PRD TECH's A+RU PROCESS FOR NUTRIENT RECOVERY

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One of the major concerns regarding municipal wastewater treatment plant discharge is the rising concentration of nutrient compounds, specifically nitrogen and phosphorus.

Nitrogen and phosphorus are the primary causes of cultural eutrophication (i.e., nutrient enrichment due to human activities) in surface waters. The most recognizable manifestations of this eutrophication are algal blooms that occur during the summer. Chronic symptoms of over-enrichment include low dissolved oxygen, fish kills, murky water, and depletion of desirable flora and fauna.

Wastewater treatment plants that employ conventional biological treatment processes designed to meet secondary treatment effluent standards typically do not remove total nitrogen (TN) or total phosphorus (TP) to the extent needed to protect receiving waters.

However, wastewater treatment facilities are increasingly being required to address this issue by implementing treatment processes that reduce effluent nutrient concentrations to levels that regulators deem sufficient to protect the environment. Implementation usually involves major process modifications to a plant, such as: making a portion of the aeration basin anaerobic and/or anoxic, which reduces the aerobic volume and limits nitrification capacity. Clarifier solids loading is usually the factor that limits the concentration of biomass available for nitrification, so common practice is to increase bioreactor volume in order to increase treatment capacity. This can be very expensive and sometimes impossible if space is limited.

NUTRIENT REDUCTION PROCESSES

There are two possible approaches for reducing nutrients in wastewaters: (1) Nutrient Recovery; and (2) Nutrient Destruction. Nutrient destruction utilizes biological nitrification and denitrification reactions to destroy nitrogen and precipitates phosphorus biologically. Use of biomedia to grow biofilms, such as in Integrated Fixed Film Activated Sludge (IFAS) enables simultaneous nitrification and denitrification within the same vessel. However, nutrient destruction involves significant aeration costs, is impacted by ambient temperature and involves major equipment modifications. Further, nutrients have "value" that can be exploited for economic gain.

There are several types of biological treatment systems that can be used to achieve nitrogen removal from wastewaters. Biological treatment systems can be classified based on the contact mechanism between the wastewater and the biomass. Biomass can be either suspended in the wastewater or immobilized on a solid substrate or biomedia. The wastewater can either flow through a mixed reactor or a plug flow reactor system.

Biological removal of ammonia is generally achieved by combining anoxic and aerobic treatment system. Pre-anoxic treatment systems use an anoxic basin followed by an aerobic reactor, with recycle of wastewater from the aerobic tank to the anoxic system to denitrify the nitrate produced in the aerobic section. Post-anoxic systems combine an aerobic system followed by an anaerobic section to achieve denitrification. Post-anoxic systems have the disadvantage of also reducing sulfate to sulfides, forming hydrogen sulfide, with its associated odor issues. Sequencing batch reactors have the advantage of varying the anoxic and aerobic condition time durations to achieve the desired level of denitrification.

Membrane bioreactors can achieve better nitrification than suspended culture reactors, mainly due to retention of the nitrifiers, which are slow growing organisms and hence tend to get washed out easily. The main issue with membrane bioreactors is membrane fouling and the high cost of the membrane systems.

Alternative nutrient recovery processes includes the following:

1. Recovery of struvite (magnesium ammonium phosphate) from digester supernatant (e.g., Ostara's Pearl Nutrient Recovery Process); Only 5-15% of nitrogen is recovered through phosphate-based precipitation processes.

2. Production of biosolids-enhanced granular inorganic fertilizers (e.g., Unity Envirotech's fertilizer granulation process and VitAG's ammonium mix process).
3. Air stripping of ammonia followed by gas absorption to produce ammonium sulfate; Full-scale ammonia-stripping towers have been decommissioned because of operational problems and cost – (a) process has failed during cold weather, due to freezing; (2) sacling of tower packing, especially when lime was used to raise the pH; and (c) does nor achieve low ammonia concentration; and
4. Liqui-Cell's Membrane process for directly converting ammonia in water to ammonium sulfate using a membrane contactor; air trapped within the membrane pores separates the wastewater from the sulfuric acid, and water is prevented from entering the pore due to membrane hydrophobicity; However, the presence of surfactants wets the membrane pore, resulting in process failure.

Clearly, there is a need for simultaneous recovery of both nitrogen and phosphorus from wastewaters

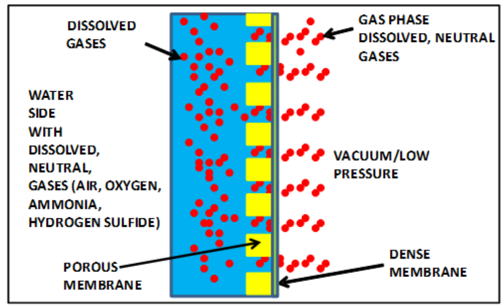
PRD TECH's AMMONIA$^+$ RECOVERY (A$^+$RU) PROCESS

PRD Tech, Inc. has developed a process that can simultaneously, but independently recover nitrogen and phosphorus from wastewater. The process involves the following steps:

1. Precipitation of phosphorus as Calcium Phosphate by using Calcium Hydroxide and advanced settling techniques; this produces a solid Calcium Phosphate plus organic matter product;
2. Addition of Calcium Hydroxide raises the pH, which converts the ammonium to dissolved ammonia gas; this gas is recovered using a membrane process that can produce ammonia-water (19 wt% ammonia), ammonium salt, such as ammonium sulfate or ammonium nitrate or ammonium chloride.

