**Part I: Nitrogen**

![Periodic Table of the Elements](image_url)

- The element **Nitrogen** (N) is highlighted in the periodic table.

**Legend:**
- Lanthanide Series: Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu
- Actinide Series: Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr
Nitrogen Topics

- **Problems**: why remove?
- **Forms**: what is found in wastewater?
- **Conversions**: what reactions change one form to another?
- **Removal concepts**: how is N removed from wastewater?
- **Process considerations**: what design and operational factors influence removal?
Problems: Why Remove Nitrogen?

- Ecological consequences:
  - Greenhouse gases
  - Nitrogen may stimulate excess algae growth (eutrophication)
  - Oxidation of ammonia exerts high oxygen demand
  - Ammonia is toxic to aquatic organisms (< 1 mg/L total ammonia as N)
Problems: Ammonia Toxicity

From 2009 Draft EPA document: data shown are for CCC with mussels present.
Problems: Why Remove Nitrogen?

- Human/health consequences:
  - Nitrate: need < 10 mg/L for potable water
  - Ammonia in drinking water supplies increases chlorine demand to achieve a free residual
Forms: What N is Found in Wastewater?
Forms: Basic Categories

- (Gas vs.) dissolved vs. particulate
- Organic vs. inorganic
### Forms: N Compounds

<table>
<thead>
<tr>
<th>Compound</th>
<th>Dissolved or Particulate?</th>
<th>Organic vs. Inorganic?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrite ($\text{NO}_2^-$)</td>
<td>Dissolved</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Nitrate ($\text{NO}_3^-$)</td>
<td>Dissolved</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Ammonia ($\text{NH}_3$)</td>
<td>Dissolved</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Ammonium ($\text{NH}_4^+$)</td>
<td>Dissolved</td>
<td>Inorganic</td>
</tr>
<tr>
<td>Dissolved organic nitrogen (DON)</td>
<td>Dissolved</td>
<td>Organic</td>
</tr>
<tr>
<td>Particulate organic nitrogen (PON)</td>
<td>Particulate</td>
<td>Organic</td>
</tr>
</tbody>
</table>

**Filtered TKN**

**Unfiltered (total) TKN**
Forms: TIN? TKN? TN???

- TIN = nitrate + nitrite = NOx
- TKN = ammonia + organic nitrogen
- TN = NOx + TKN
  = NOx + ammonia + SON + PON
### Wastewater Strength

<table>
<thead>
<tr>
<th>Form</th>
<th>Strong</th>
<th>Medium</th>
<th>Weak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>85</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Organic</td>
<td>35</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Ammonia</td>
<td>50</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Nitrite/Nitrate</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Metcalf & Eddy)

### Forms: Typical Concentrations in Raw Domestic Wastewater

- **TKN**
- **Ammonia ~ 60% of TKN**

(Metcalf & Eddy)
Forms: A Note on DON/SON and PON

• DON or SON:
  – Urea, amino acids
  – Refractory component (rDON) is not removed with biological treatment: some rDON in raw (~1-2% of raw TKN) and some rDON produced in process

• PON
  – Algae, organic particles
  – Biomass
Conversions: Overview

• Organic nitrogen converted to inorganic: hydrolysis
• Inorganic nitrogen used for growth
  – Incorporate into biomass: assimilation
  – Convert from ammonia to nitrate: nitrification
  – Convert from nitrate to nitrogen gas: denitrification
Conversions: N Cycle in WWTP

- **Organic N (proteins, urea)**
- **Ammonia N**
  - **O₂**
  - **Nitrite N**
    - **O₂**
    - **Nitrate N**
    - **Nitrite N**
  - **Nitrogen Gas**
- **Organic N (microroganisms)**
- **Organic N (biosolids)**
- **Organic Carbon (no oxygen)**

