The AmmEl Process for the Treatment of Ammonia in Wastewater

Leonard P. Seed, Daren D. Yetman and Gene S. Shelp
Enpar Technologies Inc., Guelph, Ontario

Abstract

Mine and mill effluents are often contaminated with ammonia-N due to use of ammonia based compounds, such as ammonia-based explosives (ANFO), flotation reagents in milling, cyanide destruction, and as a pH regulator (uranium precipitation). Ammonia is known to be toxic to aquatic species and has been listed as a toxic compound by Environment Canada. Enpar Technologies Inc. has developed a novel patented ion-exchange/electrochemical technology, the AmmEl System, to treat ammonia in wastewater streams. The AmmEl System uses a two-stage approach to treat ammonia; the first stage utilizes ion-exchange to remove ammonia from the wastewater followed by electrochemical oxidation of the captured ammonia directly to N_2 gas.

The AmmEl system has been pilot tested at the City of Guelph wastewater treatment plant. Two separate wastewater streams were tested; Case (I) as a pre-treatment system for a high strength wastewater stream (700 mg/L NH_3-N) and Case (II) to treat a low strength effluent stream (5 mg/L NH_3-N). In the Case I test, the AmmEl system was able to remove greater than 93% of the ammonia from the wastewater. In Case II, the AmmEl system was effective at removing the ammonia-N from the wastewater stream to less than the 1 mg/L target level, producing an average concentration of 0.6 mg/L in the treated effluent.

The AmmEl system has been proven to be an effective method for removing ammonia from a variety of waste streams and is applicable for the treatment ammonia in mine/mill effluent. The system is a robust and cost effective alternative to existing ammonia removal technologies.

Introduction

Mine and mill effluents are often contaminated with ammonia-N due to use of ammonia based compounds, such as ammonia-based explosives (ANFO), flotation reagents in milling, cyanide destruction, and as a pH regulator (uranium precipitation) (Hawley, 1977; SENES Consultants Ltd., 1999). The listing of ammonia as a toxic substance by Environment Canada (Environment Canada and Health Canada, 2001), coupled with increased public concern about water quality is likely to result in more stringent discharge requirements for ammonia.

One approach used by the mining industry to address ammonia contaminated effluent is to lower the pH of the wastewater to render the effluent less toxic (due to a shift of the NH_3/NH_4^+ equilibrium) (Beak International Inc., 2000). While this approach will assist in meeting acute lethality discharge requirements, the total ammonia-N released to the environment is not reduced.

Current technology for treating ammonia relies on biological activity, i.e. nitrification, to convert ammonia to nitrate. Total nitrogen removal requires an additional biological process to remove nitrate from wastewater prior to discharge. Biological treatment systems are adversely affected by cold temperatures and changes in effluent composition.

A novel patented ion-exchange/electrochemical treatment technology (the AmmEl system) has been developed by Enpar Technologies Inc. This paper presents the principals behind the technology and summarizes the results of pilot testing of the AmmEl system at the City of Guelph wastewater treatment plant.

Description of AmmEl Process

The AmmEl system is a 2-stage process; the first stage consists of removal of ammonium from the waste stream using a zeolite ion-exchange (IX) medium followed by the second stage, electrochemical oxidation of ammonium in the ion-exchange regenerant solution to N_2 gas. Zeolites are naturally occurring and readily available aluminosilicate minerals, which have been demonstrated to have a strong binding affinity for NH_4^+. The use of zeolites in municipal wastewater treatment for the removal of ammonia has been well documented by Liberti (1982). Zeolites have also been investigated to remove ammonia from uranium mill effluent (SENES Consultants Ltd., 1999)

A schematic of the overall process illustrating the combined system is presented in Figure 1. Once the IX media is loaded with ammonium (Stage 1), the media is regenerated by circulating a brine solution through the column. The ammonium ion is transferred into the regenerant solution and is subsequently oxidized to N_2 gas using an electrochemical reactor, as described by the following reactions:

$$2NH_4^+ \rightarrow N_2 + 8H^+ + 6e^-$$

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

$$2NH_4^+ + 3HOCl \rightarrow N_2 + 3H_2O + 5H^+ + 3Cl^-$$

The overall result is the oxidation of ammonia to nitrogen gas.

