SCS ENGINEERS

SCS TECHNICAL BULLETIN

TREATMENT OF AMMONIA IN WASTEWATER AND LEACHATE - CONSIDERATIONS AND TECHNOLOGIES

November 2018

Reducing the amount of ammonia in landfill leachate and other industrial wastewaters is often necessary to meet discharge standards. Proven wastewater treatment technologies can effectively reduce ammonia concentrations, but selecting the right technology requires careful consideration. This Technical Bulletin provides background on ammonia in wastewater, and reviews factors to consider in selecting a treatment technology.

The Basics

Ammonia is a form of nitrogen, and laboratory tests for wastewater measure nitrogen in three basic forms:

- **Ammonia and Ammonium** (NH_3+NH_4 as nitrogen),
- **Total Kjeldahl Nitrogen** (TKN = NH_3+NH_4 + organic nitrogen), and
- **Total Nitrogen** (TKN + nitrite-N + nitrate-N)

All three are related, and any of the three can be subject to discharge limitations. Nitrogen is a nutrient used in fertilizers but can be toxic to aquatic life at low concentrations. Ammonia is toxic to aquatic life, while ammonium is less toxic. It is important to know the discharge limitations before choosing a treatment technology.

Another important wastewater parameter is **pH** because pH affects the concentration of ammonia and ammonium present in the wastewater. At a constant temperature (e.g., 20°C) and at a lower pH (<7), the ionic form – ammonium (NH4) – is 100% present, and at a higher pH (>10 pH) the gaseous form – ammonia (NH3) – approaches 100% present. Wastewater that has a pH of between 7.0 and 11.5 has an equilibrium of ammonium and ammonia that change with the pH (e.g., the lower the pH, the more ammonium is present and the higher the pH, the more ammonia is present, at a given temperature).

Membrane Technology for Wastewater Treatment

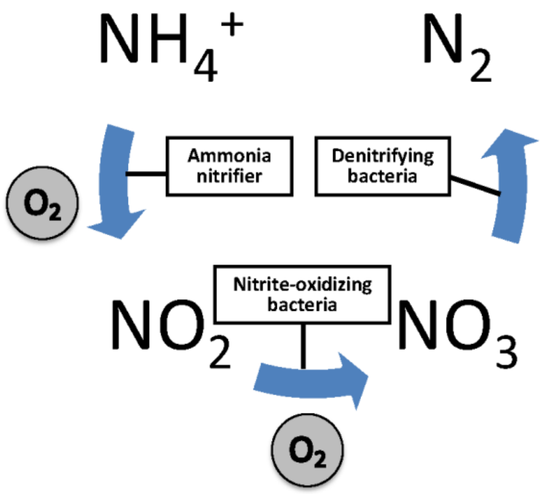
Temperature also affects the ammonium/ ammonia concentration, with lower temperature wastewater having lower concentrations of ammonia when compared with higher temperature wastewater at the same pH. The effect of temperature on the concentration of ammonia in wastewater increases with higher wastewater pH.

For example, a water sample that has a pH of 9.0 and temperature of 40°F will have ~10% ammonia and ~90% ammonium, whereas the same water sample (pH of 9.0) at 90°F will have ~48% ammonia and ~52% ammonium. Both water samples will have the same analytical result for total ammonia (NH3+NH4), regardless of temperature.

Treatment Methods

Eight of the most common and effective treatment and disposal methods for wastewater with elevated ammonia or nitrogen are summarized below. The type of process used will depend on what specific nitrogen compounds (e.g., ammonia, ammonium, nitrite, nitrate, and organic nitrogen) require removal or reduction, initial concentrations, and the target post-treatment concentration.

Biological Treatment. Total ammonia and organic nitrogen can be converted into less toxic nitrites and nitrates (NO_2 +NO_3) by bacteria through microbiological degradation or "nitrification." Nitrification of wastewater is carried out by nitrifiers, (e.g., *Nitrosomonas* and *Nitrobacter* bacteria) in an aerated, temperature- and pH-controlled bioreactor or other aeration facility. The nitrifier bacteria require oxygen and carbon as well as alkalinity for pH control. Denitrification is facilitated by denitrifying bacteria (e.g., *Pseudomonas* and *Bacillus* bacteria) in an anoxic environment, converting NO_3 to nitrogen N_2 gas, which is released to the atmosphere.



Wastewater Nitrification and Denitrification Reactions

Several biological treatment methods are effective at removing ammonia, TKN, and total nitrogen from wastewater. For example, a membrane bioreactor (MBR) uses denitrification and nitrification in the "bioreactors" to treat high ammonia (100 to >2,000 milligrams per liter [mg/L]) and organics (>30,000 mg/L biochemical oxygen demand or BOD) in wastewater. Use of ultrafiltration allows the MBR-treated wastewater to be discharged with minimal suspended solids. Biosolids are retained in an MBR to circulate back through the bioreactor tank(s).

