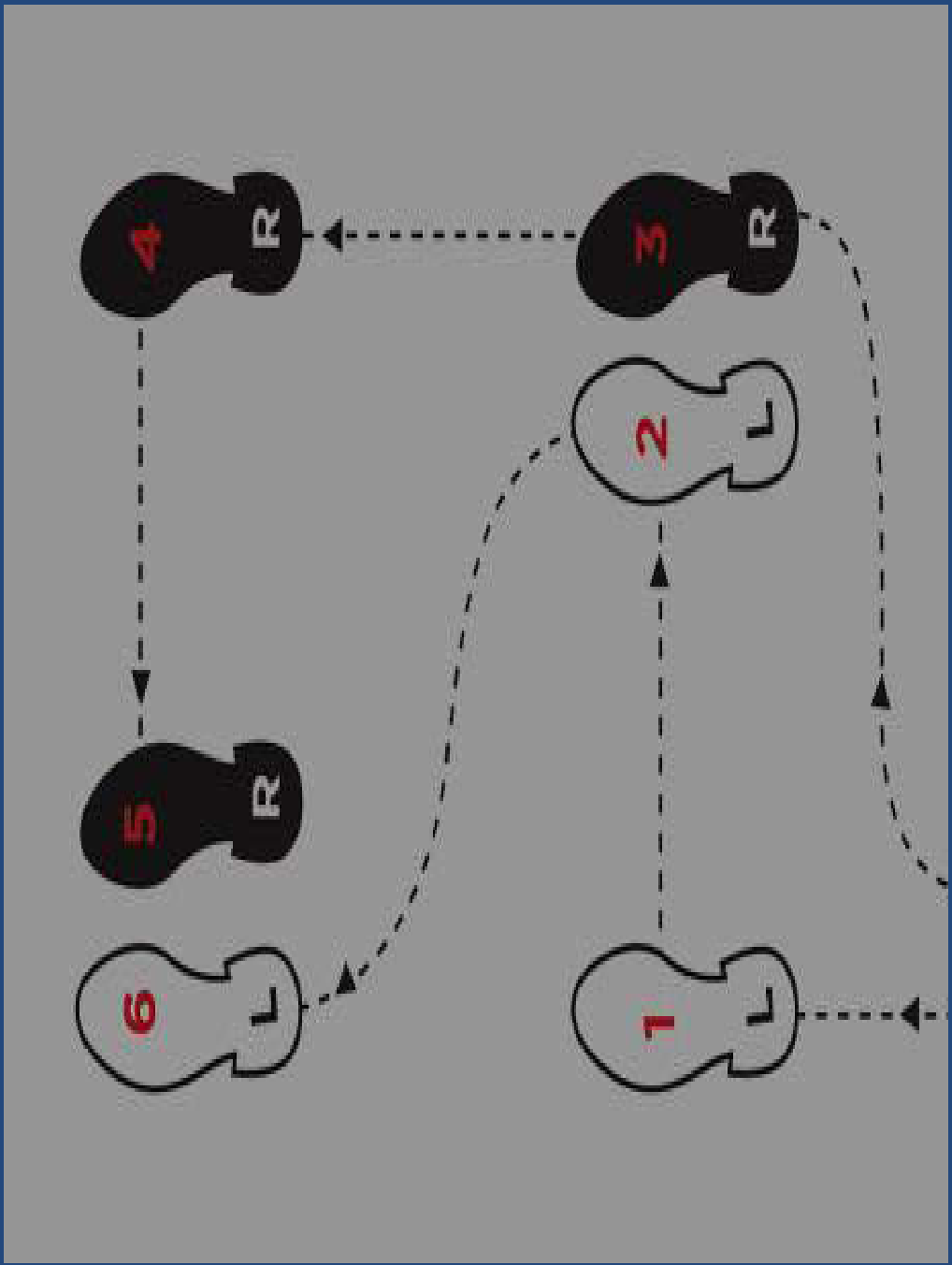


Given the right habitat in which to prosper …

Nitrifying bacteria will lower Ammonia (NH_4) to 0.5 mg/L or Less

And, add Nitrate (NO_3) into the waste stream

Nitrogen Removal – Step 2
Denitrification: Nitrate
(NO_3) removal



Nitrate (NO_3) Removal - Denitrification

Create a Habitat so the Bacteria that Remove Nitrate (NO_3) will be motivated to do it…

- Little to Zero DO
- -100 ORP
- Surplus BOD (High F:M)
- Time (HRT)

They give back one-half of the Alkalinity that the Nitrifiers removed

Nitrate (NO_3) Removal

Nitrate
(NO_3)

Nitrate (NO_3) Removal

BOD

Nitrate
(NO_3)

Nitrate (NO_3) Removal

BOD

Oxygen

Nitrate

(NO_3)

Nitrate (NO_3) Removal

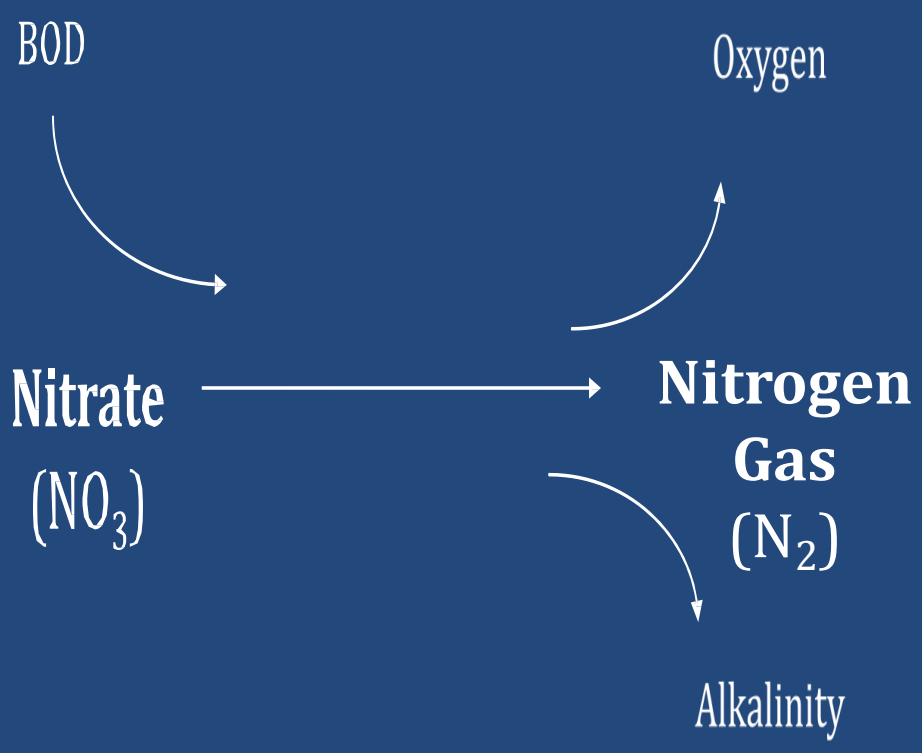
BOD

Nitrate (NO_3)

