Lagoon Microbiology

By David Branham

Summertime poses special circumstances for wastewater operators. The changes in temperature has a direct effect on the predominate microorganisms and thus affects both activated sludge, as well as lagoons. This article will address what happens in a lagoon system.

This is to acknowledge that much of this article was taken from "Lagoon Systems in Maine," an internet article with no author given. I have found that the internet is an invaluable source of information.

Microorganisms found in aerated facultative ponds are more diverse than those observed in many other biological treatment processes, due to the diverse growth environments present. Both aerobic and anaerobic bacteria are involved as well as algae and some higher life forms such as protozoon's, rotifers, daphnia, and insect larvae.

Aerobic Bacteria

The **aerobic bacteria** that occur are similar to those found in other treatment processes such as activated sludge. Three functional groups occur: freely dispersed, single bacteria; floc-forming bacteria; and filamentous bacteria. All function similarly to oxidize carbon (BOD) to produce CO_2 and new bacteria as new sludge.

Many bacterial species that degrade wastes grow as single bacteria dispersed in the wastewater. Although these readily oxidize BOD, they do not settle and hence often leave the lagoon system in the effluent as solids (TSS). These tend to grow in lagoons at high organic loading and low oxygen conditions. Even more important are the **floc-forming bacteria**, those that grow in a large aggregate (floc) due to exocellular polymer production (the glycocalyx). This growth form is important as these flocks degrade BOD and settle at the end of the process, producing a low TSS effluent.

A number of **filamentous bacteria** occur in lagoon, usually at specific growth environments. These generally do not cause any operational problems in lagoons, in contrast to activated sludge where filamentous bulking and poor sludge settling is a common problem.

Most **heterotrophic bacteria** have a wide range in environmental tolerance and can function effectively in BOD removal over a wide range in pH and temperature. Aerobic BOD removal generally proceeds well from pH 6.5 to 9.0 and at temperatures from 3-4 °C to 60-70 ºC (mesophilic bacteria are replaced by thermophilic bacteria at temperatures above 35ºC). BOD removal generally declines rapidly below 3-4ºC and ceases at 1-2ºC.

A very specialized group of bacteria occurs to some extent in lagoons (and other wastewater treatment systems) that can oxidize ammonia via nitrite to nitrate, termed nitrifying bacteria. These bacteria are strict aerobes and require a redox potential of at least +200 m V (Holt et al. 1994). It was once thought that only two bacteria were involved in nitrification: Nitrosomonas europaea, which oxidize ammonia to nitrite, and Nitrobacter winogradskyi, which oxidizes nitrite to nitrate. It is now known that at least five genera of bacteria oxidize ammonia and at least three genera of bacteria oxidize nitrite (Holt et al. 1994)

Besides oxygen, these nitrifying bacteria require a neutral pH (7-8) and substantial alkalinity (these autotrophs use CO_2 as a carbon source for growth). The pH effects on the growth of nitrifying bacteria indicates that complete nitrification would be expected at pond pH values between pH 7.0 and 8.5. Nitrification ceases at pH values above 9 and declines markedly at pH values below 7. This results from the growth inhibition of the nitrifying bacteria.

Nitrification however is not a major pathway for nitrogen removal in lagoons. Nitrifying bacteria exists in low numbers in lagoons. They prefer attached growth systems and/or high MLSS sludge systems.

Anaerobic Bacteria

Anaerobic, heterotrophic bacteria that commonly occur in lagoons are involved in methane formation (acid-forming and methane bacteria) and in sulfate reduction (sulfate reducing bacteria). Anaerobic methane formation involves three different groups of anaerobic bacteria that function together to convert organic materials to methane via a three step process.

General anaerobic degraders – many genera of anaerobic bacteria hydrolyze proteins, fats, and poly saccharides present in wastewater to amino acids, short chain peptides, fatty acids, glycerol and mono - disaccharides. These have a wide environmental tolerance in pH and temperature.

Acid-forming bacteria - this diverse group of bacteria converts products from above under anaerobic conditions to simple alcohols and organic acids such as acetic, prop ionic, and butyric. These bacteria are hardy and occur over a wide temperature and pH range.

Methane forming bacteria – these bacteria convert formic acid, methanol, methylamine, and acetic acid under anaerobic conditions to methane. Methane is derived in part from these compounds and in part from CO_2 reduction. **Methane bacteria** are environmentally sensitive and have a narrow pH range of 6.5 – 7.5 and require temperatures > 14 ° C.

Note that the products of the acid formers (principally acetic acid) become the substrate for the methane producers. A problem at times exists where the acid formers overproduce organic acids, lowering the pH below where the methane bacteria can function (a pH < 6.5). This can stop methane fonnation and lead to a build up of sludge in a lagoon with a low pH. In an anaerobic fennenter, this is called a "stuck digester". Also, methane fennentation ceases at cold temperature, probably not occurring in most lagoons in the wintertime in cold climates.