The membrane process uses a proprietary module to dgas the dissolved ammonia gas from the wastewater. The basic principle behind this degassing method is shown in Figure 1.

Figure 1. Basic principle of the Membrane Degassing process to remove ammonia from wastewater.



A membrane separates the water, containing dissolved gas, from the low gas-phase pressure side, thereby allowing the dissolved gas to transport across the membrane into the gaseous side. This principle can be used to separate any dissolved gas, such as ammonia, hydrogen sulfide, carbon dioxide or oxygen.

Main advantages of the A$^+$RU process are as follows:

- Recovery of both nitrogen and phosphorus, as two independent products – Calcium phosphate fertilizer and ammonium salt solution, which can be combined to make a variety of fertilizers with different N,P content;
- Recovery of nitrogen and phosphorus can be independently controlled to achieve the desired water effluent requirements;
- Chemical usage are coagulant for Calcium Phosphate precipitation, Calcium hydroxide and appropriate acid, for ammonium salt production;
- Produces saleable products (Bio-Ammonia products and Calcium Phosphate);
- Removes divalent metals as hydroxides, which reduces their content in the wastewater; and
- Simple to install and cost-effective to operate.

Information needed to determine the cost-effectiveness of the A$^+$RU Process includes wastewater flowrate, influent concentrations of nitrogen and phosphorus and alkalinity, which determines the consumption of Calcium Hydroxide.

The A^+RU process can be used to recover Nitrogen and Phosphorus from the following wastewater streams:

1. Municipal effluent from the wastewater treatment process;
2. Anaerobic digester effluent from activated sludge to biogas process, that is enriched in nitrogen and phosphorus;
3. Liquid effluents from anaerobic digesters in farms, food waste to biogas processes, etc.; and
4. Sludge handling and treatment facilities that attempt to convert the sludge into organic fertilizer, and produce water enriched in ammonia.

The U.S. EPA estimates that more than 7 million dry tons of solids (45 million cubic yards) are generated annually for use or disposal by the >16,000 municipal wastewater treatment facilities nationwide (U.S.). Decreasing landfill capacity has caused regulators to require increasingly more recycling and diversion from landfills. For many communities, land application represents a cost-effective and viable option compared to land-filling or incineration. However, decreasing farmland and encroaching housing developments make it more and more difficult to recycle wastewater residuals with increasing resistance from urban and suburban residents.

Nutrient recovery has the potential to transform dairy nutrient management by reducing the amount of phosphorus and nitrogen in liquid and solid wastes. Nutrient recovery technologies produce concentrated nutrient products that can be more economically transported than manure.
Nutrient recovery processes generate a product, which is more stable, homogenous, and predictable than manure. This can make the products more appealing to crop producers, who can store them, better control application rates, with or without inorganic fertilizers, has the potential to produce products with desired NPK balances. Finally, nutrient recovery products, such as struvite and ammonium sulfate, are pathogen-inert chemicals.

A combined Anaerobic Digestion-Nutrient Recovery system has greater capital and operating costs, but also (depending on the system) has the potential to generate greater revenues and profits, in addition to addressing major concerns of nutrient pollution from Anaerobic Digestion alone.

Products produced from the A^+RU Process are the following:

1. Calcium Phosphate mixed with some organic matter, which can be marketed as an Organic-Phosphorus fertilizer product; and
2. Ammonium salt or ammonium-water solution, which can be marketed as an ammonium fertilizer or used for wastewater disinfection.

Economics of the A+RU Process

Digested sludge filtrate from a typical municipal plant has the following range of nutrient concentrations:10-300 mg/L of orto-P; and
500-800 mg/L of ammonium nitrogen.

Nitrification costs can be calculated as follows: 4.6 lbs of oxygen consumed per lb of N removed; 1.1-1.94 lbs of oxygen needed per kWh (fine pore aeration); and electricity costs \$0.10-\$0.15/kWh, resulting in \$0.51 - \$1.34/lb N removed by nitrification. Methanol cost for denitrification is \$0.50/lb NO_3-N removed.

Since 0.45 lbs of ammonia are removed per lb of P during nitrification, cost of P removal by nitrification ranges from \$0.34-\$0.59/lb P removed.

For the A+RU process, cost of Calcium Hydroxide is \$300/dry ton, and the required lime consumption (mg $Ca(OH)_2$/L) is approximately 1.5 times the total alkalinity (as mg $CaCO_3$/L). If the anaerobic digestate alkalinity is 1000 mg $CaCO_3$/L, then the cost of calcium hydroxide will be \$0.75/lb P removed. However, although nitrification can only remove a fraction of P present in the wastewater, the A+RU process can remove P at over 95% efficiency.

The cost of coagulant, calcium hydroxide and acid can be paid from sales of the fertilizer products (calcium phosphate + organic solids and ammonium sulfate) resulting in a net positive cash flow. Economic comparison with conventional nitrogen destruction approaches which includes nitrification and denitrification, has shown that there are significant investment and operating cost savings with the A^+RU recovery process.