Nitrogen Removal from Wastewater

A Primer

Overview. Municipal wastewater treatment plants remove nitrogen in two ways.

ONE. Typically, somewhere on the order of 10 mg/L of influent nitrogen is converted to the bacteria that end up as waste activated sludge. Because nitrogen makes up about twelve percent of the dry weight of secondary sludge, and a slightly smaller percentage of primary sludge… Every 8-10 mg/L of effluent TSS contains one mg/L of "suspended" nitrogen.

TWO. Treatment plants convert the majority of the incoming nitrogen from one form to another in a three step biological process. That is, those that remove nitrogen do…

> Step 1. Organic-nitrogen is converted to ammonia-nitrogen by an anaerobic process called ammonification.
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> Step 2. Ammonia-nitrogen is converted to nitrate-nitrogen by an aerobic biological process called nitrification.
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> Step 3. Nitrate-nitrogen is converted to nitrogen gas biologically in a low oxygen (anoxic) environment. During denitrification, nitrogen gas bubbles harmlessly out of wastewater into the atmosphere.

Ammonification. The majority of the nitrogen contained in raw sewage (urea and fecal material) is converted from organic-nitrogen to ammonia as it travels through sewer pipes. As a result, the majority of the influent nitrogen is ammonia. In most plants, less than 2 mg/L of organic-nitrogen passes through the treatment plant untreated. The rest is converted to ammonia.

Ammonification is an anaerobic process. It is sometimes called hydrolysis.

Most treatment plants do nothing to enhance organic-nitrogen removal; it is not managed. However, treatment facilities with total-nitrogen effluent limits can oftentimes reduce the organic nitrogen to less than one mg/L by incorporating an anaerobic treatment step at the front of the plant.

Nitrification. Ammonia removal is an aerobic biological process. Technically, bacteria convert ammonia to nitrate; it isn't really "removed." Nitrification only works on ammonia. Organic-nitrogen is not converted to nitrate.

Nitrifying bacteria are more sensitive than BOD removing bacteria. Generally, nitrification occurs only under aerobic conditions at dissolved oxygen levels of more than 1.0 mg/L. Nitrification requires a long retention time, a low food to microorganism ratio (F:M), a high mean cell residence time (measured as MCRT or Sludge Age), and adequate pH buffering (alkalinity). A plug-flow, extended aeration tank is ideal. Temperature, is also important, but not really.

The nitrification process produces acid. The acid lowers the pH of the biological population in the aeration tank and is – unless buffered – toxic to the nitrifying bacteria. An aeration tank alkalinity of no less than 50-100 mg/L is required.

Water temperature also affects the rate of nitrification. At temperatures below 20 degrees C, nitrification proceeds at a slower rate, but will continue at temperatures below $10^{o}C$. However, if nitrification is lost, it will not resume until the temperature increases to well over $10^{o}C$.

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Denitrification. The biological reduction of nitrate to nitrogen gas is performed by bacteria that live in a low oxygen environment. To thrive, the bacteria need BOD – soluble BOD. Particulate BOD needs to be broken down into solution before it is of value. The highest growth rate can be found when using methanol or acetic acid. A slightly lower rate using raw wastewater will occur, and the lowest growth rates are found when relying on waste sludge at low water temperatures.

Denitrifying organisms are generally less sensitive to toxic chemicals than nitrifiers, and recover from toxic shock loads quicker than nitrifiers.

Wastewater cannot be denitrified unless it is first nitrified.

THE WATER PLANET COMPANY

111 Huntington Street • New London, Connecticut 06320 • Office: 860.444.0866 • Fax: 860. 444.0896