Nitrification Basics for Wastewater Systems

The rendering industry has a specific challenge not encountered in most wastewater systems in the form of handling unusually high amounts of ammonia in meeting effluent discharge compliance. When plants and animals die in nature, they are mainly degraded by bacteria and the nutrients are recycled back to nature. Nature has a way of self-correcting itself to keep everything in balance.

One major source of correction or adjustment is nitrification. Nitrification is defined as the biological or biochemical removal (oxidation) of ammonia (NH₄⁺) by certain bacteria in the presence of oxygen. This special group of bacteria are called “nitrifiers,” “nitrifying bacteria,” or “nitrification bacteria.” Wastewater generated by the rendering industry along with other protein-related food processing industries will generate high levels of ammonia due mainly to the biological breakdown of proteins.

This process generally proceeds as proteins are degraded through the action of special enzymes called proteases. Amino acids are further degraded to organic compounds with the generation of ammonia through a process called deamination. Deamination of amino acids can proceed under both aerobic (with oxygen) and anaerobic (without oxygen) conditions. The generation of the resulting ammonia will be in two major forms, depending upon the pH of the waste. At a higher pH (more than 9.0), ammonia will be in the gaseous form, NH₃, and at a lower pH (less than 9.0) in the water-soluble ammonium ion form, NH₄⁺. The gaseous form at a higher pH is the most toxic form to humans, animals, and aquatic life. Nitrification bacteria will be interested in the NH₄⁺ ammonium ion form.

Below are the basic process requirements for the nitrification process.

1. Approximately 4.6 milligrams per liter (mg/L) or parts per million (ppm) of oxygen (Environmental Protection Agency 1975) is required for every ppm NH₄⁺ oxidized to nitrates (NO₃⁻). Another way of looking at this is 4.6 pounds of oxygen is needed to remove one pound of ammonia (NH₄⁺) while maintaining a minimum baseline of 50 mg/L total alkalinity.

5. Approximately 7.2 mg/L of alkalinity is required to remove one mg/L of ammonia (NH₄⁺) while maintaining a minimum baseline of 50 mg/L total alkalinity.

6. Alkalinity boosters are generally needed in low alkalinity wastewaters because nitrification is an acid generating process. Some candidates for use are sodium carbonate (Na₂CO₃), sodium bicarbonate (NaHCO₃), calcium carbonate (CaCO₃), caustic soda (NaOH), and lime (Ca(OH)₂). Lesser-known alkalinity boosters used with great results are those derived from seawater, which contain beneficial trace minerals needed and stabilized carbonates in the form of magnesium and calcium salts.

7. Proper temperature control is needed to maintain proper growth rates of nitrifying bacteria. Their naturally slow growth rates in comparison to heterotrophic (CBOD removing) bacteria is problematic during cold weather. An ideal temperature range would be 28 to 30 degrees Celsius (C) for full activity. Nitrification proceeds at approximately 50 percent at 15 degrees C, 20 percent at 10 degrees C, and zero percent at five degrees Celsius or less. Wastewater lagoons are most susceptible to temperature inhibition because of larger wastewater volumes and less bacterial concentrations per milliliter.

Inhibition of Nitrification in Rendering and/or Kill Plants

The degradation by-products of proteins, fats, and cleaners/sanitizers can challenge nitrification bacteria if not properly treated. Ammonia (high levels), sulfide, and organic acid by-products or intermediates from protein degradation can be inhibitory as well as fatty acids and glycerol (an alcohol) generation from fats, oils, and grease degradation.

Sanitizers and cleaners such as quaternary ammonium compounds, surfactants (anionic, non-ionic), and wastewater treatment polymers can produce ammonia, organic acid, and alcohol by-products that can also be inhibitory. These inhibitions are more pronounced in systems without pretreatment and/or anaerobic digesters to lower concentrations of the aforementioned entities prior to aerobic treatment. Even with these treatment steps included, ammonia levels have been observed in some instances to exceed 1,000 mg/L in the influent to the aerobic processes designed to handle nitrification and CBOD removal. High levels of ammonia can cause substrate inhibition (toxicity) of the nitrification process.

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<tr>
<th>Table 1. Classical Equations for the Nitrification Process</th>
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<tr>
<td>NH₄⁺ + Oxygen (O₂) + Nitrosomonas spp. → NO₂⁻ + O₂ + Nitrobacter spp. → NO₃⁻ (ammonium ion) (nitrate)</td>
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<tr>
<td>Nitrification is an aerobic, acid-generating process, with the following process equations: NO₂⁻ + 2.0 O₂ → NO₃⁻ + 2H⁺ + water + energy NO₂⁻ + 0.5 O₂ → NO₃⁻ + energy NH₄⁺ + 2.0 O₂ → NO₃⁻ + 2H⁺ + water + energy (Overall net reaction)</td>
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Bioaugmentation as an Aid to Nitrification

The likelihood of having the benefit of soil runoff or some form of inflow/infiltration is slim to non-existent. As a result, nitrifying bacteria will not be naturally added to aerobic systems. Most wastewater systems in the rendering industry have anaerobic digesters in front of or upstream of aerobic processes and will get zero nitrifying bacteria with the influent. They will simply have to be added to the process from another source.

One source is to add activated sludge from a similar process containing high numbers of nitrifying bacteria. The other source is to add a commercially available bioaugmentation product. Seeding with another activated sludge source generally will not contribute to the number or activity of nitrifying bacteria needed in the short term. There is also the risk of adding some unwanted bacteria such as filamentous bacteria that can cause some sludge bulking and other issues such as excessive foaming.

The best solution is to add commercially available nitrifying bacteria to produce the desired nitrification or ammonia removal results. Products containing *Nitrosomonas* spp. and *Nitrobacter* spp. are the most common and best rated based on activity (nitrogen removal rates) rather than count value. This is an important point in evaluating products from vendors.

Effective products generally have an average range of 500 mg NH₃ and 500 mg NO₂⁻ removal per hour per kilogram or liter product. Count values (colony-forming units per milliliter) are hard to obtain due to the difficulty to culture nitrifying bacteria using traditional plate methods. Trace mineral based bio-stimulants have been extremely helpful in accelerating nitrification rates. This author has observed increased nitrification rates at 10 degrees C with the use of such products.

Conclusion

Winter months traditionally offer the greatest challenges in meeting ammonia compliance results. Proper process controls along with the proper activity levels of nitrifying bacteria are essential.

Nitrification can be a challenging process under normal conditions in rendering wastewater plants due to the higher concentrations of ammonia generated compared to municipalities and other industries. The lowering of wastewater temperatures will only exacerbate the common problems encountered. Having the proper insights to process control and knowledge of bioaugmentation solutions will be ultimately helpful.

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Large colony of stalked ciliate thriving in sequence batch reactor under low ammonia conditions at 100 times phase contrast.