Implementing & Optimizing Nitrogen Removal at Activated Sludge Wastewater Treatment Plants

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IMPLEMENTING & OPTIMIZING NITROGEN REMOVAL AT ACTIVATED SLUDGE WASTEWATER TREATMENT PLANTS

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WEBINAR
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Implementing/Optimizing N-Removal at Activated Sludge wastewater treatment plants

Upcoming Webinars
Phosphorus Removal in Activated Sludge – February 18th
P&N Removal in Activated Sludge – March 2014
Sequenced Aeration – April 2014
N&P Removal in Oxidation Ditches – May 2014
Trickling Filter Operations – June 2014

Today’s Webinar
Habitats
Nitrogen Removal in SBR & MLE Plants
Modify Operations to Create the Right Habitats
Monitor & Optimize
Comments, Questions & Answers
Making the Treatment Plant a Good Home for the Bacteria that Live there

To optimize biological nitrogen removal, wastewater treatment plant operators need to provide bacteria with the habitats they like best.

Knowing a bit about technology...

And, being willing to experiment...

It isn’t all that difficult to make most any treatment plant provide better Nitrogen Removal.
Biological Nitrogen Removal:
First, 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, 4 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.
Biological Nitrogen Removal:
Next, Nitrate (NO$_3$) is converted to Nitrogen Gas (N$_2$)

**Oxygen Poor Habitat**
ORP* of -100 mV or less (DO < 0.3 mg/L)
Surplus BOD* (100-250 mg/L: 5-10 times as much as NO$_3$)
Retention Time* of 45-90 minutes

Gives back Oxygen
Gives back Alkalinity (3.5 mg/L per mg/L of NO$_3$ → N$_2$)

*Approximate, each facility is different.
Nitrogen Removal in an SBR, Sequencing Batch Reactor
Sequencing Batch Reactor (SBR)
Ammonia ($NH_4$) Removal: Nitrification

Ammonia ($NH_4$) Removal
Target: $NH_4 < 0.5$ mg/L

$NH_4 \rightarrow NO_3$
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

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.
**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.
Nitrogen Removal:
MLE (Modified Ludzack-Ettinger) Process
MLE (Modified Ludzack-Ettinger) Process

Anoxic Zone

Internal Recycle

Aerobic Zone

Secondary Clarifier

Return Sludge

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 (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

**Anoxic Zone**
- NO$_3$ $\rightarrow$ N$_2$

**Aerobic Zone**
- NH$_4$ $\rightarrow$ NO$_3$

**Secondary Clarifier**

Internal Recycle

Return Sludge

**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 (NH₄⁺) Removal
Good Aerobic Habitat: ORP +100 mV
NH₄⁺ < 0.5 mg/L

Nitrate (NO₃⁻) Removal
Stressed Anoxic Habitat: ORP 0 to -100 mV
NO₃⁻ > 4 mg/L: bacteria will not convert Ammonia (NH₄⁺) to Nitrate (NO₃⁻)
MLE with way too much Internal Recycle

**Anoxic Zone**

**Aerobic Zone**

**Secondary Clarifier**

**Internal Recycle**

**Return Sludge**

**Ammonia (NH₄⁺) Removal**
- Poor Aerobic Habitat: ORP +50 mV
- NH₄⁺ > 0.5 mg/L

**Nitrate (NO₃⁻) Removal**
- Poor Anoxic Habitat: ORP 0 mV or higher
- NO₃⁻ > 4 mg/L
Experimenting with YOUR plant:
Finding the “Right” Process Control Strategy

... and, Optimizing Nitrogen Removal
Optimize Ammonia (NH\textsubscript{4}) Removal
Ammonia (NH$_4$) Removal

**Target: less than 0.5 mg/L**

Raise mixed liquor

... the higher the better for N-Removal.

Keep ORP at +100 mV (or higher) by adjusting DO settings until ...

... enough DO & ORP to reduce NH$_4$ to 0.5 mg/L ...

... but not so much as to move too much DO into Anoxic or waste electricity.

**Warning:** pH and Nitrite (NO$_2$)
Step 2: Optimize Nitrate (NO$_3$) Removal
Operate Aeration Tank as SBR
**Conventional Activated Sludge operated as SBR**

**Primary Clarifier**

**Aeration Tank**

**Secondary Clarifier**

**Maintain Ammonia (NH₄) Removal**
- Target: NH₄ < 0.5 mg/L
- ORP: +100 mV long enough (60 minutes)

**Nitrate (NO₃) Removal**
- Target: NO₃ < 4 mg/L
- ORP: -100 mV long enough (30 minutes)
- If habitats are good and NO₃ remains high, likely not enough BOD.
- Search for additional BOD.

Cycle air ON to remove NH₄ & OFF to remove NO₃

Use ORP to adjust AirON/AirOFF times
Operate Aeration Tank as MLE
MLE Process Modification of Conventional AS Plant

Primary Clarifier → Aeration Tank → Secondary Clarifier

Maintain Ammonia (NH₄⁺) Removal
Target: NH₄⁺ < 0.5 mg/L
ORP: +100 mV

Nitrate (NO₃⁻) Removal
Target: NO₃⁻ < 4 mg/L
ORP: -100 mV
Unless RAS can be increased to 200% or more, NO₃⁻ target of 4 mg/L will be hard to achieve
MLE Process Modification of Conventional AS Plant

Primary Clarifier
Anoxic Tank

Aeration Tank

Secondary Clarifier

NO₃ → N₂

NH₄ → NO₃

Maybe use Primary Clarifier as pre-Anoxic Tank
Maybe install Internal Recycle Pump(s)

Sludge Holding Tank
Primary Clarifier → Aeration Tank → Secondary Clarifier

- NH₄ → NO₃
- NO₃ → N₂

Maybe use Sludge Holding Tank or Gravity Thickener as post-Anoxic Tank

MLE Process Modification of Conventional AS Plant
MLE & SBR Modification of Conventional AS Plant

Or, modify operations to incorporate SBR and MLE Processes

MLE & SBR Modification of Conventional AS Plant
Monitor and Control the Process

Review and Analyze Data every day
Maintain Optimized Habitats
Monitor Treatment Efficiency

Be Prepared to make Process Changes every day
Preemptive changes to keep Habitats Ideal
Reactive changes to meet Treatment Requirements
Summary

Operational changes allow many (most) Activated Sludge Plants to remove nitrogen.

Provided alkalinity exists, first optimize Ammonia ($\text{NH}_4$) removal...

Dial in MLSS, DO/ORP

Maintain Ammonia ($\text{NH}_4$) removal while optimizing Nitrate ($\text{NO}_3$) removal...

Dial in ORP and look for sources of BOD

Keep an eye on effluent Nitrite ($\text{NO}_2$); > 0.5 mg/L is a problem.

Monitor and Adjust DAILY for the rest of your life!
Making clean water affordable
Thank You!

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Upcoming Webinars
11 AM EST February 18th: Activated Sludge Phosphorus Removal
March ‘14: Activated Sludge N&P Removal
April ‘14: Sequenced Aeration, an Innovative/Effective Process Design
May ‘14: N&P Removal in Oxidation Ditches
June ‘14: Trickling Filter Operations