Nitrogen Removal From Wastewater

Capital Avoidance Strategies

For little to no cost, operations can be changed in order to reduce organic-nitrogen, ammonia and nitrate concentrations in the final effluent of municipal wastewater treatment plants. A discussion of various strategies follows.

Enhanced Ammonification. Because effluent organic-nitrogen concentrations are typically quite low (generally less than 2 mg/L), few treatment plants seek to reduce organic-N.

Nonetheless, treatment facilities with total-Nitrogen limits can oftentimes – with little effort and little cost – improve ammonification to provide an extra 0.5 to 1.5 mg/L reduction in total-Nitrogen.

This is done by creating an ANAEROBIC zone at the front end of the treatment plant. We've done it by converting pre-anoxic denitrification tanks to fully anaerobic conditions by reducing the internal recycle rate and managing the DO in the aeration tanks.

Enhanced Nitrification. Nitrification needs lots of air, not necessarily 2 mg/L, but a goodly amount. Nitrifiers grow slowly and generally need a hydraulic retention time of at least 6 hours, more at temperatures below 15oC. Nitrification requires a high mean cell residence time (sludge age); typically a MCRT of 8 days or more. Nitrification needs alkalinity; if there isn't enough alkalinity in the raw wastewater to maintain at least 50 mg/L, it has to be added.

It is often cheap and easy to create an attractive habitat for nitrifying bacteria using existing wastewater tankage. The least expensive way to improve nitrification is to slow down the flow rate by reducing the internal recycle rate and or RAS rate. This approach may result in monetary savings as well.

The next best way is to raise the dissolved oxygen concentration in the aeration tank(s) or put one or more empty aeration tanks into service. Additional electricity will be required.

If sufficient alkalinity doesn't exist, none of these strategies will work without supplemental alkalinity. Every mg/L of ammonia converted to nitrate consumes 7.1 mg/L of alkalinity. The least expensive way of adding alkalinity is to create it during denitrification. Denitrification adds back about 50% of the alkalinity removed during nitrification. In instances where the conditions are favorable for nitrification, but the reaction is incomplete, ammonia removal might be improved by generating alkalinity by cycling the air off in order to create periods of anoxic conditions. Caution: If dissolved oxygen or retention time are limiting nitrification, this strategy will worsen, not improve nitrification.

In small treatment facilities, 50-pound bags of baking soda (sodium bicarbonate) can be mixed with 100 or more gallons of water in day tanks and pumped into the wastestream using chemical feed pumps. In larger plants, tanker truck deliveries of liquid magnesium hydroxide can be transferred to holding tanks and pumped into the wastestream with chemical feed pumps. Chemicals such as sodium hydroxide are widely used but do present safety concerns.

Nitrification design standards are generally very conservative. It is good to recognize and understand them, but don't allow the textbook "requirements" inhibit experimentation. Most treatment facilities can do more with less.

Nitrogen Removal From Wastewater

Capital Avoidance Strategies

In order to establish and maintain nitrification it is important to monitor Dissolved Oxygen (D.O.), Alkalinity, TKN (and/or Ammonia), and Nitrate daily. Same day results are important! The daily use of test strips such as those manufactured by Hach may be sufficient. The ideal monitoring practice is to use in-line instrumentation connected to a SCADA system.

Regardless of how the data is collected, it won't be of much value unless it is regularly reviewed and used in making process adjustments. Written Standard Operating Procedures (SOPs) can be an invaluable tool.

It has been our experience that once a plant has been set up to effectively nitrify, it continues to do so unless (a) a toxin is discharged into the sanitary sewers, (b) equipment failure, or (c) temperatures fall very low. Facilities that struggle with consistent nitrification are those very few with influent nitrogen concentrations of 75 mg/L or more, or facilities where the basics – e.g., air, alkalinity – are ignored.

Denitrification. For denitrification to occur, nitrified wastewater needs to reside 1-2 hours in a low-oxygen, high BOD environment. The easiest way to create such a space is to cycle the aeration tank air. Another way is to create an a low oxygen area of sufficient size ahead of the aeration tank(s) and to pipe all return activated sludge to the inlet end of the anoxic tank so that it mixes with the incoming wastewater.

The two key parameters for denitrification are low DO (less than 0.5 mg/L) and surplus BOD (ideally around 5 mg/L of soluble BOD per mg/L of nitrate produced during nitrification). It is also important to mix the contents of the anoxic tank. This can be done using mixers, or if it is possible to direct influent flow into the settled layer of mixed liquor during the aeration-off cycle, it may be done without the need for any mechanical mixing.

The effectiveness of pre-anoxic denitrification tanks are often limited by the amount of available BOD. Any number of strategies are available to improve BOD availability. The fact is, not all BOD is the same to denitrifying bacteria. Particulate BOD (that included with TSS) is of little use. Of the soluble forms of BOD, denitrifying bacteria most effectively utilize volatile fatty acids (VFAs) and simple carbon chains such as alcohols.

Sufficient BOD often exists in influent. If too much BOD is being removed during primary treatment to provide the 5:1 ratio, better results may be obtained by taking one or more primary clarifiers out of service.

If enough BOD exists, but it is largely insoluble, it may be necessary to provide a short period of aeration prior to the anoxic stage. The pre-aeration period will allow for the particulate BOD to be made soluble and therefore available to the denitrifying bacteria.

If there isn't enough BOD coming in to satisfy demand, it may be possible to supplement using internal waste streams. One practice is to create fermentation tanks. "Fermentation" is essentially the same thing as anaerobic treatment except that the waste gets just enough air to prevent methane production. This can be done by periodically (for example, an hour per day) aerating the anaerobic waste.

Nitrogen Removal From Wastewater

Capital Avoidance Strategies

The most common sources of fermented waste are primary gravity thickeners and recycled waste sludge from sludge holding tanks. Another excellent source is septage. Septage contains a significant quantity of volatile fatty acids. Volatile fatty acids (VFAs) are not only good food for denitrifying bacteria, VFAs promote biological phosphorus removal. Treatment facilities that receive septage take in a BOD source that is well suited to denitrification. The challenge is to pace the septage flow and to divert it to where it is most needed.

When denitrification tanks are established ahead of aeration tanks, design manuals typically call for the internal recycling of 300% of the influent flow to move the nitrified mixed liquor into the anoxic zone. at a rate of 300% of influent flow. We've found this rate to be much too high. It is not only possible to denitrify with no internal recycling (under the right conditions), we have found it almost commonplace for treatment plants to recycle so much flow that denitrification is inhibited. Too high of an internal recycle rate brings in too much oxygen and reduces the anoxic retention time below what is necessary for denitrification to occur.

It has been our experience that effective denitrification enhances operations. It almost always creates a mixed liquor with less foaming, and a bacterial population that settles better in clarifiers. And, denitrification adds back alkalinity, which in turns assists nitrification.

Although a hardier biochemical process, we've found that the denitrification process in many facilities requires more day-to-day fine tuning than is required to maintain effective nitrification. A loss of denitrification – unlike restoring nitrification, a process than can take weeks to accomplish – can typically be remedied in two or three day's time. If denitrification is lost, it may be necessary to temporarily provide the nitrification tank with a dose of chemical alkalinity to compensate for the alkalinity that would have been returned if denitrification were ongoing. This, because denitrification adds 3.5 mg/L of alkalinity for every mg/L of nitrate converted to nitrogen gas.