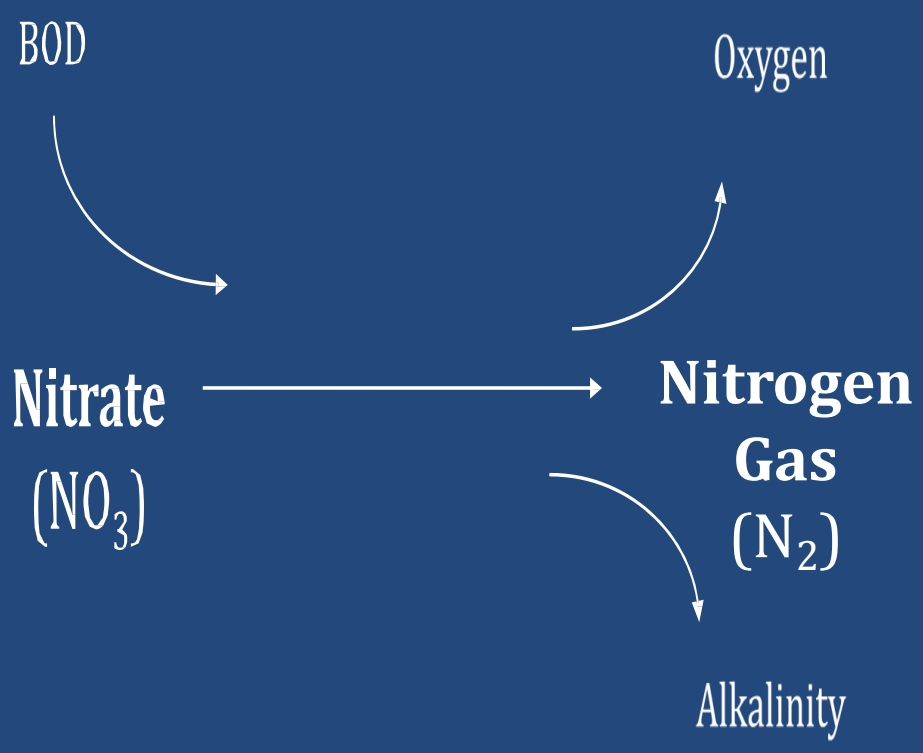
Oxygen

Alkalinity

Nitrate (NO_3) Removal



Nitrate (NO_3) Removal



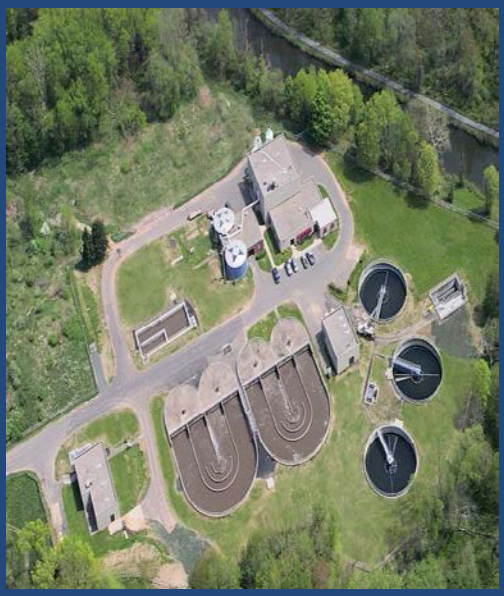
Denitrification

- Habitat
- Low DO / ORP High
- BOD
- Adequate Retention time
- Gives back alkalinity

Nitrate Removal

H

abitats



Nitrate Removal Habitat

When given the right environmental conditions …

Denitrifying bacteria will reduce Nitrate (NO_3) to 2.0 mg/L, maybe less

Nitrogen Gas will escape into the atmosphere

Effluent total-N will be very low

Recapping what we've discussed

Ammonia (NH_4) Removal - Nitrification

High DO & ORP

Nitrate (NO_3) Removal - Denitrification Low DO & ORP

High BOD

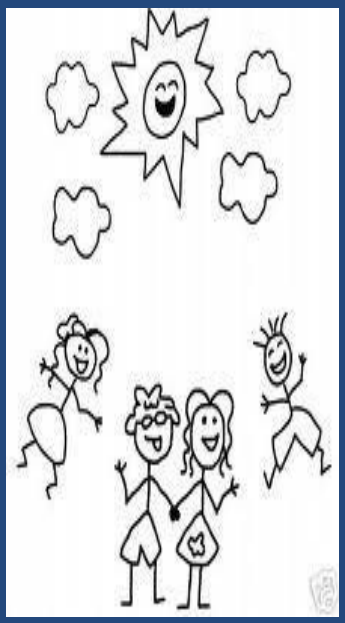
Long Retention time Gives back alkalinity

Plenty of Alkalinity

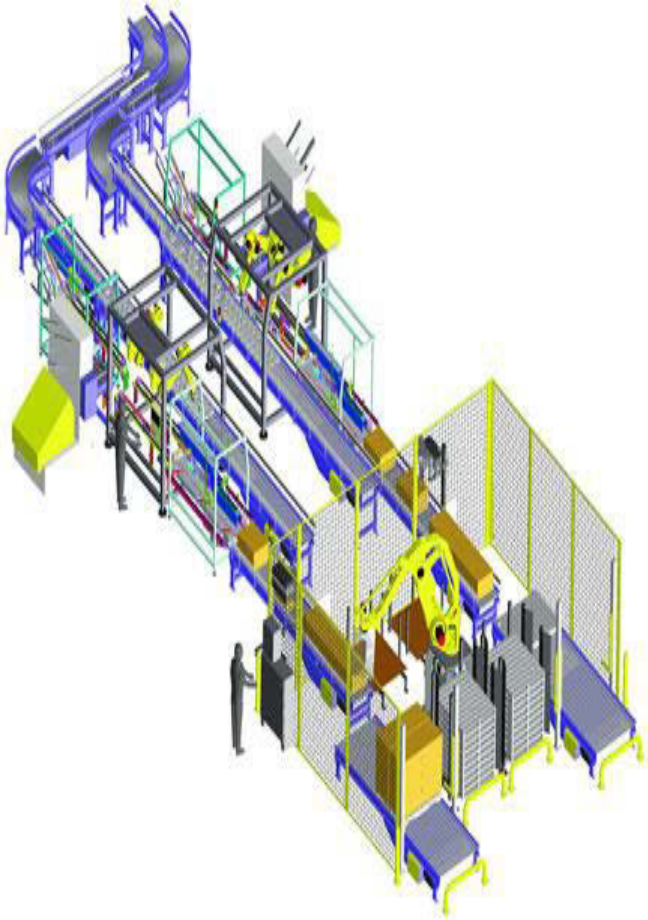
High MCRT, High

Discussion

To get the most out of your treatment plant, make it a great place for bacteria to live…

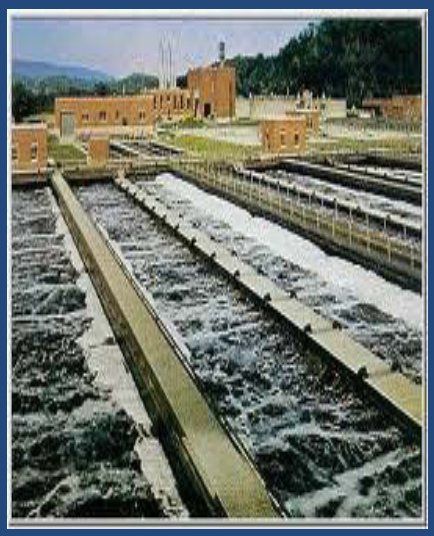


Making Nitrogen Removal Happen with Technology!

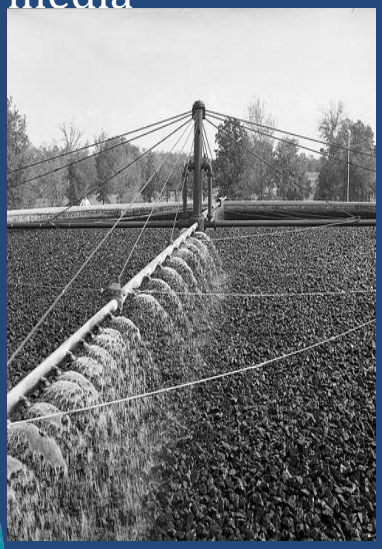


Ammonia (NH_4) Removing Technologies

Extended aeration



Two-stage fixed media



HABITAT

Dissolved Oxygen (DO) & ORP High MLSS (MCRT / SRT; Low F:M)

Low BOD Time (HRT)

Alkalinity to keep pH from

Nitrate (NO_3) Removing Technologies

Post-Anoxic Denitrification

Pre-Anoxic Denitrification (MLE: Modified Ludzack-Ettinger)

SBR, or Cycling between Nitrification and Denitrification

Oxidation Ditch (Bardenpho)