Pilot Testing at the City of Guelph

Pilot System

The pilot system consisted of three IX columns, 20 cm in diameter by 1.7 m high coupled with a 2.4 kW electrochemical reactor. The basic operation of the system is presented in Figure 2. Two of the IX columns (1 and 2) are operated in series to treat the wastewater while the third column undergoes regeneration. The columns are cycled, using a programmable controller, to provide continuous treatment of the wastewater. The system can be configured with a recirculation loop for the treatment of high concentration effluent (dashed line).

During the regeneration cycle, the brine solution is circulated through both the column and the electrochemical reactor. The electrochemical reactor is operated at a current of 600 A DC and a potential of 4 V to oxidize the ammonia to N_2 gas.

Scope of Testing

Pilot testing was conducted on-site at the City of Guelph Wastewater Treatment Plant. Two distinct wastewater streams were tested during the pilot programme; i) sludge dewatering effluent and ii) clarified secondary activated sludge effluent.

Treatment of Sludge Dewatering Effluent

<u>Objective</u>

The AmmEl system was investigated for use as a pre-treatment system to remove ammonia from sludge dewatering effluent prior to returning the effluent to the WWTP for further processing. The treatment objective was to decrease the ammonia concentration in the effluent by 90%, and thus decrease the ammonia loading to the WWTP.

<u>Wastewater Characteristics and Operating Conditions</u>

A side stream was collected directly from the sludge belt press and pumped to the AmmEl pilot system at a flow rate of 2 L/min. The system was configured with a recycle loop to maintain a column flow rate of 18 L/min. The ammonia-N concentration of the dewatering effluent was found to vary from 200 to 1000 mg/L over the course of the trial. The suspended solids content of the stream was relatively high in the range of 200 to 400 mg/L.

Treatment of Clarified Secondary Effluent

<u>Objective</u>

The objective of this phase of testing was to evaluate the AmmEl system for use as a polishing system to remove ammonia-N from clarified secondary activated sludge effluent prior to discharge. The treatment objective was to reduce the ammonia-N to less than 1 mg/L in the treated effluent

<u>Wastewater Characteristics and Operating Conditions</u>

A side stream from the secondary clarifier was directed to the pilot AmmEl system at a flow rate of 14 to 16 L/min. The ammonia-N concentration was found to vary from <1 to 5 mg/L. Sampling revealed that the ammonia-N concentration fluctuated on cyclic basis with a peak ammonia-N level occurring between 18:00 to 20:00 h daily.

The control program for the treatment system was modified such that the treatment system was shut down and bypassed when the wastewater ammonia-N concentration was less than 1 mg/L NH_3-N. In other words, the system was turned off when treatment was not required. Therefore, during bypass operation, the inlet and outlet sampling points are identical. The mode of operation is summarized in Figure 3.

Treatment Results

Sludge Dewatering Effluent

The results of a typical treatment run are presented in Figure 4. The AmmEl system was effective at removing >93% of the ammonia-N from initial levels of 700 mg/L. The high levels of suspended solids in the effluent did not appear to have an adverse impact on operation of the system.

Treatment of Clarified Secondary Activated Sludge Effluent

The results of a typical treatment run are presented in Figure 5. As indicated by Figure 3, the inlet and outlet sample points are the same for the system during bypass. The AmmEl system was effective at reducing the ammonia-N concentration in the wastewater stream to less than 1 mg/L with an average of approximately 0.6 mg/L. The results also demonstrate a unique feature of the AmmEl system; intermittent operation is possible if required.