Another type of biological treatment is sequencing batch reactors (SBRs) that involve multi-step biological processes to treat high nitrogen wastewaters. More traditional biological treatment methods, such as activated sludge, can be used for wastewater with a low ammonia concentration (<30 to 40 mg/L ammonia).

Discharge to POTW. If a Publicly-Owned Treatment Works (POTW) that uses biological treatment is locally available, and will allow the landfill or industrial facility to discharge their leachate or wastewater, this option is often the least expensive. A POTW is designed to treat ammonia and other constituents that are found in leachate and wastewater using the activated sludge method of treatment.

However, these facilities are not usually designed to treat concentrated wastewater and will often charge the generator based on the ammonia concentration, as well as other chemicals found in leachate and industrial discharges. If a POTW is not locally available, wastewater may be hauled by truck to the POTW, and the wastewater generator may incur higher costs.

Breakpoint Chlorination. Ammonia nitrogen removal can be accomplished chemically by adding chlorine to wastewater, which causes ammonia to oxidize, primarily to nitrogen gas. This method is generally only used to "polish" effluent wastewater with less than 20 mg/L ammonia. It takes 7.6 pounds of chlorine to oxidize 1 pound of ammonia.

However, because other constituents in the wastewater are often readily oxidizable (e.g., organics), the amount of chlorine required can be significantly higher. Additional issues include the potential production of nitrogen trichloride (NCl_3) gas, which is toxic and explosive, as well as increasing the concentration of total dissolved solids (TDS) and the need to control pH.

Thorough mixing is critical to the effectiveness of breakpoint chlorination, as is pH control. Fifteen mg/L of alkalinity is consumed per mg/L of ammonia oxidized, so alkalinity must be monitored and added if it is not already present as a pH buffer in the wastewater.

Air/Steam Stripping. By raising the wastewater pH to between 10.8 and 11.5, the wastewater's total ammonia equilibrium is driven toward 100% ammonia gas (NH3). The higher pH wastewater can then be passed through an air or steam stripping tower, where air or steam is forced through cascading wastewater, which causes the ammonia gas to be "stripped" from the wastewater.

Wastewaters with ammonia concentration greater than 100 mg/L require steam stripping; air stripping is ideally for ammonia concentrations between 10 mg/L and 100 mg/L. *Caution: There* *can be strong odors, tower scaling, and cold weather freezing unless each of these potential problems is addressed.*

SCS Engineers Industrial Wastewater Treatment

Selected Ion Exchange. Contact with specific ion exchange media can remove ammonia, nitrite, and nitrate from wastewater through adsorption. One medium used to remove ammonia is called clinoptilolite. Separate ion exchange media are used for nitrite and nitrate removal, if necessary. Significant pre-treatment is required before passing wastewater through the ion exchange media, including removal of total suspended solids (TSS) and competing ions such as those associated with hardness as well as aluminum, and iron.

Ozone/Hydrogen Peroxide. Total ammonia and organic nitrogen can be removed through ozone oxidation and hydrogen peroxide. The ozone and hydrogen peroxide oxidizes ammonia to primarily nitrogen gas. Ozone can also assist with effluent disinfection if needed. As with other oxidation processes, competing constituents that can be oxidized will increase the consumption of ozone and peroxide.

Evaporation. Heating wastewater, either with landfill gas or waste heat (e.g., flare or micro-turbine exhaust), in an evaporator can convert wastewater to water vapor, thereby reducing the wastewater volume by up to 95%. Ammonia and other odors (e.g., from sulfides, like H_2S) can be generated as part of the evaporator vapor plume. Concentrated solids resulting from the evaporation process need to be disposed, normally in a landfill.

Deep Injection Well. Wastewater may be injected into the subsurface through specially designed and permitted wells in regions where the regulatory framework supports permitting of a well and where there is appropriate geology for liquid disposal. Appropriate geology includes a subsurface zone where wastewater can be injected far below potential drinking water formations, and that is separated from potential drinking water by impermeable formations.

Special construction methods are required, including redundant means for environmental protection of underground sources of drinking water. Depending on the local geology and wastewater considered for injection, the depth of an industrial wastewater deep injection well can range from 3,000 feet to greater than 12,000 feet. Geologic formations that will accept wastewater include porous sandstone and permeable carbonate formations.

General Information

Consider conducting bench-scale and pilot-scale testing for any nitrogen removal or treatment system. As with any wastewater treatment process, if the wastewater or leachate quality changes, the makeup of nitrogen compounds remaining may also change.