HABITAT

Little to Zero DO

-100 or lower

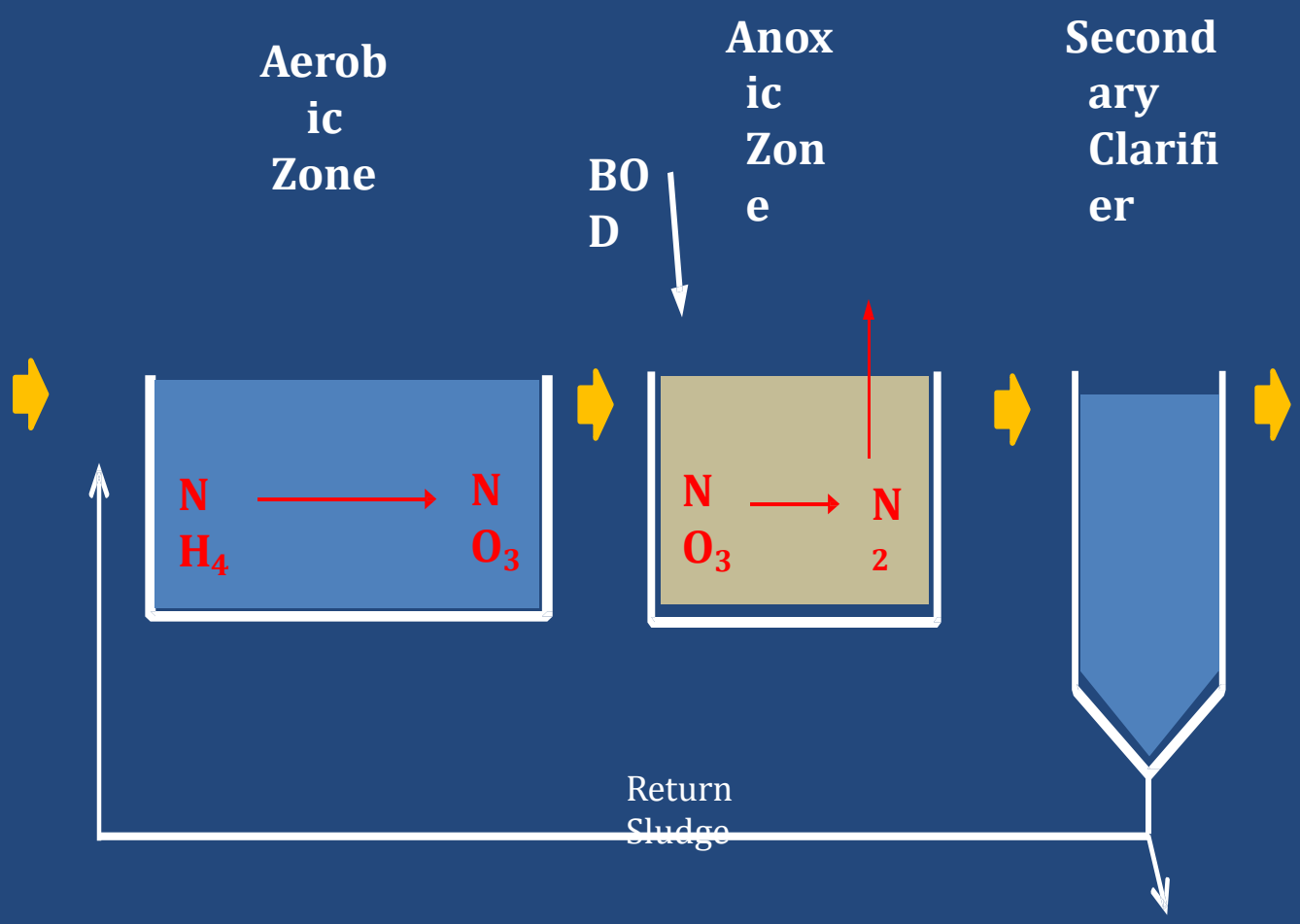
ORP Surplus BOD

(High F:M) Time

(HRT)

Post Denitrification Process

Post Anoxic



Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L

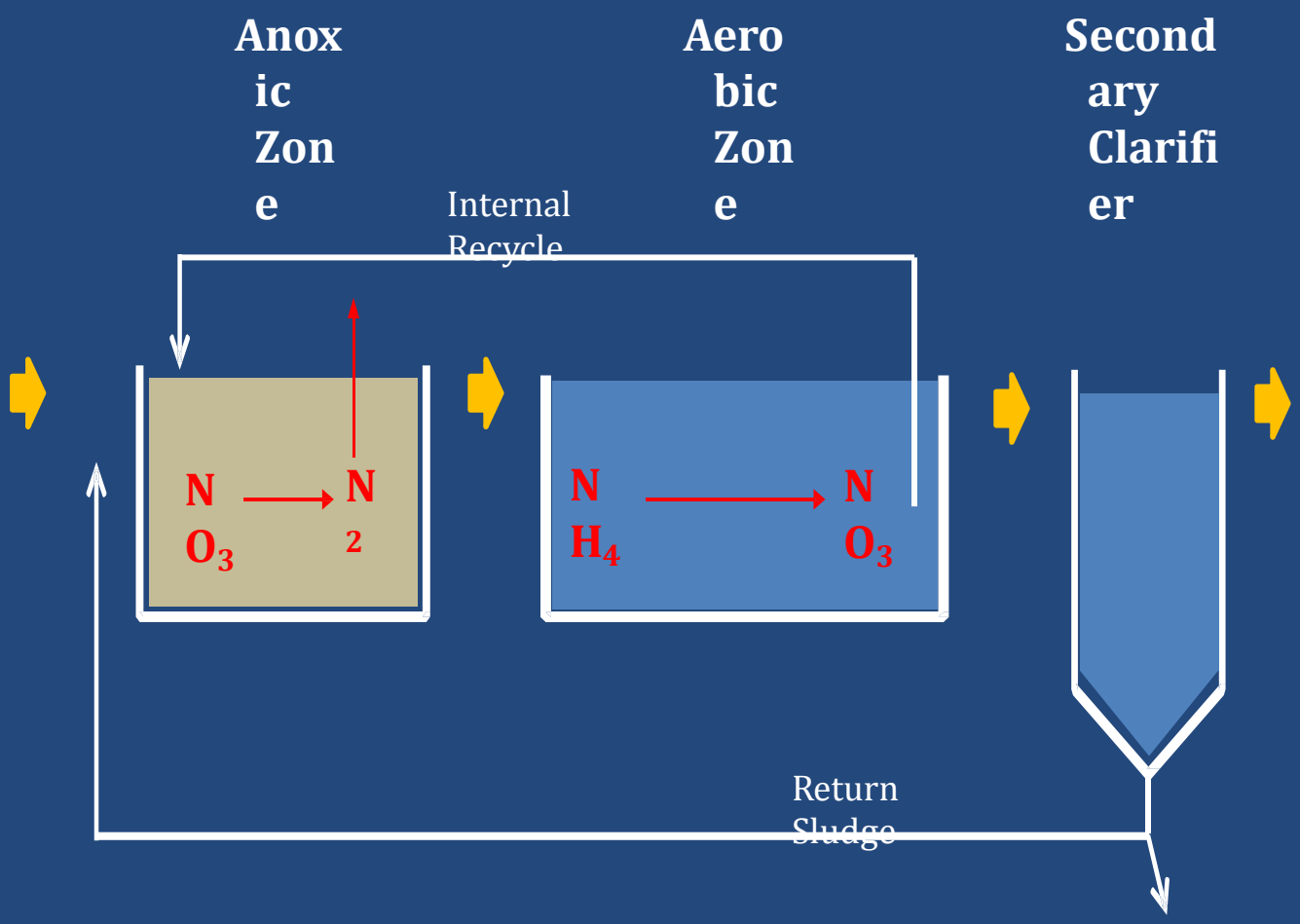
Nitrate (NO_3) Removal

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

MLE Process

(Modified Ludzack-Ettinger)