Treatment Costs

Operating

The operating costs (power and chemicals) for the AmmEl system are estimated to be between \$2.20 to \$2.40 per kg NH_3-N removed.

Capital Cost Comparison

The capital cost of the AmmEl system was compared against attached growth nitrification systems according the scenario presented by Environment Canada (2003). The scenario consisted of an add-on tertiary ammonia removal system for the post-treatment of lagoon effluent with the following characteristics:

- ammonia-N concentration of 20 mg/L
- discharge requirement <5 mg/L
- flow rate of 1000 m^3/day.

The capital cost for the AmmEl system for the above scenario is estimated at \$1.5 M; by comparison typical attached growth nitrification systems are expected to range from \$1.65 to \$2.9 M (Environment Canada 2003).

Summary

The AmmEl system has been demonstrated to be effective at removing ammonia in a variety of wastewaters and has direct application to the treatment of mine/mill effluent.

The main advantages of the AmmEl system are:

1. Completely eliminates total nitrogen loading, i.e. no conversion to nitrate.
2. Achieves low effluent ammonia concentrations.
3. Handles effluent containing high suspended solids.
4. The treatment system is not affected by cold wastewater temperature.
5. No start-up or acclimation period required; intermittent operation is feasible if required.
6. Fully automated and remotely monitored.
7. Cost competitive with existing treatment technologies.

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References

Beak International Inc. 2000. Non-Acutely Lethal Mining Effluent Technologies (NALMET) Program. Wastewater Technology Centre, Environment Canada.

Environment Canada. 2003. Treatment Processes for the Removal of Total Ammonia-Nitrogen from Municipal Wastewater Discharges. *In press*.

Environment Canada and Health Canada. 2001. Priority substances list assessment report. Ammonia in the Aquatic Environment. Cat. No. En40-215/55E. Environment Canada and Health Canada.

Hawley, J.R. 1977. The Use, Characteristics and Toxicity of Mine-Mill Reagents in the Provinces of Ontario. Waste Management Branch, Ontario Ministry of the Environment.

Liberti, L. 1982. Ion exchange advanced treatment to remove nutrients from sewage. P225-238. In *Physicochemical Methods for Water and Wastewater Treatments*. Ed. By L. Pawlowski, Elsevier.

SENES Consultants Ltd. (1999). Report on Technologies Applicable to the Management of Canadian Mining Effluents. Environmental Protection Services, Environment Canada.

