Nitrogen Removal Training Program

Module 1
Nitrogen in the Aquatic Environment

- Forms of Nitrogen and Nitrogen Transformations
- Nitrogen in Surface Waters
- Water Quality Impacts of Nitrogen Discharges
- Nitrogen in Wastewater
Nitrogen Removal Training Program
Module 1

Forms of Nitrogen and Nitrogen Transformations
# Forms of Nitrogen in the Environment

## Unoxidized Forms of Nitrogen
- Nitrogen Gas (N$_2$)
- Ammonia (NH$_4^+$, NH$_3$)
- Organic Nitrogen (urea, amino acids, peptides, proteins, etc...)

## Oxidized Forms of Nitrogen
- Nitrite (NO$_2^-$)
- Nitrate (NO$_3^-$)
- Nitrous Oxide (N$_2$O)
- Nitric Oxide (NO)
- Nitrogen Dioxide (NO$_2$)
Nitrogen Fixation

• Biological Fixation - Use of atmospheric nitrogen by certain photosynthetic blue-green algae and bacteria for growth.

\[
\text{Nitrogen Gas} \quad \xrightarrow{\text{Biological Fixation}} \quad \text{Organic Nitrogen}
\]

\[
\text{N}_2 \quad \rightarrow \quad \text{Organic Nitrogen}
\]

• Lightning Fixation - Conversion of atmospheric nitrogen to nitrate by lightning.

\[
\text{Nitrogen Gas} \quad + \quad \text{Ozone} \quad \xrightarrow{\text{Lightning}} \quad \text{Nitrate}
\]

\[
\text{N}_2 \quad + \quad \text{O}_3 \quad \rightarrow \quad \text{NO}_3^-
\]

• Industrial Fixation - Conversion of nitrogen gas to ammonia and nitrate-nitrogen (used in the manufacture of fertilizers and explosives).
Certain blue-green algae and bacteria use atmospheric nitrogen to produce organic nitrogen compounds.
Atmospheric Fixation

Lightning converts Nitrogen Gas and Ozone to Nitrate.
Industrial Fixation

Nitrogen gas is converted to ammonia and nitrate in the production of fertilizer and explosives.
Ammonification and Assimilation

Ammonification - Conversion of organic nitrogen to ammonia-nitrogen resulting from the biological decomposition of dead plant and animal tissue and animal fecal matter.

Organic N + microorganisms → ammonia

(NH$_4^+$/NH$_3$)

Assimilation - Use of ammonia and nitrate-nitrogen by plants for growth

Ammonia + Carbon Dioxide + Sunlight + Plants → Plant Tissue

(NH$_4^+$/NH$_3$) (CO$_2$) (Organic N)

Nitrate + Carbon Dioxide + Sunlight + Plants → Plant Tissue

(NO$_3^-$) (CO$_2$) (Organic N)
**Hydrolysis and Amination**

**Hydrolysis** - Conversion of organic nitrogen to ammonia nitrogen by enzymes secreted by bacteria, plants and animals in a reaction which adds water.

\[
\text{C-NH}_2 + \text{H}_2\text{O} \xrightarrow{\text{Protease}} \text{C-OH} + \text{NH}_3
\]

(Protein) \quad \text{(Organic C)} \quad \text{(Ammonia)}

\[
\text{H}_2\text{NCONH}_2 + \text{H}_2\text{O} \xrightarrow{\text{Urease}} \text{HCO}_3^- + \text{NH}_3
\]

(Urea) \quad \text{(Bicarbonate)} \quad \text{(Ammonia)}

**Amination** - Use of ammonia-N by bacteria to form new bacteria

Ammonia + Organic C + Oxygen + Phosphorus → New Bacteria
Ammonification & Hydrolysis Followed by Nitrification and Assimilation

Ammonification and hydrolysis

Decaying Organic Matter

Ammonia in soil and water

Ammonia converted to nitrate by nitrification.

