Nitrogen Pollution **Solutions**

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

By William E. Brown, W. Doug Hankins & Edward J. Leonard

Managing nitrogen release to meet increasingly stringent standards

Concern over nitrogen releases will result in many secondary treatment facilities having to be upgraded to achieve total nitrogen effluent 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.

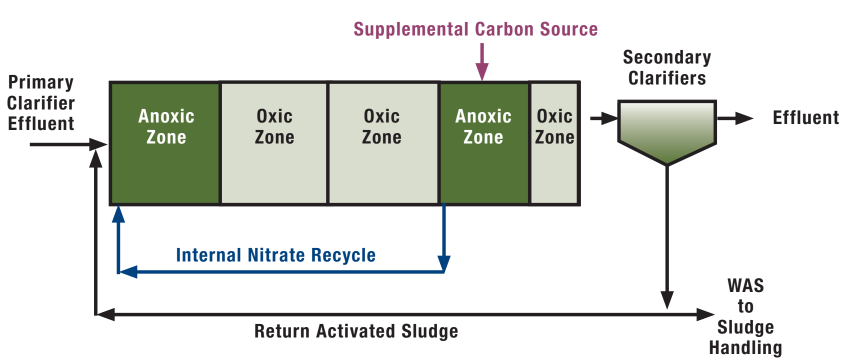
First, the organic nitrogen and ammonia have to be oxidized to nitrite and then to nitrate in an aerobic environment (nitrification). In the second step, the nitrate has to be reduced to nitrogen gas under anoxic conditions (denitrification). Denitrification processes can be grouped in two categories: substrate-level (exogenous) denitrification and endogenous-level denitrification.

Substrate-level denitrification processes can typically achieve effluent total nitrogen levels in the range of 6 to 8 mg/L. These processes are characterized as having an initial anoxic zone in which the influent biochemical oxygen demand 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 nonbiodegradable nitrogen. Endogenous-level denitrification processes are characterized by having anoxic zones at or near the end of the aeration basins. A supplemental carbon source such as methanol can be used to mimic substrate-level reaction rates in the post-anoxic zone to reduce the size of the treatment volume and improve reliability.

There are many biological nitrogen removal (BNR) process configurations available; which one is best for a given facility is case-specific and depends

Figure 1. Four-Stage Bardenpho Process Flow Diagram



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.

on a variety of factors (e.g., effluent standards, waste characteristics, existing treatment plant configuration, site constraints, etc.). A brief description of the technical solutions and typical applicability is provided below.

Level I Nitrogen Limit

Level I nitrogen limits—6 to 8 mg/L annual average and generally referred to as BNR—can be achieved biologically through a number of activated sludge process modifications. These modifications include the baseline requirement of having aerated (oxic) and anoxic conditions occurring in the bioreactors, and they typically include:

- Modified Ludzack-Ettinger (MLE);
- Step-feed denitrification;
- Sequencing batch reactors (SBRs);
- A/O oxidation ditches;
- Cyclic aeration processes;
- Integrated fixed-film activated sludge (IFAS); and
- Membrane bioreactors (MBRs).

Level II Nitrogen Limit

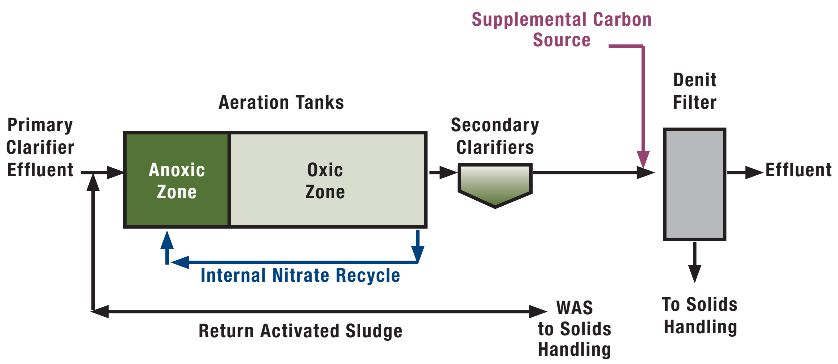
Level II nitrogen limits—3 to 5 mg/L annual average and generally referred to as enhanced nitrogen removal (ENR)—can be achieved biologically through a number of activated sludge process modifications. The lower end of Level II is considered the current limit of technology.

Similar to those of Level I, these process modifications all include the baseline requirement of having anoxic and 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: four-stage Bardenpho (MLE with secondary anoxic and oxic zones); level I systems followed by denitrification filter; IFAS; and MBRs.

The MLE process has been used extensively for nitrogen removal and is generally considered the baseline alternative when evaluating nutrient removal facilities for Level I treatment. The four-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 II treatment.

Figure 2. MLE Process with Dentrification Filter Process Flow Diagram



The 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 I treatment, and it can also approach Level II treatment. SBRs are commonly employed at small to mid-sized plants.

MBRs are another activated sludge process modification that uses membrane filtration as a physical barrier (versus clarification). This typically allows 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 I or Level II 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.

The IFAS process combines suspended growth and attached growth to effectively increase the capacity of an activated sludge system. Media is added to the aeration tank to provide the surface for biofilm growth. The main benefit of IFAS is its ability to provide effective treatment with considerably less aeration tank volume than other technologies. It can be configured as either an MLE or Bardenpho process and is typically considered where site constraints prevent needed expansion of aeration tanks.

Extended aeration systems—including simultaneous nitrification/denitrification processes, cyclic aeration processes, various oxidation ditch processes and the 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 a similar appropriate biological process to achieve Level II treatment, and they come in two commercially available configurations: downflow and upflow filters. They offer added benefits if very low total suspended solids are desired in the effluent.

Choosing a Process

Stringent nitrogen standards are becoming more prevalent. There are many process options available to achieve low nitrogen standards, the more common of which are described above. These can be coupled with an anaerobic reactor to provide biological phosphorus removal and nitrogen removal.

The best solution is a function of many variables. It is prudent to analyze all appropriate options and select a solution on life-cycle costs and operational considerations. WWD

William E. Brown, P.E., is president and CEO of Wright-Pierce. Brown can be reached at 888.621.8156. W. Doug Hankins, P.E., is secondary and tertiary systems technical leader at Wright-Pierce. Hankins can be reached by e-mail at wdh@wright-pierce.com. Edward J. Leonard, P.E., is senior project manager for Wright-Pierce. Leonard can be reached by e-mail at ejl@wright-pierce.com.

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