Large subsurface wastewater treatment system process control monitoring for nitrogen

Troubleshooting guidance

The following guidelines are intended to be used by large subsurface wastewater treatment system (LSTS) operators in addition to the Operation and Maintenance manual to assist with process control. The goal of this process control monitoring is to obtain data that will help in evaluating and understanding the nitrogen removal process at your facility and is necessary for making informed operational changes related to total nitrogen removal.

Raw domestic wastewater typically contains 40-70 milligrams per liter (mg/L) of total nitrogen that enters the wastewater treatment facility in the form of Total Kjeldahl Nitrogen (TKN). Nitrification is an aerobic treatment process that converts ammonia to nitrate and is the first step in the removal of total nitrogen. Nitrification is often the most difficult step in meeting the permit-required end of pipe total nitrogen limits set by the Minnesota Pollution Control Agency.

Total Nitrogen = TKN + nitrate + nitrite
TKN = organic nitrogen + ammonia

Temperature

Nitrification rates drop significantly at low temperatures. Typically, the temperature must be greater than 7 degrees Celsius to maintain nitrification. Once nitrification is lost due to low temperatures, it is very difficult to re-establish a population of nitrifying bacteria without warming the water. Therefore, care should be taken to protect the system from low temperatures.

- Systems with large surface areas exposed to the elements like wetlands and sand filters should consider covering or insulating the cells during winter months. Impacts to dissolved oxygen (DO) should be considered as covers may also reduce air movement and lower DO concentrations.
- Systems with the ability to increase the biomass (active population of bacteria) should consider doing so before going into winter to account for the slower growth rates of the bacteria. For suspended growth systems, this would involve increasing the SRT and/or tank volume. For attached growth systems, this would involve increasing the surface area available for the bacteria.
- Increasing recirculation rates typically provide better treatment however increasing recirculation rates can also lower temperatures.
- If nitrification cannot be maintained due to temperature, the facility should consider:
  - Housing the treatment system in a heated building
  - Providing additional insulation to tanks and treatment units
  - Heating the wastewater
  - Preheating the air used in aeration
  - Bio augmentation by adding colonies of nitrifying bacteria.

pH/alkalinity

It is recommended that the potential of hydrogen (pH) of the wastewater be between 6.8 and 8.0 to maintain consistent nitrification. It is also important to have a consistent pH to allow the bacteria to acclimate. Alkalinity will act as a buffer in controlling the change in pH. In order to verify that enough alkalinity is available to stabilize the pH, it is recommended that the effluent alkalinity be at least 50 mg/L with a level of 100 mg/L preferred. The process of nitrification will consume 7.14 milligrams (mg) of alkalinity per 1 mg of ammonia converted to nitrate. Therefore, having high influent ammonia can significantly reduce alkalinity reducing the nitrification rate. Systems with low alkalinity that experience large swings in pH or pH levels outside of the recommended operating range should:

- Add alkalinity in the form of chemical addition.
- Consider internal recycle of denitrified wastewater back to the pretreatment unit. Half of the alkalinity used to nitrify can be recovered through the denitrification process.
- Check influent for toxic condition contributing to high/low pH.

Dissolved oxygen

Dissolved oxygen (DO) levels less than 2 mg/L can limit nitrification. It is important to maintain 2 mg/L throughout the aeration zone. DO should be checked at multiple points in the system to ensure there are not locations with low DO. If DO is lower than 2 mg/L:

- Increase the time that blowers are operating.
- Increase the number of blowers that are operating if possible.
- Check diffusers and pipes for breaks or leaks.
- Checking air pressure and flow rates regularly can help with detection of leaks.
- Increase recirculation rates.
- Check influent loading and any return flows that might be high in loading.
- It is also important that DO is not too high as the denitrification process will need an anoxic condition with no free oxygen. Any oxygen passed on to the denitrification process will consume additional biochemical oxygen demand (BOD) and require additional tank volume before the anoxic condition is met.

Ammonia

Nitrification converts ammonia to nitrate. Measuring ammonia after the nitrification process verifies that the facility is nitrifying. The ammonia after nitrification should be as low as possible; typically systems designed for complete nitrification have ammonia of 1 mg/L or less. Any rise in ammonia from normal operating conditions should be monitored closely as it may indicate the system is losing nitrification. Remaining ammonia passed on to the denitrification process will not be treated further which will contribute to the effluent total nitrogen. Effluent total nitrogen contains untreated ammonia, non-reactive organic nitrogen, nitrogen tied up in the bacterial cells and any nitrate remaining after denitrification. Therefore, ammonia concentration above 5 mg/L just prior to denitrification may prohibit the facility from meeting a 10 mg/L total nitrogen limit. If ammonia levels begin to rise:

- Follow above guidance for temperature, pH/alkalinity and DO
- Verify actual pumping rates and recirculation rates
- Check for short circuiting/even distribution of wastewater across the tank/media
- Increase recirculation rate
- Increase solids retention time
- Check for toxicity
- Evaluate treatment capacity with respect to influent BOD and TKN loading

Nitrate

Denitrification is the final step to remove total nitrogen and is the reduction of nitrate into nitrogen gas. The concentration of nitrate at this point in the process indicates the amount of carbon source (BOD) needed to denitrify. Approximately 4 mg/L of BOD is required for every 1 mg/L of nitrate removed. Depending on the process configuration, this carbon demand will need to be met through either chemical addition or by recycling nitrified effluent to the head of the plant to pick up the BOD in the septic tank or a combination of both. The concentration of nitrate also indicates the potential alkalinity that may be recovered for use in the nitrification pretreatment tanks.

Things to consider in the denitrification process if nitrate remains high in the effluent and ammonia is low:

- Presence of DO will prevent the denitrification of nitrate. DO could be coming from many sources.
    - Too much DO in the flow from the nitrifying unit, return flows or the use of air lift pumps
    - Too much turbulence from mixing resulting in air entrainment
    - Back mixing from the aeration zones may introduce DO and prevent an anoxic condition
- Insufficient mixing leading to short circuiting and reduced efficiency.
- Insufficient carbon source due to empty chemical feed tanks, worn chemical feed tubes and/or fittings, broken or plugged chemical feed lines, etc.
- Overloading of the system beyond design conditions.
- Mixing should not damage media or prevent biofilms from establishing on the media.

In addition to the above internal monitoring parameters, influent wastewater characteristics are important in evaluating operational changes. The presence of toxicity or high influent total nitrogen may require some facilities to add additional treatment capacity or find the source of toxicity.