

# Biological Nutrient Removal

By David Branham

By the time this article comes to print summer will only be a memory, and fall will be well under way. Hot weather will give way to cool evenings and milder days. Aha, love this time of year; it is by far my favorite.

Okay, okay, back to business. Summer was a tough one this year for several systems. No nitrification or too much nitrification, or no chlorine residual; **yikes** where did it go? So let's take a look at what was happening in the systems. Tall order you say. Yea you're right. Of course, many "things" can and will go wrong, causing upsets, but due to lack of time and magazine space I will address some of these other issues that may plague your system during the hot summer months in a future issue of H2Oregon. For now, let's start with taking a look at what happens with the nitrogen cycle.

First, let's look at the different forms of nitrogen and where they come from in the wastewater industry. Nitrogen can exist in many states of oxidation, ranging from reduced ammonia/ammonium to highly oxidized nitrates; in all, nitrogen can exist in seven states of oxidation. However, only ammonia (and organic derivatives), nitrogen gas, nitrites, and nitrates have significance in aquatic environments. In ammonium and organic nitrogen compounds, which are the forms most closely associated with plants and animals, its oxidation state is -3. At the other extreme, when nitrogen is in the nitrate form, its oxidation state is +5. The most prevalent forms of nitrogen in wastewater are organic ammonium and nitrate nitrogen. Therefore, having the presence of these forms of nitrogen typically requires treatment. Domestic municipal wastewater normally contains about 60% in nitrogen form and 40% in the ammonium form. Normally, very little (less than 1%) of the nitrogen is in the oxidized form of nitrate or nitrite.

Boy, I'm starting to get confused already, but let's follow it through and see if we can make sense out of it.

## NITROGEN SOURCES :

Because nitrogen compounds are found throughout the environment, the potential sources are infinite. In our industry the primary sources are: urea and fecal matter. Other sources include chemical fertilizers, runoff, and industrial discharges, which top the list of human-made sources. Industrial discharges, typically high in nitrogen, include feedlots, rendering plants, milk and tobacco processors, certain synthetic fiber plants and industries that clean with ammonia-containing compounds. But as I stated earlier, by far the largest source of nitrogen in wastewater is human fecal matter.

To break it down further, raw wastewater typically contains only nitrogen and ammonium. Organic nitrogen comes from proteins, amines, nucleic acids, peptides, amino acids, and other constituents that are excreted in fecal matter. Ammonium originates from bacteria mineralization of proteins and urea, which is the principal component of urine. Nitrites and nitrates typically are not found in raw wastewater because most raw wastewater does not contain free oxygen for nitrification. Nitrates are only found in raw wastewater that has significant contributions from industries or from drinking water with high nitrate concentrations.

## NITROGEN TREATMENT:

Well here comes the crux of the problem during the **hot** summer season. **Temperature and pH are crucial at this time of year!** An operator **must** adjust the *Return activated sludge rate (RAS)* as well as the *wasting rate* when temperatures get warmer. Also, one must be aware that at a pH of 8 and below, the proportion of ammonium typically exceeds 99%. However, the equilibrium shifts to 50% at approximately a pH of 9.5 and at a pH of 11, and ammonia predominates. Because of this, proper adjusting and monitoring of your system is paramount.

During wastewater treatment, most of the organic nitrogen is metabolized to ammonium. The ammonium can be assimilated into bacteria or further oxidized to nitrates. This process is communally referred to as nitrification. The biological nitrogen removal process ensures conversion of organic nitrogen and ammonium to nitrate-nitrogen. In addition these processes

provide oxygen-deficient environments that allow the nitrates to be converted to molecular nitrogen, or what's known as denitrification. But one must remember that this process does not remove all of the influent nitrogen. A small portion of the organic ammonia is not metabolized to ammonium and passes through these treatment processes as nonbiodegradable total Kjeldahl nitrogen (TKN). It is believed that this portion of the TKN consists of nitrogen heterocycles such as purine, pyridine, and pyrimidine. The nitrogen in these compounds is contained within a ring structure and is not easily degraded. However, the total quantity of all the nonbiodegradable TKN typically is 1mg/L, with a range of 0.5 to 2.5 mg/L.

### TYPICAL NITROGEN CONCENTRATIONS:

Typical nitrogen concentrations for raw domestic wastewater are shown in the table below.

Nitrogen removal by primary clarification is largely caused by settlement of gross solids containing organic nitrogen. Secondary treatment efficiencies are primary because of bacteria assimilation and subsequent sludge wasting. Advanced nutrient removal processes are required to increase nitrogen removal efficiencies beyond 30%. Whoa, my head is spinning after all that. Remember that these are average numbers that are used in conventional

activated sludge processes. Of course, some of the newer technologies being used for nutrient removal get much better results than that, such as, the membrane filter system.

All this brings me back to where we started. You may be saying "who cares" this doesn't apply to my system. No, maybe not yet, but remember it's only a matter of time before the 20 or more new TMDLs come to your neighborhood. And on another note, lagoon systems are not immune to all this hoopla. If you are operating a wastewater system in the Pacific Northwest and your discharge goes into any body of water, I guarantee it's only a matter of time before nutrient removal will be an issue; tertiary treatment anyone?

The following sources have been utilized to write this article.

*Biological and Chemical Systems for Nutrient Removal*  
Published by Water Environment Federation

*Phosphorus and Nitrogen Removal from Municipal Wastewater*  
Principle and practice  
Second Edition  
Published by Sedlak

<b>Concentration (as N)<sup>a</sup></b>	<b>In lb/ Mil. Gal <sup>b</sup></b>	<b>Generation kg/cap/a (lb/cap/yr)<sup>c</sup></b>
<b>In mg/L</b>		
Total 20-85	167-709	3.4-5.0
Organic 8-35	67-292	(7.5-11)
Free ammonia/ammonium 12-50	100-417	(4.8- 8.8)

<sup>a</sup> Typical concentrations in fresh domestic wastewater.

<sup>b</sup> lb/mil. \* 0.1198 = g/m<sup>3</sup>.

<sup>c</sup> lb/cap/yr \* 0.4536 =kg/cap/a.