NITROGEN & PHOSPHORUS REMOVAL: REVIEW

GRANT WEAVER, PE & WASTEWATER OPERATOR

HELENA, MONTANA
JUNE 9 & 10, 2015

www.cleanwaterops.com
Optimizing wastewater treatment for nutrient removal

Yesterday
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

Today
Cost-Savings / Sludge Reduction Modifications
Review
Group Discussion & Design
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)
Ammonia (NH₄) Removal

Ammonia (NH₄)
Ammonia ($NH_4$) Removal

Oxygen

Ammonia ($NH_4$)
Ammonia (NH$_4$) Removal

Oxygen

Ammonia (NH$_4$)

Alkalinity
Ammonia \((NH_4)\) Removal

Oxygen

Ammonia \((NH_4)\) → Nitrite \((NO_2)\)

Alkalinity
Ammonia ($NH_4$) Removal

- Ammonia ($NH_4$)
- Nitrite ($NO_2$)
- Oxygen
- Alkalinity
Ammonia (NH$_4$) Removal

- Ammonia (NH$_4$)
- Nitrite (NO$_2$)
- Nitrate (NO$_3$)

Steps:
1. Ammonia (NH$_4$) is oxidized by oxygen to nitrite (NO$_2$) and alkalinity.
2. Nitrite (NO$_2$) is further oxidized by oxygen to nitrate (NO$_3$).
**Ammonia (NH₄) Removal**

- Oxygen

**Ammonia (NH₄)**

- Alkalinity

**Nitrite (NO₂)**

- Oxygen

**Nitrate (NO₃)**

Nitrification Habitat
- High DO / ORP
- Low BOD
- Plenty of Alkalinity
- High Sludge Age
- Long Retention time
Given the right habitat in which to prosper ...

Nitrifying bacteria will lower Ammonia (NH₄) to 0.5 mg/L or Less

And, add Nitrate (NO₃) 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 (NO₃) Removal

Nitrate
(NO₃)
Nitrate ($NO_3^-$) Removal

BOD

Nitrate
($NO_3^-$)
Nitrate \((NO_3)\) Removal

BOD → Nitrate \((NO_3)\) → Oxygen
Nitrate (NO$_3^-$) Removal

- BOD
- Nitrate (NO$_3^-$)
- Oxygen
- Alkalinity
Nitrate (NO$_3$) Removal

Nitrate (NO$_3$) $\rightarrow$ Nitrogen Gas (N$_2$) $\rightarrow$ Oxygen $\rightarrow$ Alkalinity $\rightarrow$ BOD
Nitrate (NO₃) Removal

Nitrate (NO₃) → Nitrogen Gas (N₂)

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

BOD

Oxygen

Alkalinity
Nitrate Removal Habitat

When given the right environmental conditions ...

Denitrifying bacteria will reduce Nitrate (NO₃) 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 (NH₄) Removal - Nitrification
- High DO & ORP
- Low BOD
- Plenty of Alkalinity
- High MCRT, High Sludge Age, Low F:M
- Long Retention time

Nitrate (NO₃) Removal - Denitrification
- Low DO & ORP
- High BOD
- Long Retention time
- Gives back alkalinity
To get the most out of your treatment plant, make it a great place for bacteria to live...
**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.
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: $2 \text{ mg/L TSS} = 0.1 \text{ mg/L t-P}$
**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...

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<th>P Limit</th>
<th>max TSS</th>
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