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Nitrogen Pollution **Solutions**

Managing nitrogen release to meet increasingly stringent standards

Over the better part of the past four decades, secondary wastewater treatment has been the norm, with only a small fraction of facilities having to meet more advanced standards. However, increasing water quality concerns are making nutrient standards common place. Over the next decade, advanced wastewater treatment for nitrogen and phosphorus nutrient removal will become the norm.

In marine and estuarine environments, nitrogen is typically the nutrient of concern. To address growing water quality concerns, control of nitrogen releases to the environment is becoming a top priority for communities across this country, even many inland communities, as rivers ultimately make their way to the sea. This growing concern over nitrogen will result in many secondary treatment facilities having to be upgraded to achieve total nitrogen effluent standards. Wright-Pierce, a leading provider of water, wastewater and infrastructure engineering services, is assisting dozens of municipalities in the Northeast address nutrient standards.

In the typical secondary treatment plant about 20% to 40% of the nitrogen is removed via settling of insoluble forms of nitrogen tied up in influent solids and biomass cell growth/wasting. To remove more nitrogen, a couple of things have to happen. First, the organic nitrogen and ammonia have to be oxidized to nitrite and then to nitrate in an aerobic environment (nitrification). Then in a second step, the nitrate has to be reduced to nitrogen gas under anoxic conditions (denitrification). Denitrification processes can be grouped in two categories: substrate level (exogenous) denitrification and endogenous level denitrification. Substrate level denitrification processes can typically achieve effluent total nitrogen levels in the 6 to 8 mg/l range. These processes are characterized as having an initial anoxic zone (i.e., unaerated zone within the aeration basins) in which the influent BOD is the substrate that drives the denitrification process. When substrate level processes are coupled with endogenous level denitrification, effluent total nitrogen levels of 3 to 5 mg/l are possible, depending on the level of residual non-biodegradable nitrogen. Endogenous level denitrification

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Newly installed 4-stage, Bardenpho process at Glastonbury, CT Water Pollution Control Facility is expected to reduce effluent total nitrogen levels to 3.7 mg/l on an annual average basis , bringing the facility into compliance with the state's General Permit for Nitrogen Discharge limits."

processes are characterized by having anoxic zones at or near the end of the aeration basins. A supplemental carbon source, like methanol, can be used to mimic substrate level reaction rates in the post anoxic zone to reduce the size of the treatment volume and to improve reliability.

There are many biological nitrogen removal process configurations available; which one is best for a given facility is very case specific and depends on a variety of factors such as the effluent standards, the waste characteristics, the exiting treatment plant configuration, site constraints, etc. A brief description of the range of technical solutions and typical applicability is provided below.

Level 1 Nitrogen Limit (6 to 8 mg/l, annual average)

Level 1 nitrogen limits, generally referred to as biological nitrogen removal (BNR), can be achieved biologically through a number of activated sludge process modifications. These process modifications all include the baseline requirement of having aerated (oxic) and anoxic conditions occurring in the bioreactors and typically include:

- Modified Ludzack-Ettinger (MLE)
- Step Feed Denitrification
- Sequencing Batch Reactors (SBR)
- A/O Oxidation Ditches
- Cyclic Aeration processes
- Integrated Fixed Film Activated Sludge (IFAS)
- Membrane Bioreactors (MBR)

Level 2 Nitrogen Limit (3 to 5 mg/l, annual average)

Level 2 nitrogen limits, generally referred to as enhanced nitrogen removal (ENR), can be achieved biologically through a number of activated sludge process modifications. The lower end of Level 2 is considered the current limit of technology. Similar to Level 1, these process modifications all include the baseline requirement of having anoxic and aerated (oxic) conditions occurring in the bioreactors; however, a secondary anoxic and oxic step is typically required. This step can occur within the bioreactors or in a tertiary process (i.e., filtration). In many cases, supplemental carbon is required for the secondary anoxic bioreactors. The process modifications typically include:

- 4-Stage Bardenpho (MLE with secondary anoxic and oxic zones)
- "Level 1" Systems followed by denitrification filter
- Integrated Fixed Film Activated Sludge (IFAS)
- Membrane bioreactors (MBR)