MLE (Modified Ludzack-Ettinger) Process



Ammonia (NH_4) Removal

Target: NH_4 < 0.5 mg/L

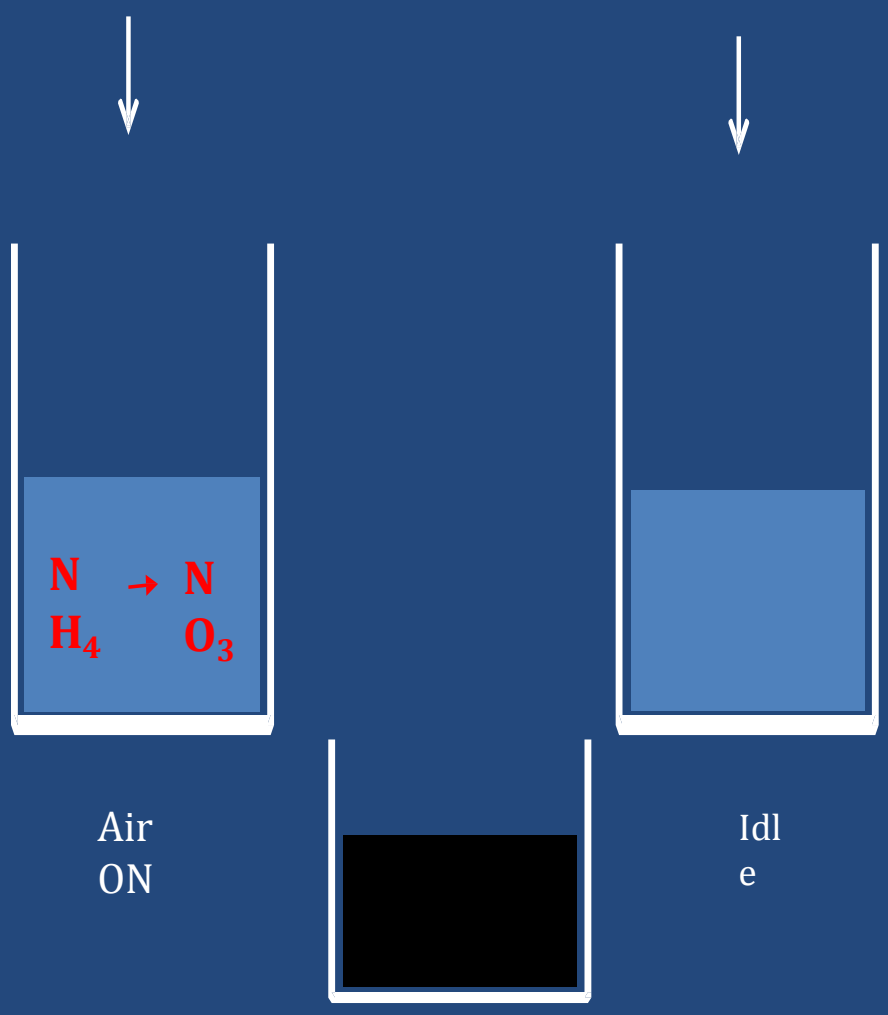
Nitrate (NO_3) Removal

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

SBR Process

(Sequencing Batch Reactor)

