Anoxic Treatment Systems
Operation, Cost and Troubleshooting
• Primary mechanism is dissimilation (biological denitrification) by a mixture of facultative heterotrophic bacteria

\[
\text{NH}_3 \rightarrow \text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2 \text{ (gas)}
\]

• Secondary mechanism is through assimilation (biomass growth); uptake is limited: 12-14% by biomass weight

• Need aerobic zone to provide nitrification, and an anoxic (low or zero DO) zone to provide denitrification

• Organic carbon food source (BOD) needed; can use methanol, ethanol, glycerin, acetic acid, untreated wastewater

• Level of denitrification controlled by mixed liquor recirculation rate through the anoxic zone
• Numerous
• Anoxic zone with recycle (Modified Ludzak-Ettinger) is common process
• Others include SBR, on/off aeration system, alternating aerobic/anoxic zones, oxidation ditch with alternating zones, step feed, etc.
• Basic concepts are the same – combination of anoxic and aerobic zones
• Anammox

\[ \text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{N}_2 \text{(gas)} + 2\text{H}_2\text{O} \]
The Modified Ludzack-Ettinger process is designed to use nitrate produced by the aeration zone as an oxygen source for facultative bacteria in the breakdown of raw wastewater in the anoxic basin. The first process in the treatment train is a pre-anoxic basin where influent wastewater, return sludge from the clarifier, and nitrate-rich mixed liquor pumped from the effluent end of the aeration tanks are mixed together. The influent wastewater serves as the carbon source for bacteria, return activated sludge from the clarifier provides microorganisms, and the anoxic recycle pumps provide nitrate as an oxygen source.

Modified Ludzack-Ettinger process
Cost Impacts

- Oxygen: equivalent oxidizing power of 2.86 mg recovered per mg NO₃-N removed
- Alkalinity: 3.6 mg recovered per mg NO₃-N removed; returns half of alkalinity used in nitrification
- Increase in sludge production; dependent on food source used
- Labor
- Depreciation
Construction Costs

• Depends; are you just adding an on/off timer or building a new system?
• Rough rule of thumb:
  a. Modify: $0.5 to $1.0MM per MGD
  b. New: $1.0 to $2.0MM per MGD
Beef slaughter, processing, rendering, tannery

WWTP loading (7 day average)
Flow = 3.5 MGD
Total nitrogen (influent) = 250 mg/l
Total nitrogen (effluent) = 90 mg/l
Total nitrogen removal = 64%

Anoxic system brought on line towards end of fiscal 2006

### Mechanical Plant

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Sludge Removal</th>
<th>Utilities</th>
<th>Chemicals</th>
<th>Total</th>
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2007 - 2008 Average = $1,643,454
2005 - 2006 Average = $1,631,854

$11,600 Difference
Potential Operational Problems

- Think about what makes the process work
- Low recycle rate
- Oxygen carryover from aeration zone to anoxic zone
- Insufficient available (soluble) food
- MLVSS concentration
- Temperature
Low Recycle Rate

• 2 – 4 Q usually required
NO3-N Removal at Varying Recirculation Rates

Recirculation Ratio

Percent Removal

0% 100% 200% 300% 400% 500% 600%
Oxygen Carryover

- Denitrification bacteria need an electron donor (BOD) to get rid of nitrate (NO$_3^-$) which is an electron acceptor
  \[6\text{NO}_3^- + 5\text{CH}_3\text{OH} \rightarrow 3\text{N}_2 + 5\text{HCO}_3^- + 7\text{H}_2\text{O} + \text{OH}^-\]
- Oxygen competes with nitrate as an electron acceptor
- Enzymes (reductases) used by denitrifying bacteria are repressed in the presence of oxygen – impacts assimilation process
Nitrate removal is a function of anoxic tank volume, SDNR (NO$_3$-N/biomass), and F/M$_b$ ratio (BOD/biomass; factors in influent flow rate)

The lower the hydraulic retention time, the higher the F/M$_b$ value, and therefore more BOD in the anoxic zone, but the food must be readily biodegradable in order to get an increase in SDNR

Rule of thumb: BOD:N ratio should be 4:1 – 8:1
\[ \text{NO}_r = (V_{\text{nox}}) \times (SDNR) \times (MLVSS) \]

where \( \text{NO}_r \) = nitrate removed, g/d
\( V_{\text{nox}} \) = anoxic tank volume, m³
SDNR = specific denitrification rate, g NO₃-N / g MLVSS·d
MLVSS = mixed liquor volatile suspended solids concentration, mg/L

SDNR = 0.03 \( (F/M) \) + 0.029

Where \( F/M \) = g BOD applied / g MLVSS·d in the anoxic tank

\[ F/M_b = \frac{QS_o}{V_{\text{nox}}} \times \frac{1}{X_b} \]

Where \( F/M_b \) = BOD F/M ratio based on active biomass concentration, g BOD/g biomass·d
\( Q \) = influent flowrate, m³/d
\( S_o \) = influent BOD concentration, mg/L
\( V_{\text{nox}} \) = anoxic volume, m³
\( X_b \) = anoxic zone biomass concentration, mg/L
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