**Decay**
Conversions: N Cycle in WWTP

- Organic N (proteins, urea)
- Hydrolysis
- Ammonia N
- Nitrification
- Organic N (microorganisms)
- Nitrite N
- Nitrate N
- Nitrogen Gas
- Organic N (biosolids)
- Organic Carbon (no oxygen)
Conversions: N Cycle in WWTP

- Organic N (proteins, urea)
- Hydrolysis
- Ammonia N
- Nitrification
- Organic N (microorganisms)
- Organic N (biosolids)
- Denitrification
- Nitrite N
- Nitrate N
- Nitrogen Gas
- Organic Carbon (no oxygen)
Conversions: N Cycle in WWTP

1. **Organic N (proteins, urea)**
   - Hydrolysis

2. **Ammonia N**
   - Decay
   - Ammonia-oxidizing bacteria
   - \( \text{O}_2 \)

3. **Nitrite N**
   - \( \text{O}_2 \)

4. **Nitrate N**

5. **Nitrogen Gas**
   - Organic N (biosolids)
   - Nitrite N
   - Organic Carbon (no oxygen)
Conversions: N Cycle in WWTP

- **Organic N** (proteins, urea)
  - Hydrolysis
  - Decay

- **Ammonia N**
  - $O_2$ to Ammonia-oxidizing bacteria

- **Nitrite N**
  - $O_2$ to Nitrite-oxidizing bacteria

- **Nitrate N**

- **Nitrite N**
  - Organic Carbon (no oxygen)

- **Organic N** (microorganisms)

- **Organic N** (biosolids)

- **Nitrogen Gas**
Conversions: N Cycle in WWTP

- **Organic N** (proteins, urea)
- **Hydrolysis**
- **Ammonia N**
- **Decay**
- **Nitrite N**
- **Nitrate N**
- **Organic N** (microorganisms)
- **Organic N** (biosolids)
- **Nitrogen Gas**
- **Many types of heterotrophic bacteria**
- **Organic Carbon** (no oxygen)
Removal Concepts: Basic Ideas

- What comes in must go out
  - Air
  - Water
  - Solids
- Transform to an acceptable or removable form
  - Air (N2 gas)
  - Water (effluent, e.g. nitrate)
  - Solid (biosolids)
- Remove solids
  - Sedimentation
  - Filtration
  - Membrane separation
Removal Concepts: Incorporation into Biomass

- All biological processes
- Incorporation of ammonia (or nitrate) into biomass during growth: \( \text{C}_{12}\text{H}_{87}\text{O}_{23}\text{N}_{12}\text{P} \)
- Waste biomass ~ 10% N
- Removes TN
Removal Concepts:
Incorporation into Biomass (cont.)

- Effect of influent BOD and TKN
  - Higher BOD $\Rightarrow$ more WAS $\Rightarrow$ higher percent N removed as WAS
  - Lower influent TKN:BOD ratio $\Rightarrow$ higher percent N removed as WAS

- Effect of yield
  - Higher yield $\Rightarrow$ more WAS $\Rightarrow$ higher percent N removed as WAS
Removal Concepts: Incorporation into Biomass

Percent of influent N removed in WAS vs. influent TKN/BOD ratio and yield

- Shorter SRT
- Colder Temp
- Longer SRT
- Warmer Temp

Yield
(VSS/BOD)

N/BOD ratio (mass)
in influent to bio process
**Removal Concepts: Incorporation into Biomass**

The graph shows the percent of influent N removed in WAS vs. influent TKN/BOD ratio and yield. The graph includes lines for different yield values (VSS/BOD) represented by different colors:

- **Purple**: Yield = 0.7 VSS/BOD
- **Green**: Yield = 0.6 VSS/BOD
- **Red**: Yield = 0.5 VSS/BOD
- **Blue**: Yield = 0.4 VSS/BOD

The graph includes an example:

**Example:**
- Yield = 0.6 VSS/BOD
- TKN = 35 mg/L
- BOD = 200 mg/L
- N/BOD = 0.175

The graph also indicates that shorter SRT and colder temp correlate with higher yield, while longer SRT and warmer temp correlate with lower yield.
Removal Concepts: Incorporation into Biomass