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

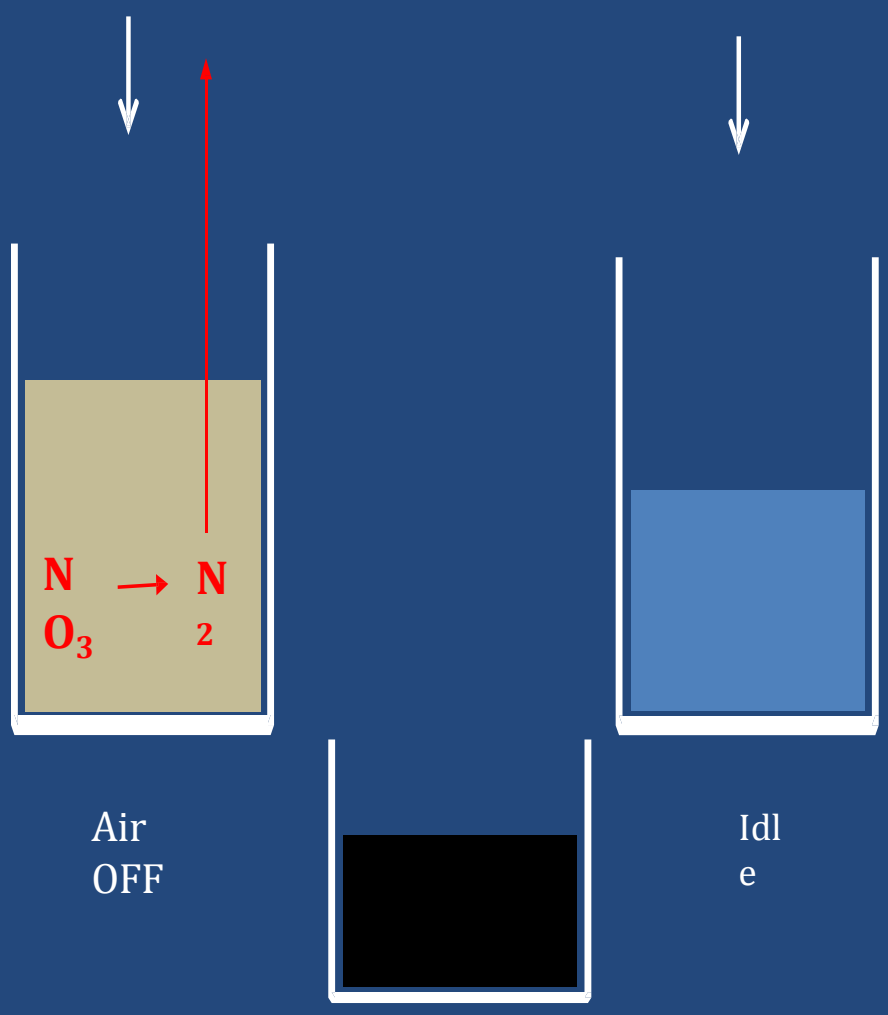


Sludge Storage

Ammonia (NH_4) Removal

Target: NH_4 < 0.5 mg/L

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

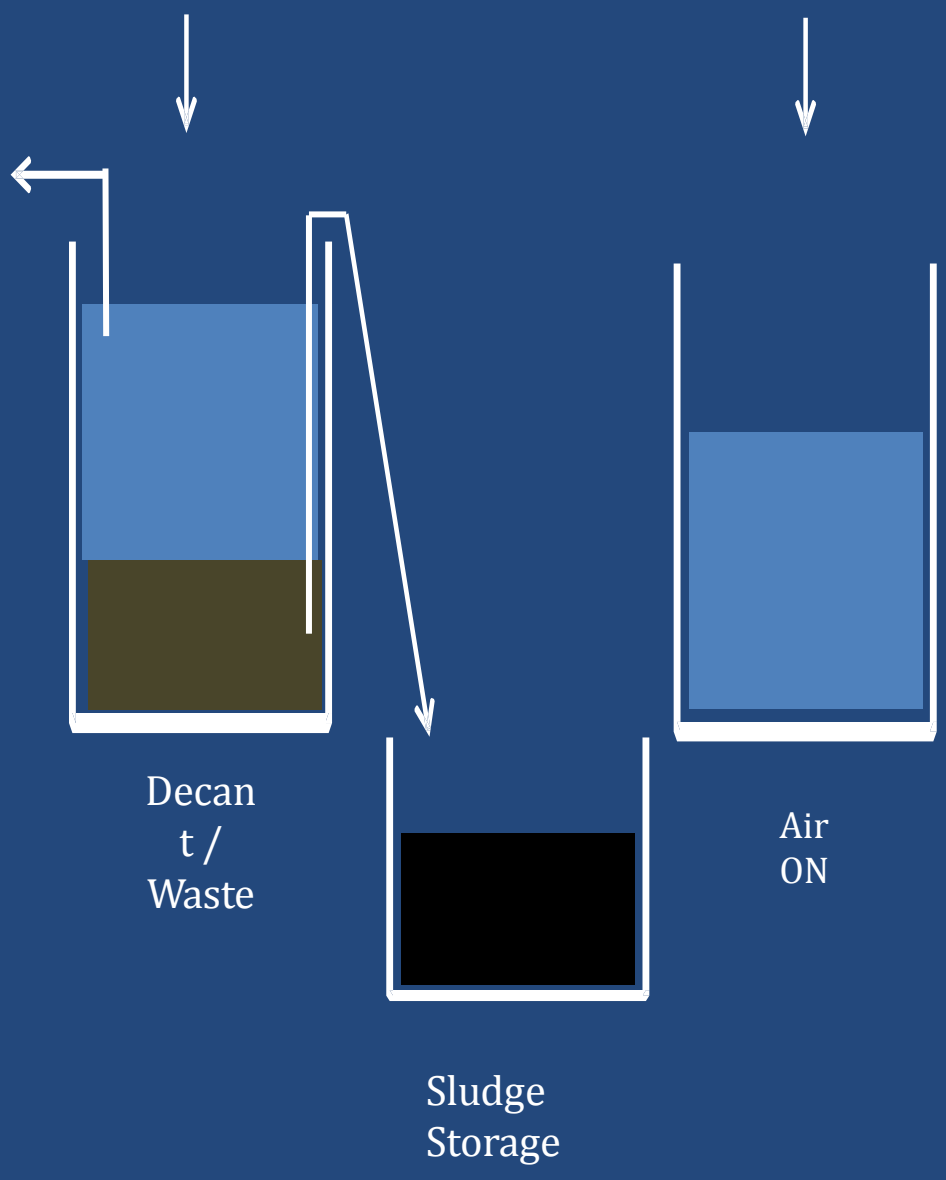


Sludge Storage

Nitrate (NO_3) Removal

Target: $NO_3 < 4$ mg/L

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



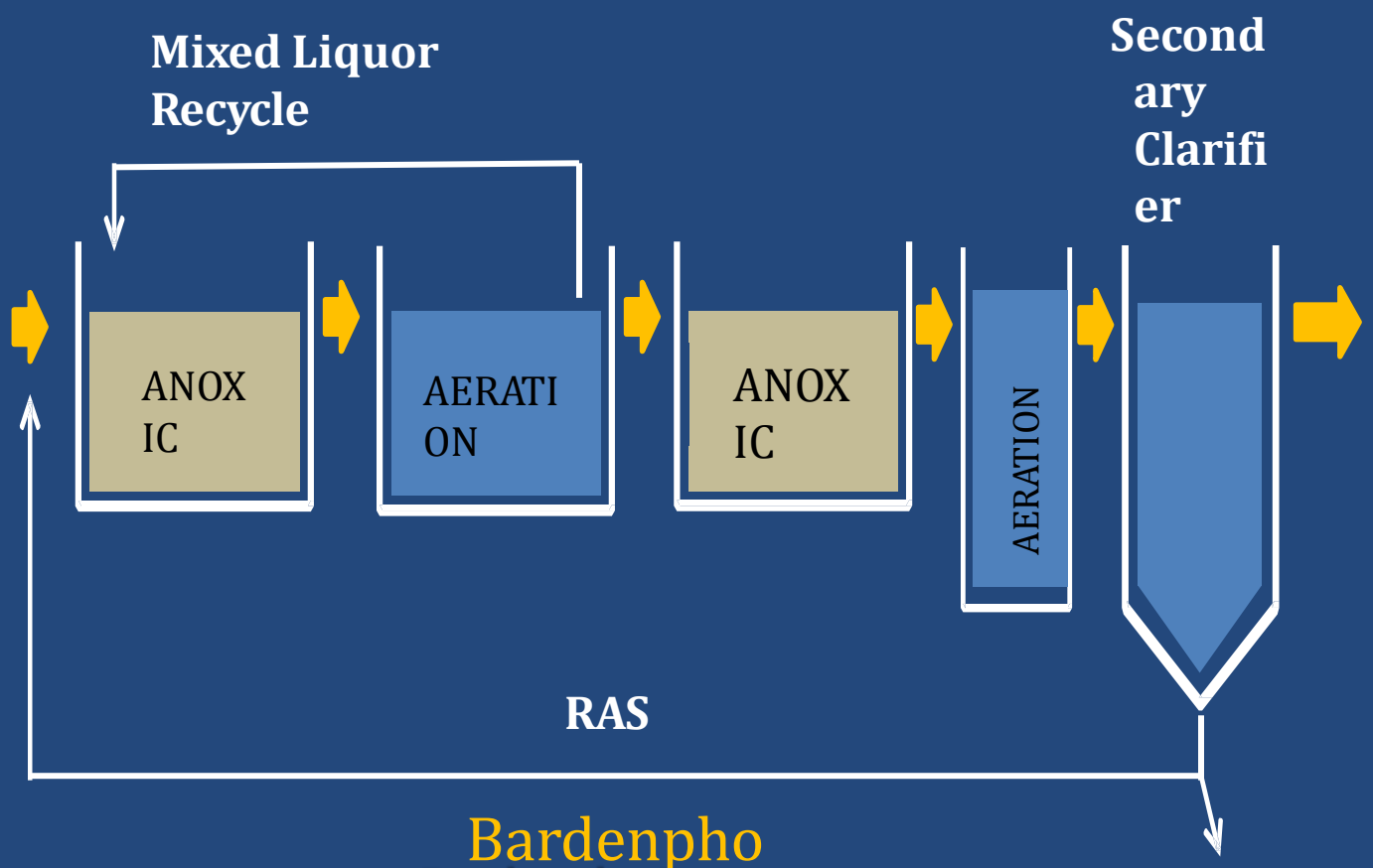
SBR Process Control:

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.

Oxidation Ditch / Bardenpho Process

Oxidation Ditch Bardenpho Process



Bardenpho Process

Bardenpho Process

Technology Discussion

Machinery provides the bacterial habitats that …

Makes Ammonia (NH_4) into Nitrate (NO_3):

Nitrification Makes Nitrate (NO_3):into

Nitrogen Gas (N_2): Denitrification

Process Control

Habitat quality - Happy bugs?
Stressed bugs?

Ongoing Field Testing

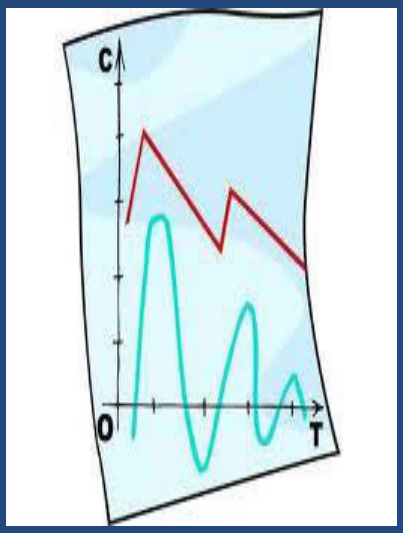
The importance of Daily Field Testing Can NOT be Overstated

You absolutely need to know what is happening in your plant TODAY

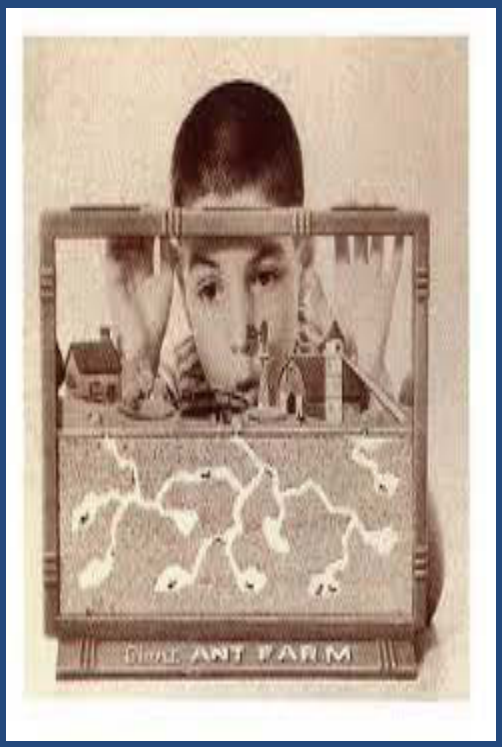
Process Control

Daily testing is necessary to monitor and control …

- Habitat quality (How happy are the bugs?) Ammonia removal
  - Nitrate removal
- Effluent quality (Am I meeting permit?)
  - Ammonia concentration
  - Nitrate concentration
- Process control changes - DAILY



Monitoring ***HABITAT CONDITIONS***



Daily testing of …

- Process control
  - parameters
  - SVI
  - M
  - L
  - S
  - S
  - D
  - O
- ORP
- Alkalinity