When there are changes to the processes that generate wastewater (e.g., landfills accept new types of waste, changes to industrial processes, etc.), testing of the newly generated wastewater helps to identify any changes to the concentration of nitrogen compounds. Considering these factors in advance can help avoid costly mistakes.

General cost information for different wastewater and leachate treatment processes is shown on the following page.

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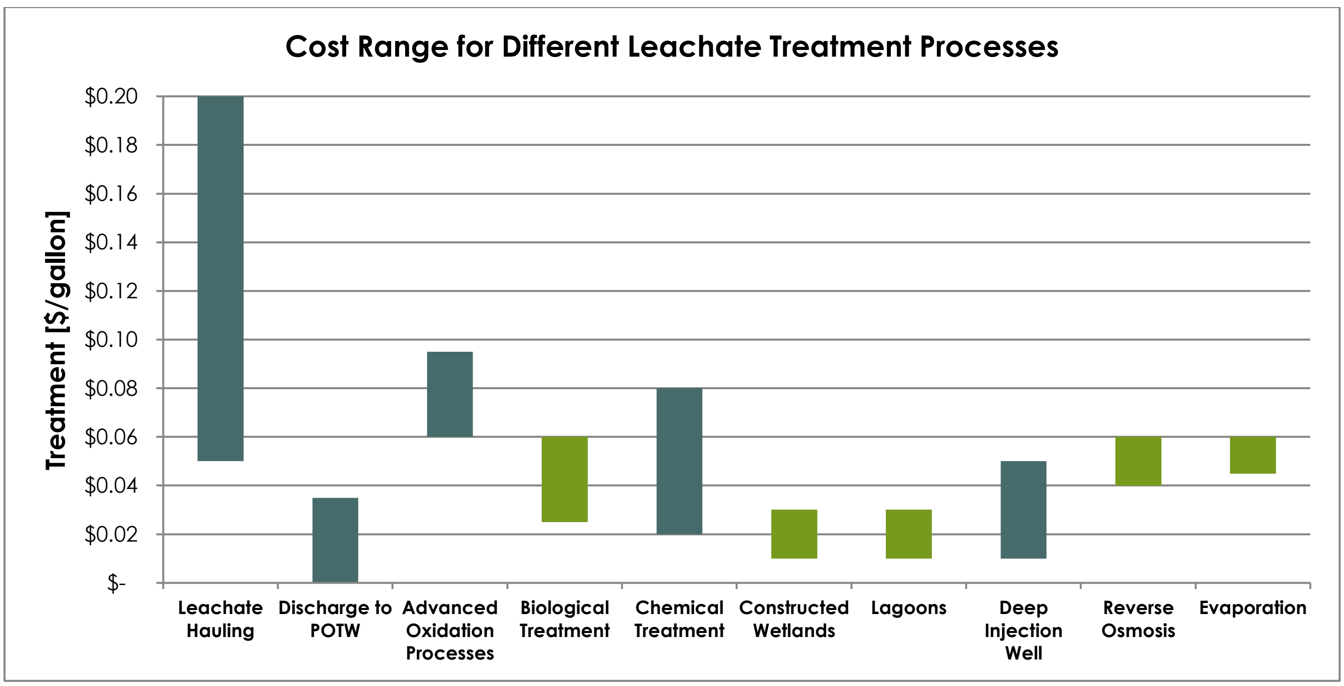
Cost Range for Different Leachate Treatment Processes

Treatment	Process	Range ($/gallon) Low	High
Off-Site	**Leachate Hauling**	$ 0.050	**$ 0.200**
	Discharge to POTW	$ -	**$ 0.035**
On-Site	**Advanced Oxidation Processes**	$ 0.060	**$ 0.095**
	Biological Treatment	$ 0.025	$ 0.060
	Chemical Treatment	$ 0.020	**$ 0.080**
	Constructed Wetlands	$ 0.010	$ 0.030
	Lagoons	$ 0.010	$ 0.030
	Deep Injection Well	**$ 0.010**	**$ 0.050**
	Reverse Osmosis	$ 0.040	$ 0.060
	Evaporation	$ 0.045	$ 0.060

Reference: Solid Waste Association of North America, Advanced Leachate Management Course Guide Table 8-3: Cost Ranges for Leachate Treatment Processes ©2014. Bold entries –modified by Sam Cooke in 2018.



Reference: Solid Waste Association of North America, Advanced Leachate Management Course Guide Figure 8-1: Cost Ranges for Leachate Treatment Processes ©2014. Bluegreen entries –modified by Sam Cooke in 2018.

It is SCS Engineers' experience that the above SWANA cost ranges are rough cost estimates based on "normal conditions." Different states/localities may have different treatment requirements/costs, and wastewater treatment processes will vary in effectiveness, depending on the individual facility's wastewater constituent concentrations.