Percent of influent N removed in WAS vs. influent TKN/BOD ratio and yield

Example:
Yield = 0.6
VSS/BOD
TKN = 35 mg/L
BOD = 200 mg/L
N/BOD = 0.175

Shorter SRT Colder Temp
Longer SRT Warmer Temp
Removal Concepts: Incorporation into Biomass

Percent of influent N removed in WAS vs. influent TKN/BOD ratio and yield

Example:
Yield = 0.6 VSS/BOD
TKN = 35 mg/L
BOD = 200 mg/L
N/BOD = 0.175

Result:
34% of N goes to WAS
35 mg/L N x 0.34 = 12 mg/L N removed
35 – 12 = 23 mg/L N remains
Removal Concepts: Incorporation into Biomass

Percent of influent N removed in WAS vs. influent TKN/BOD ratio and yield

Example:
Yield = 0.6
VSS/BOD
TKN = 70 mg/L
BOD = 200 mg/L
N/BOD = 0.35

Result:
17% of N goes to WAS
70 mg/L N x 0.17 = 12 mg/L N removed
70 – 12 = 58 mg/L N remains

Shorter SRT Colder Temp
Longer SRT Warmer Temp
Removal Concepts: Incorporation into Biomass

Percent of influent N removed in WAS vs. influent TKN/BOD ratio and yield

Example:
Yield = 0.6 VSS/BOD
TKN = 35 mg/L
BOD = 350 mg/L
N/BOD = 0.1

Result:
58% of N goes to WAS
35 mg/L N x 0.58 = 20 mg/L N removed
35 – 20 = 15 mg/L N remains

Shorter SRT
Colder Temp

Longer SRT
Warmer Temp
Removal Concepts: Nitrification

- Conversion of ammonia to nitrate
- Does not remove TN
- Mitigates toxicity and oxygen demand of effluent ammonia
- Conditions for nitrification:
  - Ammonia-oxidizing and nitrite-oxidizing biomass ("nitrifiers"): need adequate SRT at given temperature
  - Oxygen: 4.6 mg O₂ / mg N nitrified
  - Adequate pH: 7.1 mg CaCO₃ alkalinity / mg N nitrified

\[ \text{Ammonia N} \rightarrow \text{O₂} \rightarrow \text{Nitrite N} \rightarrow \text{O₂} \rightarrow \text{Nitrate N} \]
Removal Concepts: Denitrification

- Conversion of nitrate to nitrogen gas
- $\text{N}_2$ goes to atmosphere (atmosphere is 78% $\text{N}_2$)
- Removes TN
- Conditions for denitrification:
  - Denitrifying bugs ("facultative heterotrophs" or methylotrophs)
  - Carbon!
  - No oxygen: nitrate used as electron acceptor
Removal Concepts: Denitrification – Carbon Sources

- Wastewater (free!)
  - Domestic wastewater: $C_{10}H_{19}O_{3}NP_{0.1}$
- Bugs endogenous decay (slow...)
  - Bugs: $C_{12}H_{87}O_{23}N_{12}P$
- External source ($$$)
  - Want carbon, don’t want more N (or P)
  - Typical carbon courses:
    - Methanol: $CH_3OH$
    - Glycerol: $C_3H_{5}(OH)_3$
Removal Concepts:
Denitrification - Anoxia

• Anoxic (no oxygen) conditions may be unintentional:
  – Middle of floc
  – Dead zones in aerobic basin
Removal Concepts:
Denitrification - Benefits

• Recover alkalinity
  – Nitrification consumes alkalinity: -7.1 mg CaCO₃/mg N nitrified
  – Denitrification generates alkalinity: +3.6 mg CaCO₃/mg N denitrified
  – Save chemical $

• Reduce oxygen supply required for oxidation of organics
  – Denitrification “credit” = 2.8 mg O₂/mg NO₃⁻ reduced
  – Save energy $

