Operational Myths about Nitrification

(How to recognize
several common misperceptions
about nitrification)

By David Branham

First and foremost one must understand what takes place when nitrification occurs; therefore I believe that a definition of nitrification is in order. This definition is taken from *Phosphorus and Nitrogen Removal from Municipal Wastewaters Principles and Practice.*

Let us start with where sources of nitrogen in wastewater originate. Municipal wastewater of predominantly domestic origin contains nitrogen in the organic and ammonium forms. These are primarily waste products originating from protein metabolism in the human body. In fresh sewage about 60 percent of the nitrogen is in the organic form and 40 percent in the ammonium form. Bacterial decomposition of proteinaceous matter and hydrolysis of urea transform organic nitrogen to the ammonium form. Normally very little (less than 1 percent) of the nitrogen in fresh sewage is in the oxidized form of nitrate or nitrite.

Now let us look at what happens when nitrification occurs. Nitrification is the biological oxidation of ammonia to nitrate with nitrite formation as an intermediate. The microorganisms involved are the autotrophic species Nitrosomonas and Nitrobacter which carry out the reaction in two steps:

$$2\,NH_4^+ + 3\,O_2 \xrightarrow{\text{Nitrosomonas}} 2\,NO_2^- + 2\,H_2O + 4\,H^+ + \text{new cells}$$

$$2\,NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2\,NO_3^- + \text{new cells}$$

Ok so let's take a look at some of the myths about nitrification, bearing in mind that the extent of nitrification that occurs during treatment is dependent on the extent to which nitrifying organisms are present.

Myth No. 1: A Specific MCRT Is Required

In this myth it has been told that a certain mean cell residency time (MCRT) is needed to nitrify, but in reality, the MCRT required for nitrification depends on many factors. Some of the more important factors include such things as hydraulic retention time (HRT), wastewater strength, effluent limitations, temperature, pH, alkalinity, correct levels of dissolved oxygen (DO), and of coarse, solids retention time (SRT). And it is important to remember that each of these variables affects the others. What the operator needs to take into account and consideration in order for the plant to nitrify is that:

- Temperature affects the nitrification rate.
- DO levels in mixed liquor affect the nitrification rate (this can be site-specific).
- BOD levels in secondary influent affect the MLSS concentration required for nitrification.

It is important to remember that once begun, nitrification rapidly proceeds to completion unless impeded by some other condition or factor. Adding more biomass to an aeration basin usually will not solve a nitrification problem. Experience has shown, with operating facilities, that nitrification is possible in MCRTs ranging from 6 to 12 days in warmer weather states such as Mississippi. Nitrification is usually inevitable and will occur unless limited by detention time or DO concentration. The lesson here being that once enough biomass is present, doubling the biomass will not double the nitrification rate.

Myth No. 2: Lengthy Detention Times Are Necessary

One of the common misconceptions is that nitrification requires lengthy detention times. In fact, nitrification can be achieved at detention times much shorter than commonly thought, depending on SRT, temperature, DO levels, and an aeration tank's geometry. What this may mean is that as detention time decreases, an aeration tank's MLSS concentration can increase to compensate for loss of detention time. It is important to remember that nitrification is possible at detention times of 4 to 6 hours, but bear in mind that tank geometry becomes all important during shorter detention times. One of the most problematic for this seems to be the complete-mix tanks; they tend to have more short-circuiting problems than plugflow type of tanks.

Myth No. 3: Nitrification is Difficult
This myth involves the level of difficulty associated with the nitrification process itself. One example, commonly believed, is that a two-stage process is needed to achieve nitrification. But in reality, single-stage nitrification is more reliable and much less expensive in terms of total effluent quality than two-stage nitrification.

The theory of two-stage nitrification was popular in the 1970s. The belief being, that nitrification is fragile, temperamental, and cannot occur in a high-BOD environment; thus, the process needs its own tank in which to be processed. In truth, nitrification is a stable and fairly rugged process as long as sufficient MCRT, detention time, and BOD are provided.

It is the belief of most operators, in the field, that the two-stage nitrification is a great waste of tankage, and the second stage often has difficulty keeping a flocculent heterotrophic biomass alive, resulting in high levels of total suspended solids in the effluent.

Myth No 4: A Certain BOD Level Is Required
Another common myth holds that BOD must fall to 20 mg/L before nitrification can begin. However, bucket test and aeration tank profiles have shown that nitrification is a continual process that begins as soon as DO is sufficient to allow nitrifying bacteria to operate. Unlike heterotrophs that consume BOD, nitrifiers consume ammonia at a fixed rate. Remember that nitrifiers and heterotrophs that consume BOD do not "eat" the same food, and that nitrifiers do not care about BOD levels.