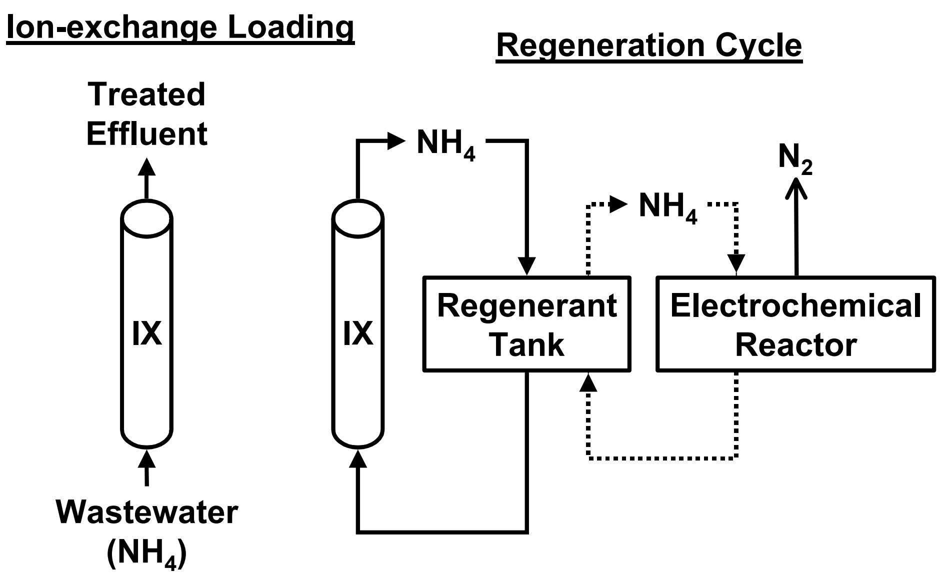

Figure 1: The AmmEl System

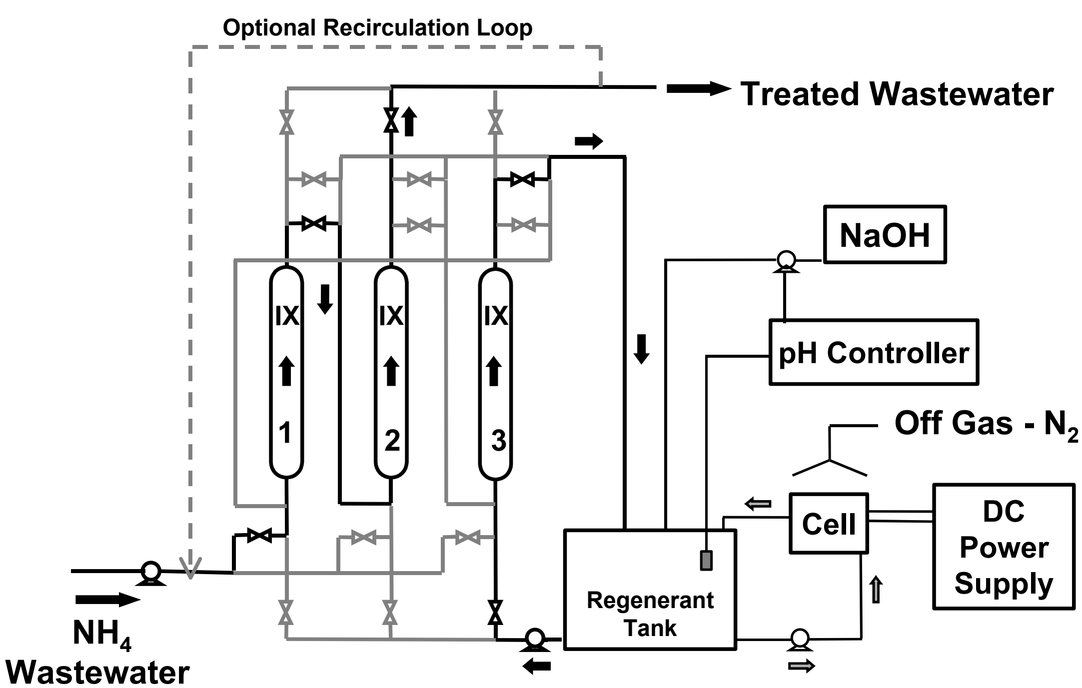

Figure 2: Schematic of Pilot System