Assimilation of nitrate and ammonia by new plant growth to form new organic nitrogen.
Combustion (Incineration)

**Incineration**

Biomass + Oxygen $\rightarrow$ Carbon Dioxide + Oxidized - N + Water Vapor

(contains C,H,N,P)

{N$_2$O, NO, NO$_2$}

**Automobile Combustion of Fossil Fuels Containing Nitrogen**

Incomplete Oxidation Generates N$_2$O (Nitrous Oxide)

Additional Oxygen Converts it to Nitric Oxide

2N$_2$O + O$_2$ $\rightarrow$ 4NO

Substantial Excess Oxygen Can Convert it to Nitrogen Dioxide

2NO + O$_2$ $\rightarrow$ 2NO$_2$
Dissolution of Combustion Products

Acid Rain From Stack Emissions

Nitric Oxide + Oxygen + Water $\rightarrow$ Nitrous Acid $\rightarrow$ Nitric Acid

\[ 4\text{NO} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{HNO}_2 \]

Nitrous Acid

\[ 2\text{HNO}_2 + \text{O}_2 \rightarrow 2\text{HNO}_3 \]

Nitric Acid

Nitrogen Dioxide + Water $\rightarrow$ Nitrous Acid $\rightarrow$ Nitric Acid

\[ 2\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_2 \]

Acid Enters Soil As Acid Rain

Scrubbing of Stack Emissions to Reduce Acid Rain

Caustic Soda Scrubbing Neutralizes Acid (H\(^+\)) to Water

\[ \text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^- \]

\[ \text{H}^+ + \text{NO}_3^- + \text{NaOH} \rightarrow \text{NO}_3^- + \text{H}_2\text{O} + \text{Na}^+ \]
Incineration and combustion of fossil fuel containing nitrogen releases oxides of nitrogen into the atmosphere. Dissolved oxides of nitrogen produce acid rain.

Caustic soda scrubbing of stack emissions minimizes atmospheric emissions but produces nitrate in solution.
Biological Oxidation (Nitrification)

Ammonia $(\text{NH}_4^+ - \text{N})$ → Nitrosomonas → Nitrite $(\text{NO}_2^- - \text{N})$ → Nitrobacter → Nitrate $(\text{NO}_3^-)$

Oxygen $(\text{O}_2)$

Alkalinity $(\text{HCO}_3^-)$
Denitrification in Anoxic Environment

Definition: Aerobic Environment Contains Dissolved Oxygen (D.O.) and Oxidized - N (Nitrate - N and Nitrite - N)

Anoxic Environment Contains Oxidized - N, but has no Dissolved Oxygen.
The Nitrogen Cycle

- Fertilizer (Ammonia, Nitrate)
- Nitrogen Fixing Bacteria
- Assimilation
- Nitrification
- Oxides of Nitrogen
- Ammonia, Organic -N in WWTP Influent
- Ammonia, Nitrate in WWTP Effluent
- Nitrification in Stream
- Biological Growth in Stream
- Denitrification in Sediments
- Industrial Fixation
- Decaying Matter
- Nitrogen Gas
- Ammonia

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Nitrogen in Surface Waters
## Nitrogen Concentrations in Natural Waters

<table>
<thead>
<tr>
<th>Type</th>
<th>N Forms</th>
<th>N Concentrations</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Water</td>
<td>Ammonium-N</td>
<td>Typically Low (near zero)</td>
<td>Contaminated Groundwater</td>
</tr>
<tr>
<td></td>
<td>Nitrate-N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mountain Stream</td>
<td>Nitrate-N</td>
<td>Typically Low (near zero)</td>
<td>Atmosphere</td>
</tr>
<tr>
<td>Large River</td>
<td>Ammonium-N</td>
<td>Low-Moderate</td>
<td>Municipal Wastewater, Runoff from Agriculture</td>
</tr>
<tr>
<td></td>
<td>Nitrate-N</td>
<td>0 - 0.5 mg/l</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organic-N</td>
<td>0 - 0.1 mg/l</td>
<td></td>
</tr>
<tr>
<td>Clean Lake</td>
<td>Ammonium-N</td>
<td>0 - 0.1 mg/l Constant w/Depth</td>
<td>Atmosphere</td>
</tr>
<tr>
<td></td>
<td>Nitrate-N</td>
<td>0 - 0.3 mg/l Constant w/Depth</td>
<td>Runoff</td>
</tr>
<tr>
<td></td>
<td>Organic-N</td>
<td>0 - 0.1 mg/l</td>
<td></td>
</tr>
<tr>
<td>Eutrophic Lake</td>
<td>Ammonium-N</td>
<td>0 - 4.5 mg/l Increases w/Depth</td>
<td>Municipal Wastewater, Runoff from Agriculture</td>
</tr>
<tr>
<td></td>
<td>Nitrate-N</td>
<td>0.1 mg/l</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organic-N</td>
<td>0 - 0.2 mg/l Decreases w/Depth</td>
<td></td>
</tr>
</tbody>
</table>
## Nitrogen Concentrations in Runoff