• To reap these benefits, denitrification must occur upstream of nitrification
Process Considerations: Conditions for Nitrification

- Ammonia-oxidizing and nitrite-oxidizing bacteria ("nitrifiers")
- Oxygen (electron acceptor)
- Alkalinity (pH sensitivity)
- No toxics
- Adequate temperature
Process Considerations: Nitrification & Oxygen

Conditions
- Maximum growth rate = 0.9 day$^{-1}$
- $T = 20^\circ C$
- $pH = 7.2$
- Adequate ammonia
Conditions
- Maximum growth rate = 0.9 day⁻¹
- T = 20°C
- pH = 7.2
- Adequate ammonia

Growth rate is half of maximum at 0.5 mg/L DO
Process Considerations:
Nitrification and pH

- Optimal nitrification occurs at pH ~ 7.2
- Rates decline significantly below pH ~ 6.8
- Rates at pH ~ 6 are < 10% of maximum
Process Considerations: Nitrification & pH

Conditions
- Maximum growth rate = 0.9 day\(^{-1}\)
- \(T = 20^\circ C\)
- Adequate DO and ammonia
Process Considerations:
Nitrification & Temperature

Growth rate at T°C = Growth rate at 20°C x 1.072(T-20)
Process Considerations: 
Nitrification – Washout SRT

- Washout of nitrifiers occurs when SRT is too short to allow microorganisms to accumulate
- Nitrifier growth rate is temperature-dependent
- Therefore, minimum SRT to avoid washout is also temperature-dependent
## Process Considerations:
### Nitrification – Washout SRT

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Washout SRT (days)</th>
<th>Washout SRT Times 2.5 Safety Factor (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>4.7</td>
<td>11.8</td>
</tr>
<tr>
<td>10</td>
<td>4.3</td>
<td>10.8</td>
</tr>
<tr>
<td>11</td>
<td>3.9</td>
<td>9.9</td>
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<td>3.6</td>
<td>9.0</td>
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<td>22</td>
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<td>3.9</td>
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<td>23</td>
<td>1.4</td>
<td>3.6</td>
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<tr>
<td>24</td>
<td>1.3</td>
<td>3.3</td>
</tr>
<tr>
<td>25</td>
<td>1.2</td>
<td>3.0</td>
</tr>
</tbody>
</table>
**Process Considerations:**

**Process Flow for Short SRT**

**Not nitrifying**

35 mg/L N in, 34% to WAS = 12 mg/L to WAS
35 -12 = 23 mg/L N remains
22 mg/L ammonia N + 1 mg/L DON = 23 mg/L TKN

Influent
TKN = 35
NO$_3^-$ = 0
Flow = 1

Aerobic

RAS
NH$_3$ = 22
DON = 1
NO$_3^-$ = 0
Flow = 0.5

WAS w/PON equivalent to 12 mg/L N

Effluent
NH$_3$ = 22
DON = 1
NO$_3^-$ = 0
Flow = 1

35 mg/L N in, 34% to WAS = 12 mg/L to WAS
35 -12 = 23 mg/L N remains
22 mg/L ammonia N + 1 mg/L DON = 23 mg/L TKN
Process Considerations:
Process Flow for Long SRT

Nitrifying

21 mg/L ammonia N converted to nitrate
21 x 7.1 = 149 mg/L CaCO₃ alkalinity consumed
1 mg/L DON remains; TKN = 2 mg N/L

Influent
TKN = 35
NO₃⁻ = 0
Flow = 1

Aerobic

Effluent
NH₃ = 1
DON = 1
NO₃⁻ = 21
Flow = 1

RAS
NH₃ = 1
DON = 1
NO₃⁻ = 21
Flow = 0.5

WAS w/PON equivalent to
12 mg/L N
Process Considerations: Nitrification and Toxics