A number of anaerobic bacteria (14 genera reported to date (Bolt et al. 1994) called **sulfate reducing bacteria** can use sulfate as an electron acceptor, reducing sulfate to hydrogen sulfide. This occurs when BOD and sulfate are present and oxygen is absent. Sulfate reduction is a major cause of odors in ponds.

Photosynthetic Organisms

Anaerobic, photosynthetic bacteria occur in all lagoons and are the predominant organisms in anaerobic lagoons. The anaerobic sulfur bacteria, generally grouped into the red and green sulfur bacteria and represented about 28 genera (Ehrlich, 1990), oxidize reduced sulfur compounds (H2S) using light energy to produce sulfur and sulfate, thus H2S is used in place of H2O as used by algae and green plants, producing SO4 – instead of O2.

All are either strict anaerobes or microaerophilic. Most common are Chromatium, Thiocystis, and Thiopedia, which can grow in profusion and give a lagoon a pink or red color. Finding them is most often an indication of organic overloading and anaerobic conditions in an intended aerobic system. Conversion of odorous sulfides to sulfur and sulfate by these sulfur bacteria is a significant odor control mechanism in facultative and anaerobic lagoons, and can be desirable.

Algae are aerobic organisms that are photosynthetic and grow with simple inorganic compounds (C02, NH3-, and PO4-) using light as an energy source.

** A special note here is that algae produce oxygen during daylight hours and consume oxygen at night.

Algae are desirable in lagoons as they generate oxygen needed by bacteria for waste stabilization. Three major groups occur in lagoons, based on their chlorophyll type: brown algae (diatoms), green algae, and red algae. The predominant algal species at any given time is dependent on growth conditions, particularly temperature, organic loading, oxygen status, nutrient availability, and predation pressure.

A fourth type of "algae" common in lagoons is the cyano-bacteria or **blue-green bacteria.** These organisms grow much as the true algae, with the exception that most species can fix atmospheric nitrogen. Blue-green bacteria often bloom in lagoons and some species produce odorous and toxic by-products. Blue-green bacteria appear to be favored by poor growth conditions including high temperature, low light, low nutrient availability (many fixed nitrogen) and high predation pressure. Common blue-green bacteria in waste treatment systems include Aphanothece, Microcystis, Oscillatoria, and Anabaena.

Algae can bloom in lagoons at any time of the year (even under the ice); however, a succession of algal types occurs over the season.

There is also a shift in the algal species present in a lagoon through the season, caused by temperature and rotifer and Daphnia predation. **Diatoms** usually predominate in the wintertime at temperatures < 60°F. In the early spring when predation is low and lagoon temperature increases above 60°F, green algae such as Chlorella, Chlamydomonas, and Euglena often predominate in waste treatment lagoons. The predominant green algae changes to species with spikes or horns such as Scenesdesmus Micractinium, and Ankistrodesmus later in the season when Rotifers and Daphnia are active. Note: These species survive predation better.

Algae grow at warmer temperature, longer detention time, and when inorganic minerals needed for growth are in excess. Alkalinity (inorganic carbon) is the only nutrient likely to be limiting for algae growth in lagoons. Substantial sludge accumulation in a lagoon may become soluble upon warming in the spring, releasing algae growth nutrients and causing an algal bloom. Sludge resolution of nutrients is a major cause of high algal growth in a lagoon, requiring sludge removal from the lagoon for correction.

The pH at a treatment lagoon is determined by the various chemical species of alkalinity that are present. The main species present are carbon dioxide (CO_2, bicarbonate ion (HCO_3), and carbonate ion (CO_3). High amounts of CO_2 yield a low lagoon pH, while high amounts of CO_3 yield a high lagoon pH.

Bacterial growth on BOD releases CO_2 which subsequently dissolves in water to yield carbonic acid (H_2CO_3). This rapidly dissociates to bicarbonate ion, increasing the lagoon alkalinity. Bacterial oxidation of BOD causes a decrease in lagoon pH due to CO_2 release.

Algae growth in lagoons has the opposite effect on lagoon pH, raising the pH due to algal use for growth of inorganic carbon (CO_2 and HCO_3). Algal growth reduces the lagoon alkalinity which may cause the pH to increase if the lagoon alkalinity (pH buffer capacity) is low. Algae can grow to such extent in lagoons (a bloom) that they consume for photosynthesis all the CO_2 and HCO_3 – present, leaving only carbonate (CO_3) as the pH buffering species. This causes the pH of the lagoon to become alkaline. pH values of 9.5 or greater are common in lagoons during algal blooms, which can lead to lagoon effluent pH violations (in most states this pH = 9). It should be noted that an increase in the lagoon pH caused by algal growth can be beneficial. Natural disinfection of pathogens is enhanced at higher pH. Phosphorus removal by natural chemical precipitation is greatly enhanced at pH values greater than pH 8.5. In addition ammonia stripping to the atmosphere is enhanced at higher pH values (NH_3 is strippable, not NH_4^+).

This should give you a good idea of what is happening in your system, and why it is important to monitor the pH value as well as the alkalinity of your system. See ya down the road. Dave