<table>
<thead>
<tr>
<th>Type</th>
<th>N Forms</th>
<th>N Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>Ammonium-N</td>
<td>&lt; 0.1 mg/l</td>
</tr>
<tr>
<td>Runoff</td>
<td>Nitrate-N</td>
<td>&lt; 0.5 mg/l</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Ammonium-N</td>
<td>0.1 - 1 mg/l</td>
</tr>
<tr>
<td>Runoff</td>
<td>Nitrate-N</td>
<td>0 - 10+ mg/l</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(typ. 0 - 1.0 mg/l)</td>
</tr>
<tr>
<td>Urban</td>
<td>Organic-N</td>
<td>0.1 - 1+ mg/l</td>
</tr>
<tr>
<td>Runoff</td>
<td>Ammonium-N</td>
<td>0.1 - 2+ mg/l</td>
</tr>
<tr>
<td></td>
<td>Nitrate-N</td>
<td>0.1 - 0.5+ mg/l</td>
</tr>
</tbody>
</table>
# Atmospheric Nitrogen: Representative Concentrations & Unit Areal Loadings

<table>
<thead>
<tr>
<th>Location</th>
<th>Nitrogen Form</th>
<th>Sampling</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Representative Concentrations, mg N/L</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long Island Sound</td>
<td>Ammonia</td>
<td>Precipitation</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Nitrate and Nitrite</td>
<td>Precipitation</td>
<td>0.32</td>
</tr>
<tr>
<td>Geneva, NY</td>
<td>Ammonia Plus</td>
<td>Precipitation</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Nitrate-Nitrogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ottawa, ON</td>
<td>Inorganic Nitrogen</td>
<td>Snow</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Ammonia</td>
<td>Rain</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Nitrate</td>
<td>Rain</td>
<td>0.35</td>
</tr>
<tr>
<td>Cincinnati, OH</td>
<td>Total Nitrogen</td>
<td>Precipitation</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>Inorganic Nitrogen</td>
<td>Precipitation</td>
<td>0.69</td>
</tr>
<tr>
<td><strong>Representative Areal Loadings, kg/ha/yr</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potomac River</td>
<td>Total Nitrogen</td>
<td>Precipitation and Dust</td>
<td>18.6</td>
</tr>
<tr>
<td>Lake Huron (Northwest)</td>
<td>Total Nitrogen</td>
<td>Precipitation and Dust</td>
<td>11</td>
</tr>
<tr>
<td>Central Europe</td>
<td>Total Nitrogen</td>
<td>Precipitation and Dust</td>
<td>20.0 - 30.0</td>
</tr>
<tr>
<td>Hamilton, ON</td>
<td>Total Nitrogen</td>
<td>Precipitation and Dust</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Total Nitrogen</td>
<td>Dust</td>
<td>2.6</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>Nitrate</td>
<td>Dust</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Sources of Nitrogen in Long Island Sound
**Distribution of Sources of Nitrogen to Long Island Sound Tons / Year (Percent)**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Point</th>
<th>Nonpoint (Natural)</th>
<th>Nonpoint (Enriched)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>STPs &amp; Industry</td>
<td>25,700(28)</td>
<td>--</td>
<td>--</td>
<td>25,700(28)</td>
</tr>
<tr>
<td>Tributaries</td>
<td>3,900(4)</td>
<td>11,600(13)</td>
<td>4,900(5)</td>
<td>20,400(22)</td>
</tr>
<tr>
<td>Coastal Runoff &amp; CSOs</td>
<td>--</td>
<td>800(1)</td>
<td>3,500(4)</td>
<td>4,300(5)</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>--</td>
<td>4,600(5)</td>
<td>2,200(2)</td>
<td>6,800(7)</td>
</tr>
<tr>
<td>Boundaries</td>
<td>--</td>
<td>22,900(25)</td>
<td>10,700(12)</td>
<td>33,600(37)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>29,600(33)</td>
<td>39,900(44)</td>
<td>21,300(23)</td>
<td>90,800(100)</td>
</tr>
</tbody>
</table>

Source: Long Island Sound Study, Comprehensive Conservation & Management Plan, 1993
Nitrogen Removal Training Program
Module 1

Water Quality Impacts of Nitrogen Discharges
Biostimulation of Surface Waters (Eutrophication)

- Excessive Plant Growth and/or Algae Blooms
- Impacts on Water Quality Include:
  - Deterioration of aesthetic quality
  - Odors from decomposing algae
  - DO depletion which can adversely affect fish life
- Factors Required for Algae Growth:
  - Nitrogen
  - Phosphorus
  - Carbon Dioxide
  - Light
  - Micronutrients
- Phosphorus Is Typically the Limiting Factor for Algae Growth in Rivers and Lakes.
- Nitrogen Can Be a Limiting Factor for Algae Growth in Estuaries.
Ammonia Toxicity

- Molecular ammonia (NH$_3$) can have toxic effects on aquatic life

- Effects may be either acute (i.e. fish mortality) or chronic (impacts on reproduction, tumors, etc.)