In a bucket test conducted at the Bay View Water Reclamation Facility (Toledo, Ohio), primary effluent and return activated sludge (RAS) were combined in a 5 gallon bucket in proportions approximately equal to their amounts in the aeration tanks and aerated. Samples were taken at intervals. After an initial lag period, nitrification proceeded at a steady pace until it was nearly depleted. Thus "***MYTH BUSTED***".

Myth No. 5: Specific DO Levels Are Required
It is a common belief among operators that DO levels of 2 to 3 mg/L or more are required to achieve nitrification but in reality, the amount of DO required for nitrification is very site-specific and varies according to many factors such as detention time, BOD loadings and tank geometry. Variations of the level of DO required could vary from less than 0.5 mg/L to more than 4 mg/L.

But keep in mind that it is important to remember that DO concentrations in mixed liquor are crucial to successful nitrification, because the nitrification rate depends on the concentration – that is, the minimum DO required for nitrification to begin; it is site-specific and will vary based on many factors, including detention time, BOD loading, food-to-microorganism ratio, tank geometry, and temperature. Let's take a look at some of the factors involved.

- As detention time increases, DO can be lower because there is more time for nitrification before the water is discharged.
- As BOD load increases, so does the demand for oxygen.
- As BOD load increases, DO outside the flock must be higher to ensure that sufficient DO remains inside the flock for nitrification.
- In terms of tank geometry, folded, multipass plug flow, tanks are the most space-efficient, however, complete-mix tanks, while less space-efficient evenly distributes BOD load throughout the tank and may enable operation at lower mixed liquor DO levels.
- Temperature can influence DO in several ways; in warmer weather, oxygen is less soluble in water making it more difficult to maintain a set DO level.

Myth No 6: BOD Loadings Must Be Strictly Limited
In the publication of *10 States' Standards,* it has been a recommendation that BOD loadings in a nitrifying system should be limited to 0.02 lb/ft^3.d. However, nitrification can be achieved at BOD loadings at least double the loadings suggested by regulatory authorities. Increasing the BOD load increases the MLSS required for nitrification and although a practical limit exists it is usually higher

than specified by the *10 States' Standards.* The table below taken from an article in WE&T publication, (June 2006). Research done by James P. Scisson, Jr., Senior Design Specialist, clearly bears out this fact.

WWTP	BOD Load, lb/ ft^3.d
Cincinnati Mill Creek	0.045
Lucas County - Maumee River	0.040
Toledo Ohio	0.025
Lower Little Miami Warren County, Ohio	0.030
BOD = biochemical oxygen demand. WWTP = wastewater treatment plant	

Myth No. 7: Nitrification Solids Settle Slowly
This myth posits that solids resulting from nitrification are light and fluffy thus settling much more slowly than non-nitrifying solids. But in reality nitrifying solids are older and more oxidized and therefore settle better. The hallmark of most single-stage nitrification facilities is a low sludge volume index (SVI) usually in the range between 50 to 100 with a clear effluent. Problems with filamentous bulking or *Nocardia* occur occasionally, these are exceptions and not the rule. In a two stage plant the second-stage MLSS tends to settle like a rock, with SVIs ranging from 50 to 70.

Recommended Standards for Wastewater Facilities (1997; Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers) – commonly referred to as the 10 States' Standards – calls for a recommendation for a peak clarifier surface overflow rate of 1000 gal/ft^2.d for plants to nitrify, as opposed to the standard of 1200gal/ft^2.d for plants that do not nitrify. And this brings up an interesting question. Why would solids that settle better need a lower surface overflow rate? Again I refer to studies done by James P. Scisson, and he states that, in fact, surface overflow rates from several treatment facilities indicate it is possible to operate facilities at flows as much as 100% of the peak rate recommended by the 10 States' Standards.

Myth No. 8: A High Percentage of RAS Is Required
The last and final myth I would like to talk about holds that a high percentage of RAS is required for nitrification, when in fact, activated sludge behaves in much the same fashion regardless of whether it nitrifies or not. Nitrification can be successful at return rates of less than 30%. However, problems can occur with septic sludge at low return rates, and again this is very site-specific.
In conclusion I would say that nitrification can be much easier than is taught, especially if operators pay close attention to facts and avoid nitrification fictions. And again as I have said many times in the past, **LAB, LAB, and more LAB**. It is so very crucial to knowing what is going on in the plant.
See ya down the road. Dave