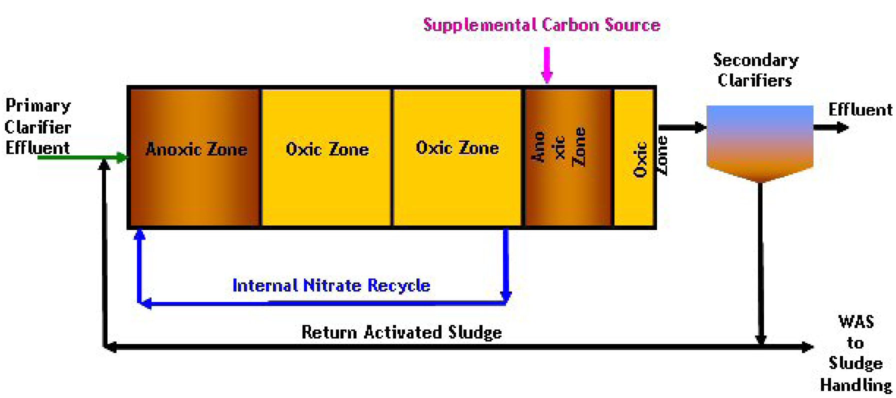
The Modified Ludzack-Ettinger (MLE) process has been used extensively for nitrogen removal and is generally considered the "baseline" alternative when evaluating nutrient removal facilities for Level 1 treatment. The 4-Stage Bardenpho Process has been used extensively for nitrogen removal and is generally considered the "baseline" alternative when evaluating nutrient removal facilities for nitrogen Level 2 treatment.

The Sequencing Batch Reactor (SBR) process is a variation of the activated sludge process that can be sequenced to operate similar to the MLE or Bardenpho Process and produce Level 1 treatment, and can also approach Level 2 treatment. SBRs are commonly employed at small to mid-sized plants.

Membrane bioreactors (MBR) are another activated sludge process modification which uses membrane filtration as a physical barrier (vs. clarification). This typically allows for the system to operate at much higher mixed liquor concentrations which reduces the aeration tank volume required. The MBR process can be configured as either an MLE or Bardenpho process and therefore can achieve either Level 1 or Level 2 treatment. The MBR process has higher capital and operating costs and tends to be considered where there are space constraints or extremely high effluent water quality requirements. (i.e., discharge to a small stream, pretreatment for reverse osmosis, etc.).

The Integrated Fixed Film Activated Sludge (IFAS) process combines suspended growth and attached growth to effectively increase the capacity of an

Four-Stage Bardenpho Process Flow Diagram



activated sludge system. In the IFAS system, "media" is added to the aeration tank to provide the surface for biofilm growth. The main benefit to the IFAS technologies is its ability to provide effective treatment with considerably less aeration tank volume than competing conventional suspended growth technologies. Similar to the MBR alternative, the IFAS process can be configured as either an MLE or Bardenpho process. Typically, the IFAS process is considered where site constraints prevent needed expansion of aeration tanks.

The Extended Aeration Systems (including simultaneous nitrification/ denitrification processes, cyclic aeration processes, various oxidation ditch processes, and Schreiber process) perform in a similar manner to MLE and Bardenpho, except that the kinetic rates are generally accepted to be lower due to the simultaneous nature of nitrification/ denitrification (i.e. less efficient zones). These processes will require larger bioreactor volumes than MLE or Bardenpho processes for the same design loadings. Typically, these processes are viable on sites where there are no space limitations.

Denitrification Filters are commonly used in conjunction with MLE (or similar appropriate) biological process to achieve Level 2 treatment. There are two main, commercially available, process configurations for denitrification filters - downflow and upflow filters. Denitrification filters offer added benefits if very low total suspended solids are desired in the effluent.

There are many BNR process configurations available. The best option for a given facility is case-specific and depends on various factors, including effluent standards, waste characteristics, site constraints, etc.

Photo of Jaffrey NH Wastewater Treatment Facility.

Choosing a Process

Stringent nitrogen standards are on the increase. There are many process options available to achieve low nitrogen standards. We have touched upon a few of the more common options above. These processes can also be coupled with an anaerobic reactor to provide biological phosphorus removal as well as nitrogen removal. The best solution is a function of many variables. It is prudent to analyze all appropriate options and to select a solution on life cycle costs and operational considerations.

MLE Process with Denitfrification Filter Process Flow Diagram