- Ammonia toxicity is impacted by water temperature and pH conditions

  - As pH increases, toxic effects are observed at lower total ammonia (NH$_3$ + NH$_4^+$) concentrations

  - As temperature increases, toxic effects are observed at lower total ammonia concentrations
EPA Chronic Criteria for Ammonia (Salmonids Absent)

Total Ammonia, mg/L as N

pH

Nitrite and Nitrate in Drinking Water

• Nitrite and Nitrate in drinking water have been medically linked to methemoglobinemia, a sometimes fatal blood disorder affecting infants (“blue babies”).

• Nitrate can be reduced to nitrite under certain conditions in the stomach and saliva.

• Nitrite can bind to iron on hemoglobin reducing transfer of oxygen to cell tissues.

• Result is suffocation accompanied by bluish tinge to skin.
Effect of Nitrification in Receiving Waters

- Naturally occurring microorganisms can oxidize ammonia to nitrite then nitrate
- Biological nitrification reduces dissolved oxygen concentrations in receiving waters and may impact aquatic life
- Magnitude of DO depletion is impacted by receiving water characteristics, wastewater discharge loadings, and environmental conditions
- Nitrification rates increase significantly with increasing water temperature. As a result, impacts are most severe during summer when low flow conditions generally coincide with high temperatures.
Example of DO Improvement to River Segments after Treatment Plant Upgrade for Nitrification

Laurel Parkway Plant, Patuxent River, MD.

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTW Effluent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBOD$_5$, (kg/d)/(mg/L)</td>
<td>159/9.5</td>
<td>17.3/0.45</td>
</tr>
<tr>
<td>NH$_3$-N, (kg/d)/(mg/L)</td>
<td>128/9.5</td>
<td>5/0.14</td>
</tr>
<tr>
<td>Total of all Sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBOD$_5$, (kg/d)</td>
<td>176</td>
<td>35.5</td>
</tr>
<tr>
<td>NH$_3$-N, (kg/d)</td>
<td>135</td>
<td>32.3</td>
</tr>
<tr>
<td>Stream</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average DO, mg/L</td>
<td>5.5</td>
<td>7.9</td>
</tr>
<tr>
<td>Minimum DO, mg/L</td>
<td>3.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Maximum CBOD$_5$</td>
<td>18</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Maximum NH$_3$-N, mg/L</td>
<td>2.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Improved Dissolved Oxygen Levels in Patuxent River Due to Treatment Plant Upgrade for Nitrification

Patuxent River at Mile 70.8

<table>
<thead>
<tr>
<th></th>
<th>1966-67</th>
<th>1978</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO</td>
<td>3.7</td>
<td>7.6</td>
<td>+108%</td>
</tr>
</tbody>
</table>

## Effect of Ammonium Oxidation on Total Oxygen Demand of Treated Wastewater Discharge

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw Wastewater Concentration (mg/l)</th>
<th>Secondary Effluent Concentration (mg/l)</th>
<th>Secondary Effluent Concentration with Nitrification (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter, mg BOD(_5)/L</td>
<td>250</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Organic Oxygen Demand, mg BOD/L</td>
<td>375</td>
<td>37</td>
<td>30</td>
</tr>
<tr>
<td>(1.5 x organic matter conc)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic and Ammonia Nitrogen, mg TKN/L</td>
<td>25</td>
<td>18</td>
<td>1.5</td>
</tr>
<tr>
<td>Nitrogenous Oxygen Demand, mg NOD/L</td>
<td>115</td>
<td>92</td>
<td>7</td>
</tr>
<tr>
<td>(4.6 x TKN conc)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Oxygen Demand, mg TOD/L</td>
<td>490</td>
<td>129</td>
<td>37</td>
</tr>
<tr>
<td>Percent TOD Due to Nitrogen</td>
<td>23.5</td>
<td>71.3</td>
<td>18.9</td>
</tr>
<tr>
<td>Percent Organic BOD Removed</td>
<td>_</td>
<td>90</td>
<td>92</td>
</tr>
<tr>
<td>Percent TOD Removed</td>
<td>_</td>
<td>73.7</td>
<td>92.5</td>
</tr>
</tbody>
</table>