Monitor Habitats: DO and ORP

Probes

pH and Alkalinity

Treatment Performance –
EFFLUENT QUALITY

Monitoring Nitrogen

Daily testing

of …

Ammon

ia

Nitrate

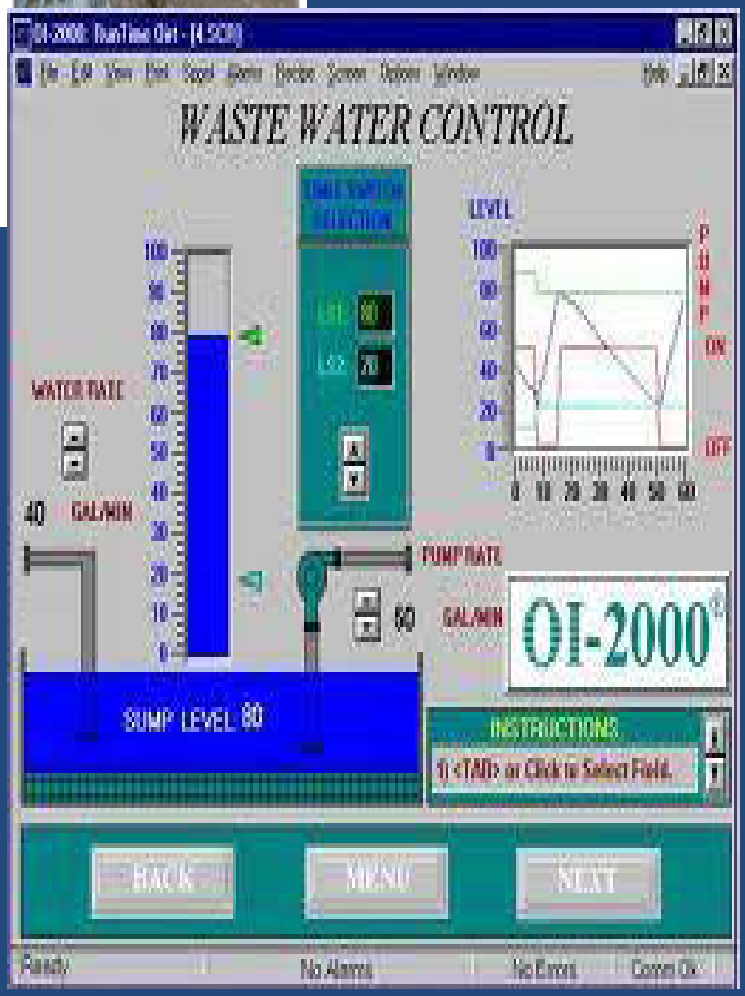
Nitrite

Lab Spectrophotometer

Daily testing of …

- Ammonia
- Nitrate
- Nitrite

In-Line Nitrogen Probes



Ammo
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Nitrate

Process Control

If Ammonia (NH_4) increases,

control … DO

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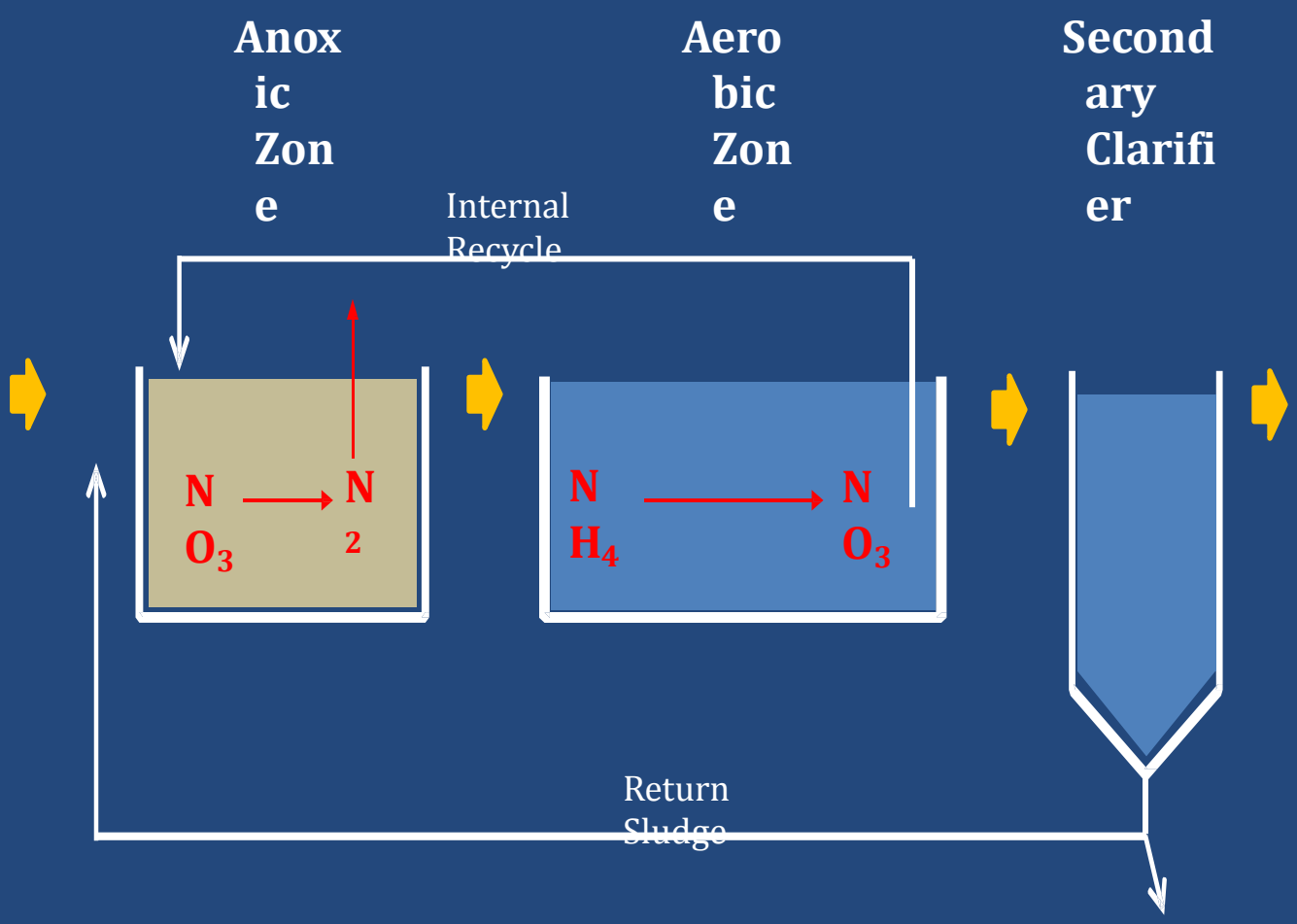
MLE (Modified Ludzack-Ettinger) Process