- Sensitive to many compounds: metals, phenolic compounds, cyanates, amines, tannins etc.
- Unionized ammonia \((\text{NH}_3)\) is also toxic
  - 100 mg N/L ammonia at pH 7 and T = 20°C inhibits ammonia oxidation
  - 20 mg N/L ammonia at pH 7 and T = 20°C inhibits nitrite oxidation
- Unionized nitrous acid \((\text{HNO}_2)\)
Process Considerations:
Conditions for Denitrification

- Denitrifying bacteria ("facultative heterotrophs" or methanol utilizers)
- No oxygen
- Nitrate
- Carbon (BOD or external source)
Some Anoxic Time or Space

Some denitrification due to anoxic zones within aeration basin
Estimate by monitoring effluent nitrate, example 19 mg/L effluent nitrate N
21-19 = 2 mg/L nitrate N removed by unintentional SNDN
(Simultaneous Nitrification/DeNitrification)

Process Considerations:
Denitrification – Anoxia with SNDN

Influent
TKN = 35
NO$_3^-$ = 0
Flow = 1

RAS
NH$_3$ = 1
DON = 1
NO$_3^-$ = 19
Flow = 0.5

Aerobic

3 mg/L N as N$_2$ gas

WAS w/PON equivalent to 12 mg/L N

Effluent
NH$_3$ = 1
DON = 1
NO$_3^-$ = 19
Flow = 1
Process Considerations:
Denitrification – Anoxic Zones

Anoxic Space
Process Considerations:

Denitrification – Nitrate

• Nitrification must occur first
• Nitrate typically delivered to anoxic zone via internal nitrified mixed liquor recycle and RAS
Process Considerations:
Denitrification – LE Recycle

0.5 Q nitrate recycle: 1Q infl = 0.5Q denite/1.5Q total = 33% denite
33% of 19 mg/L N recycled for denite = 6 mg/L N denitrified
19 – 6 = 13 mg/L nitrate N remains in effl
Process Considerations:
Denitrification – LE Recycle

0.5 Q nitrate recycle: 1Q infl = 0.5Q denite/1.5Q total = 33% denite
33% of 19 mg/L N recycled for denite = 6 mg/L N denitrified
19 – 6 = 13 mg/L nitrate N remains in effl

\[ \text{NO}_3^- = \frac{(19 \times 1) + (0 \times 0.5)}{1 + 0.5} = 13 \]
Process Considerations:
Denitrification – Recycle Efficacy

<table>
<thead>
<tr>
<th>Influent Flow, parts</th>
<th>Recycle Flow, parts</th>
<th>Total Anoxic Flow</th>
<th>Potential Denitrification = % Recycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>1.5</td>
<td>0.5/1.5 = 33%</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1/2 = 50%</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2/3 = 67%</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3/4 = 75%</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>5</td>
<td>4/5 = 80%</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>6</td>
<td>5/6 = 83%</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>9</td>
<td>8/9 = 89%</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>11</td>
<td>10/11 = 91%</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>21</td>
<td>20/21 = 95%</td>
</tr>
</tbody>
</table>

Benefit of increasing recycle declines, typically use 350% - 450%
Process Considerations:
Denitrification – Recycle Efficacy

Denitrification based on Recycle to initial anoxic zone
(ex. MLE process)

Combined Recycle Ratio (including RAS)
Process Considerations:
Denitrification – Increase LE Recycle

4 Q nitrate recycle: 1Q infl = 4Q denite/5Q total = 80% denite
80% of 19 mg/L recycled for denite = 15 mg/L N denitrified
19 – 15 = 4 mg/L nitrate N remains
Process Considerations:
Denitrification – Increase LE Recycle

4 Q nitrate recycle: 1Q infl = 4Q denite/5Q total = 80% denite
80% of 19 mg/L recycled for denite = 15 mg/L N denitrified
19 – 15 = 4 mg/L nitrate N remains