Impacts of Decaying Plant & Algal Matter on Dissolved Oxygen

- Algal Growth Stimulated by Nitrogen
- Dead Algae Falls to Bottom
- Decaying Matter Depletes Dissolved Oxygen Near Bottom of Water Body
- High D.O. during day
- Low D.O. (Hypoxia)
Long Island Sound Bottom Water Dissolved Oxygen

Nitrogen Removal Training Program
Module 1

Nitrogen in Wastewater
Forms of Nitrogen

Total Nitrogen

- Unoxidized - N (Total Kjeldahl Nitrogen)
  TKN

- Oxidized - N

  - Nitrous, Nitric Oxides
  - Nitrite Ion
  - Nitrate Ion

  - Organic-N
    - Ammonia-N
    - Ammonium-N

  SKN (Soluble Kjeldahl N) - includes ammonia(um) N plus soluble organic N

  Solids

  Gas

  Principally Soluble

  Principally Soluble
**Forms of Ammonia**

\[
\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+
\]

Ammonia (toxic to fish) \quad \text{Ammonium (not toxic to fish)}

Near neutral pH, most dissolved ammonia will be in the ionic (\(\text{NH}_4^+\)) form
# Typical Nitrogen Concentrations in Municipal & Industrial Wastewaters

<table>
<thead>
<tr>
<th></th>
<th>Municipal Wastewater</th>
<th>Industrial Wastewater</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High I/I</td>
<td>Low I/I</td>
<td>Septage</td>
<td>Vegetable Based Industry</td>
<td>Animal Based Industry</td>
</tr>
<tr>
<td><strong>NH₄⁺-N</strong></td>
<td>10</td>
<td>25</td>
<td>150</td>
<td>&lt;5</td>
<td>10-1000</td>
</tr>
<tr>
<td><strong>SKN</strong></td>
<td>12</td>
<td>35</td>
<td>200</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>TKN</strong></td>
<td>15</td>
<td>45</td>
<td>300</td>
<td>&lt;5</td>
<td>100-1000</td>
</tr>
<tr>
<td><strong>NO₂⁻-N/NO₃⁻-N</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0 - 500</td>
</tr>
<tr>
<td><strong>BOD₅</strong></td>
<td>80</td>
<td>200</td>
<td>1000</td>
<td>1000</td>
<td>—</td>
</tr>
<tr>
<td><strong>COD</strong></td>
<td>160</td>
<td>450</td>
<td>2000</td>
<td>2500</td>
<td>—</td>
</tr>
</tbody>
</table>

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Transparency 37*
## Typical Concentrations of Nitrogen in Influent & Effluent

<table>
<thead>
<tr>
<th></th>
<th>Raw Municipal Influent</th>
<th>Primary Effluent (No Nitrification)</th>
<th>Secondary Effluent (Nitrified)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NH₄⁺-N</strong></td>
<td>15</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td><strong>SKN</strong></td>
<td>18</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td><strong>TKN</strong></td>
<td>30</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td><strong>NO₂⁻-N</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>NO₃⁻-N</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total N</strong></td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td><strong>Soluble Organic - N</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Organic - N</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nitrogen Balance in an Activated Sludge Plant Flow = 1 MGD, High Rate

Raw Wastewater
250#
10#

Plant Recycle

Primary Sludge
51#

High Rate A. S. Plant

0# to Nitrogen Gas

WAS
84#

125#
(108# in solution, 17# in TSS)

3 Hour HRT
3 Day MCRT

Module 1
Transparency 39
Nitrogen Balance in a Nitrifying Activated Sludge Plant, Flow = 1 MGD

Raw Wastewater
- 250#  
- 10#

Plant Recycle
- 51#

Primary Sludge
- 209#

8 Hour HRT
8 Day MCRT, T=15°C

RAS
- 49#

WAS
- 160#

(143# in solution, 17# in TSS)

0# to Nitrogen Gas
Nitrogen Balance in a Nitrogen Removal Activated Sludge Plant Flow = 1 MGD

- Raw Effluent: 250# (10#)
- 209#
- 51#
- 54#
- 69# (61# in solution)
- WAS
- RAS
- 86# to Nitrogen Gas