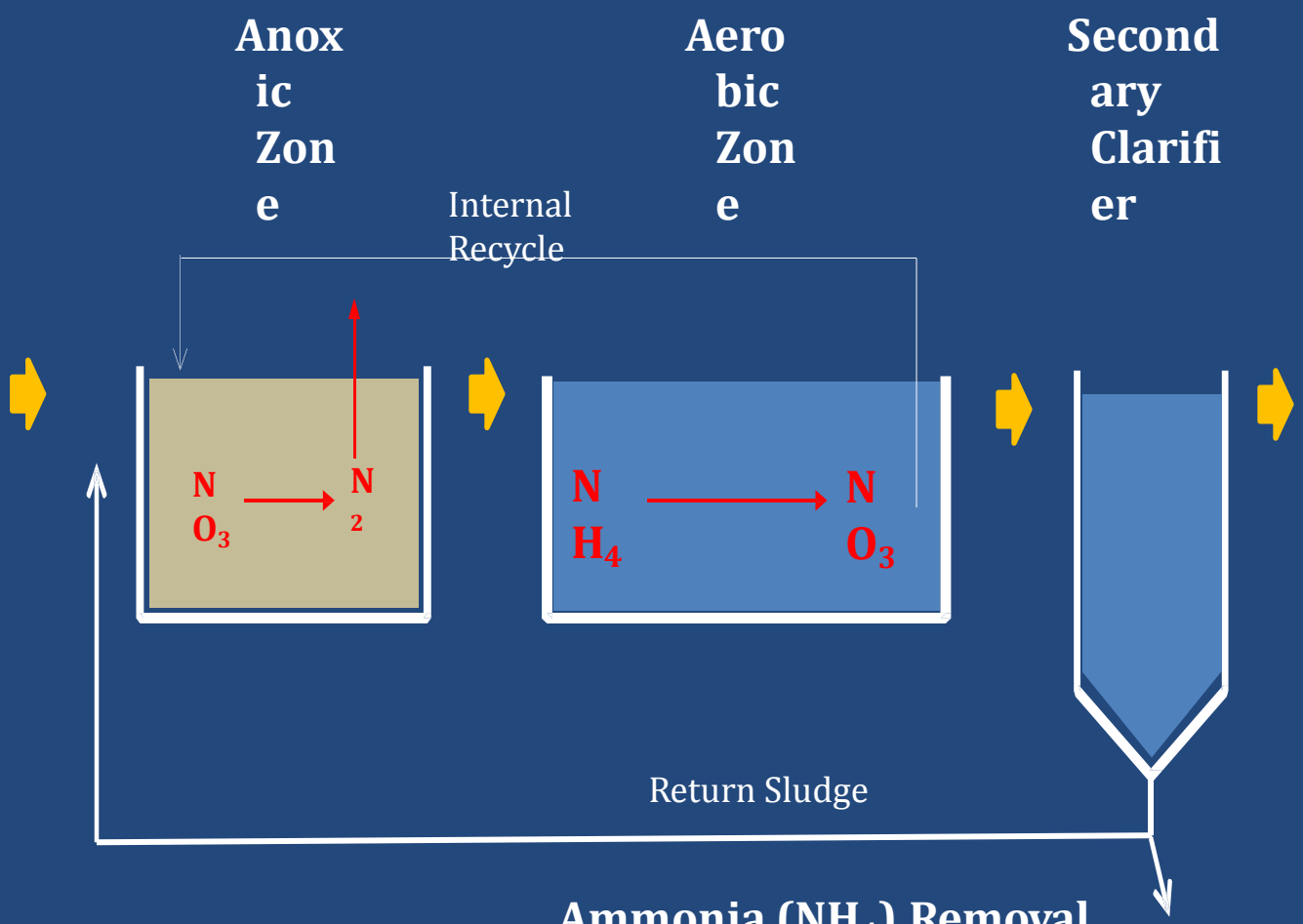
MLE Process Control:

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

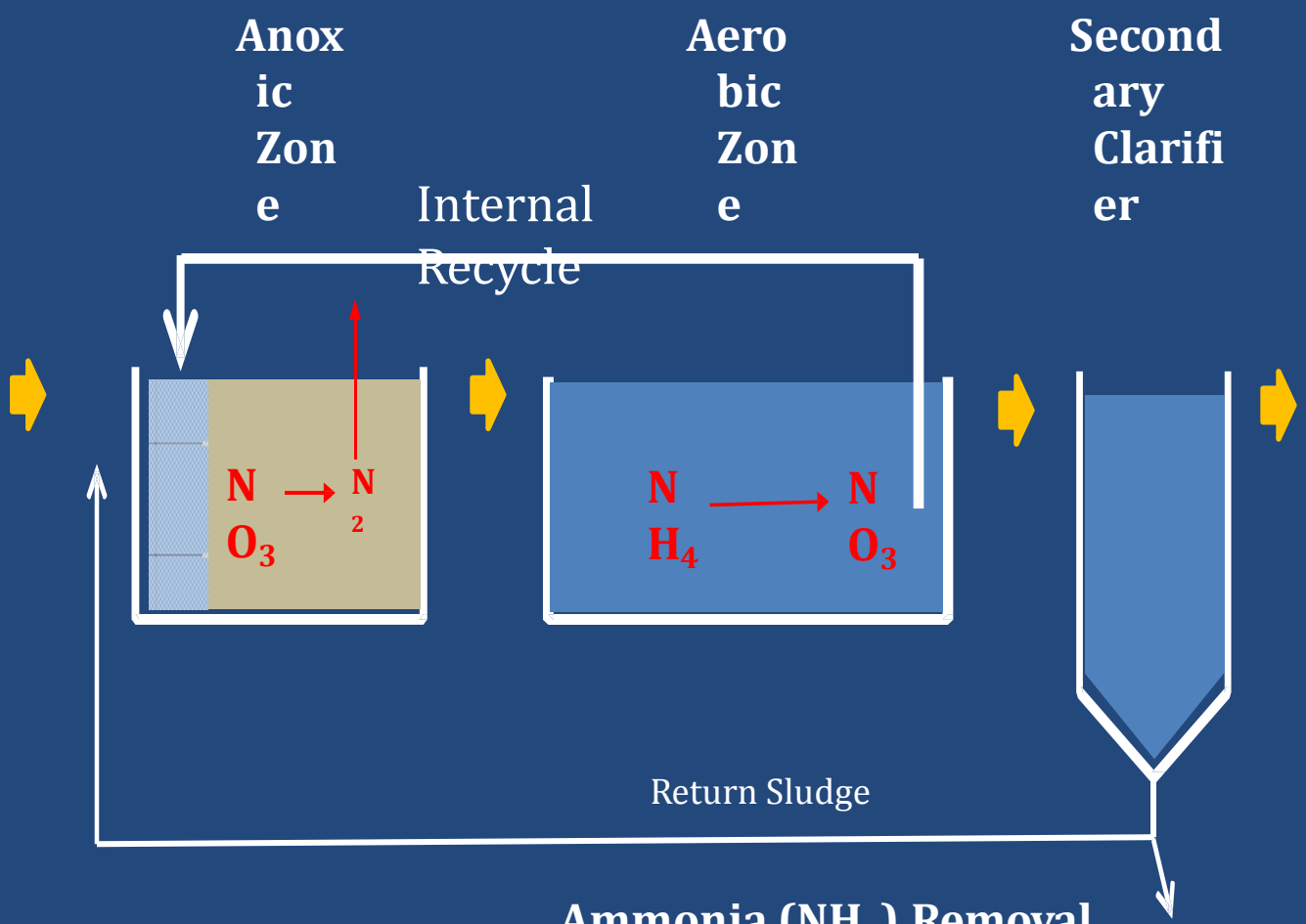
$NH_4 < 0.5$ mg/L

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

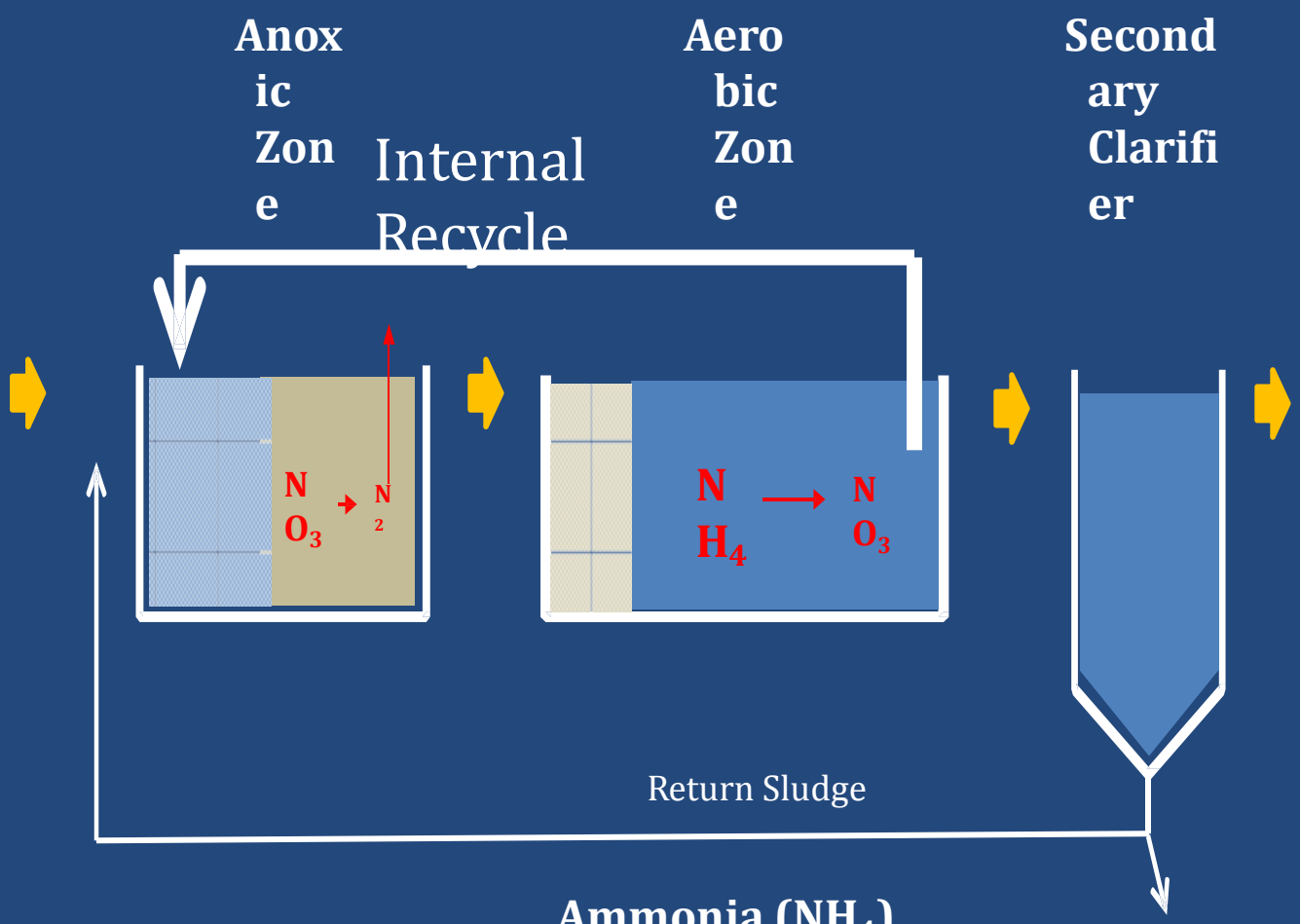
$NH_4 < 0.5$ mg/L

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

Optimizing Existing Equipment

Ongoing

- Monito
- ring of
- …
- Ammo
- nia
- Nitrite + Nitrate
- Alkalinity
- ORP

Using …

- In-line instrumentation
- connected to SCADA
- Hand-held equipment
- Field Test Kits such as Test Strips

And …

- Ongoing Process Changes to
- Optimize Habitats

Nitrogen Removal : Summary

Summary

Ammonia (NH_4)

Removal Habitat

High DO, +100

or greater ORP

High MLSS (High MCRT / Sludge

Age; Low F:M) Long Retention

Time (High HRT)

Plenty of Alkalinity

Nitrate (NO_3)

Removal

Habitat Low

DO, -100 or

lower ORP

Plenty of BOD (4+ times as much as Nitrogen)

Sufficient

Retention

Time "Gives

Back"

Alkalinity

Ammonia (NH_4) Removal Nitrification

Change Process to Make Better Habitat….

Increase DO by Bringing Less Low DO

into Aerobic Zone Reduce Internal

Recycle &/or RAS so Less Low DO

Raise MLSS and hold MLSS constant

Establish WAS rates and better

control wasting More Time in

Aerobic Zone

Reduce Internal Recycle &/or RAS so Less Flow (GPM)

Increase Alkalinity

Optimize pre-anoxic nitrate removal

Nitrate (NO_3) Removal Denitrification

Change Process to Make Better Habitat….

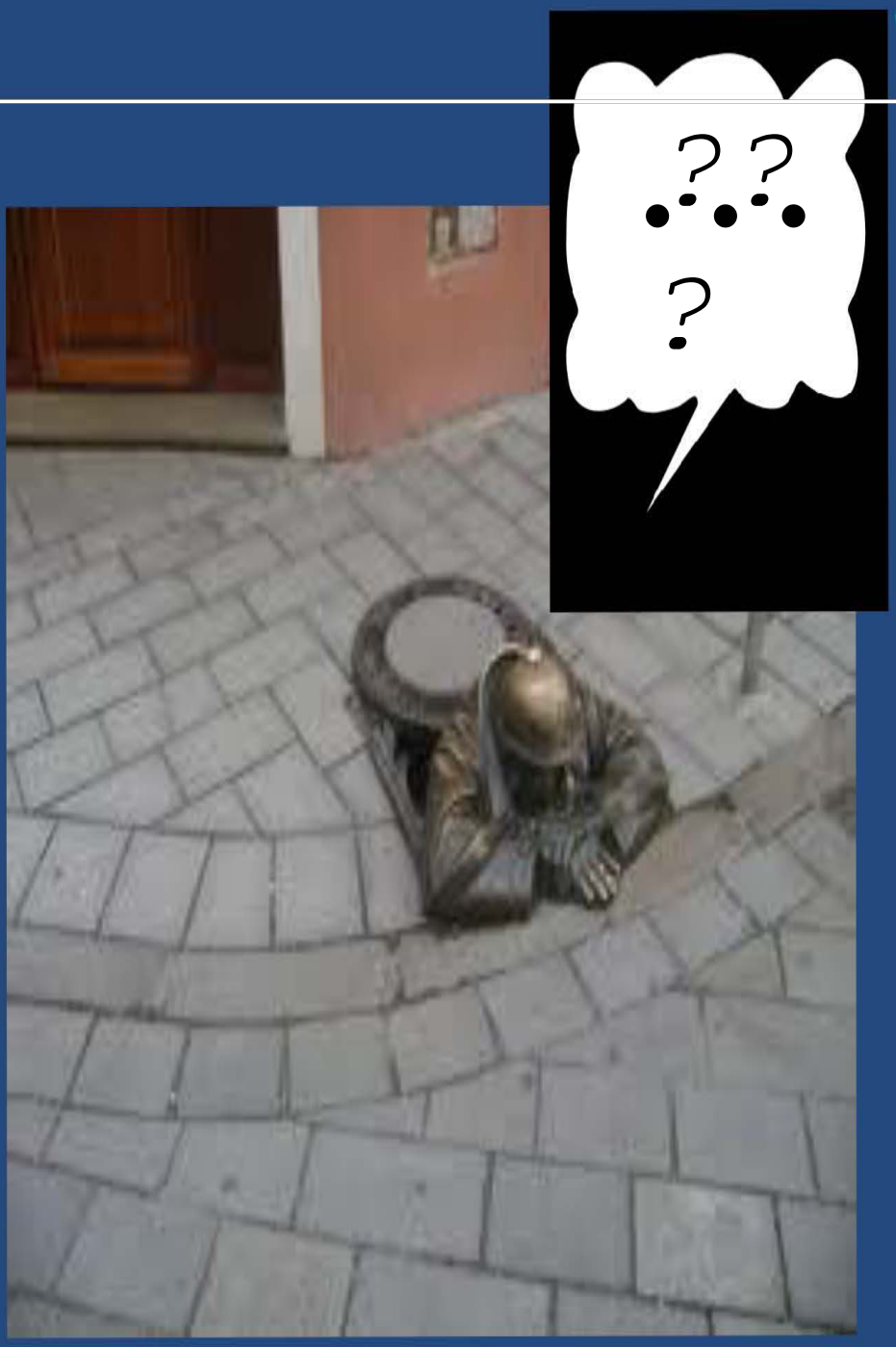
- Lower the DO in the Anoxic zone
  - Reduce Internal Recycle &/or RAS so Less High DO Cycle Aeration (Blowers or Mechanical Mixers)
- Increase BOD loading in Anoxic zone
  - Bypass Flow Around Primaries or Roughing Filters (TF) Modify Primary Clarifier Inlet Structure to Wash Out Solids
- Increase Time in Anoxic
  - Reduce Internal Recycle &/or RAS so Less Flow

Nitrate Removal, cont'd

Create Anoxic Zone Using

- Existing Tankage Install
- Mixers in Empty Tank
- Convert Primary Clarifier(s) to Mixed Anoxic Tank(s) Create Anoxic Zone within Aeration Tank

- Divert RAS to Gravity Thickener



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