Infl
TKN = 35
NO₃⁻ = 0
Flow = 1

Post – Anox
NO₃⁻ = 0
Flow = 5

Aerobic

RAS
NH₃ = 1
DON = 1
NO₃⁻ = 4
Flow = 4

Effl
NH₃ = 1
DON = 1
NO₃⁻ = 4
Flow = 1

WAS w/PON

Too much flow through clarifier!
4 Q nitrate recycle: 1Q infl = 4Q denitrification/5Q total = 80% denitrification
80% of 19 mg/L recycled for denitrification = 15 mg/L N denitrified
19 – 15 = 4 mg/L nitrate N remains

Add mixed liquor recycle

Infl
TKN = 35
NO₃⁻ = 0
Flow = 1

Anoxic
Post –Anox
NO₃⁻ = 0
Flow = 5

MLR
NH₃ = 1
DON = 1
NO₃⁻ = 4
Flow = 3.5

Aerobic
RAS
NH₃ = 1
DON = 1
NO₃⁻ = 4
Flow = 0.5

Effl
NH₃ = 1
DON = 1
NO₃⁻ = 4
Flow = 1

WAS w/PON
Process Considerations: Denitrification – Carbon

**Option 1:** BOD from WW, recycle to deliver nitrate ex. Modified Ludzak Ettinger Process (MLE)

**Option 2:** BOD from endogenous decay (may add carbon), nitrate present ex. Four Stage Bardenpho process (Option 1 & 2) (endogenous C adds ammonia N and P)

**Option 3:** BOD from external carbon source, nitrate present ex. Denite filter

No alkalinity recovery or decrease in oxygen demand for options 2 & 3
## Process Considerations: Carbon Options

<table>
<thead>
<tr>
<th>Product</th>
<th>Strength</th>
<th>NFPA Rating</th>
<th>Freezing Point, C</th>
<th>SG</th>
<th>COD Content, g/L</th>
<th>COD:N Ratio Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Health</td>
<td>Fire</td>
<td>Reactivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>100%</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>-97</td>
<td>0.79</td>
</tr>
<tr>
<td>Ethanol</td>
<td>100%</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>-114</td>
<td>0.79</td>
</tr>
<tr>
<td>Acetic Acid</td>
<td>100%</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>17</td>
<td>1.05</td>
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<tr>
<td>Corn Syrup</td>
<td>50% glucose</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>1.22</td>
</tr>
<tr>
<td>MicroC-G</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-8</td>
<td>1.20</td>
</tr>
<tr>
<td>Glycerin</td>
<td>80% (20% water)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>18</td>
<td>1.19</td>
</tr>
</tbody>
</table>
Process Considerations: Effluent Nitrogen

- Effluent DON (eDON) = TKN not converted to ammonia in biological WW treatment process
- Some may be slowly biodegradable “recalcitrant” or “refractory” (rDON)
- Some produced in process
- WERF indicates > 60% of biological WWTPs in VA & MD have eDON ≥ 1 mg/L

Figure 2. Summary of effluent dissolved organic nitrogen (DON) concentration (0.45 μm filtration) from 188 Maryland and Virginia wastewater treatment plants (Pagilla, 2007)
## Process Considerations:
**Range of N in ENR Effluents**

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>NITROGEN (mg/L as N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soluble</strong></td>
<td>HIGHLOW</td>
</tr>
<tr>
<td>Organic</td>
<td>2.5 0.5</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.75 0.25</td>
</tr>
<tr>
<td>Nitrate + Nitrite</td>
<td>2.0 1.0</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>5.25 1.75</td>
</tr>
<tr>
<td>Particulate</td>
<td>0.50 0.25</td>
</tr>
<tr>
<td>Organic</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5.75 2.0</td>
</tr>
</tbody>
</table>
Process Considerations:
Effluent TN Components for TN = 4

- Assume 4 mg/L TN limit
  - 1 mg N/L DON
  - 0.25 mg N/L PON
  - 0.25 mg N/L ammonia
  - Allows ~ 1.5 mg N/L NOx

- Nitrification and denitrification processes must be very effective