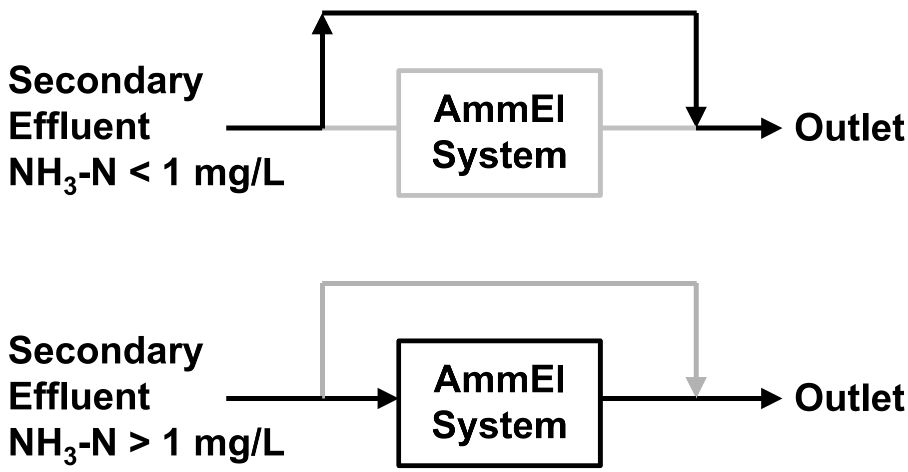

Figure 3: Mode of Operation

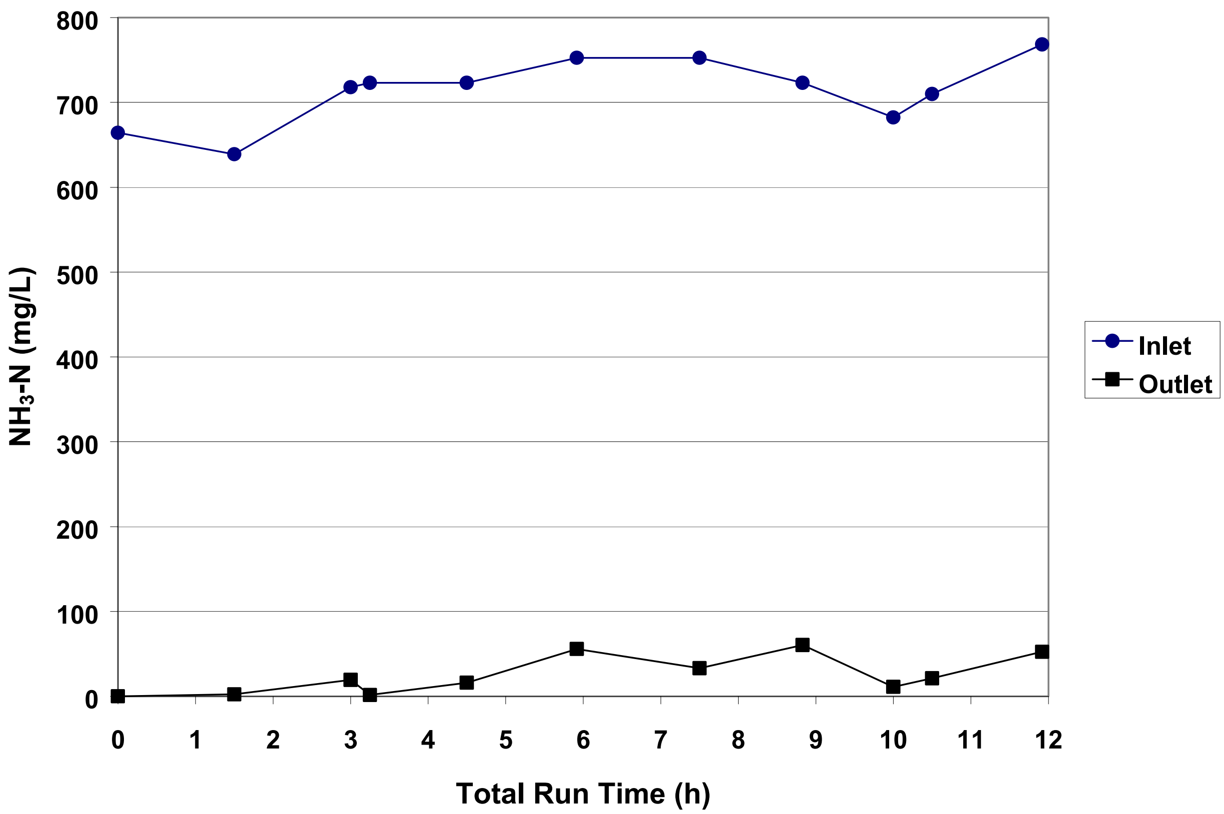

Figure 4: Treatment of Sludge Dewatering Effluent

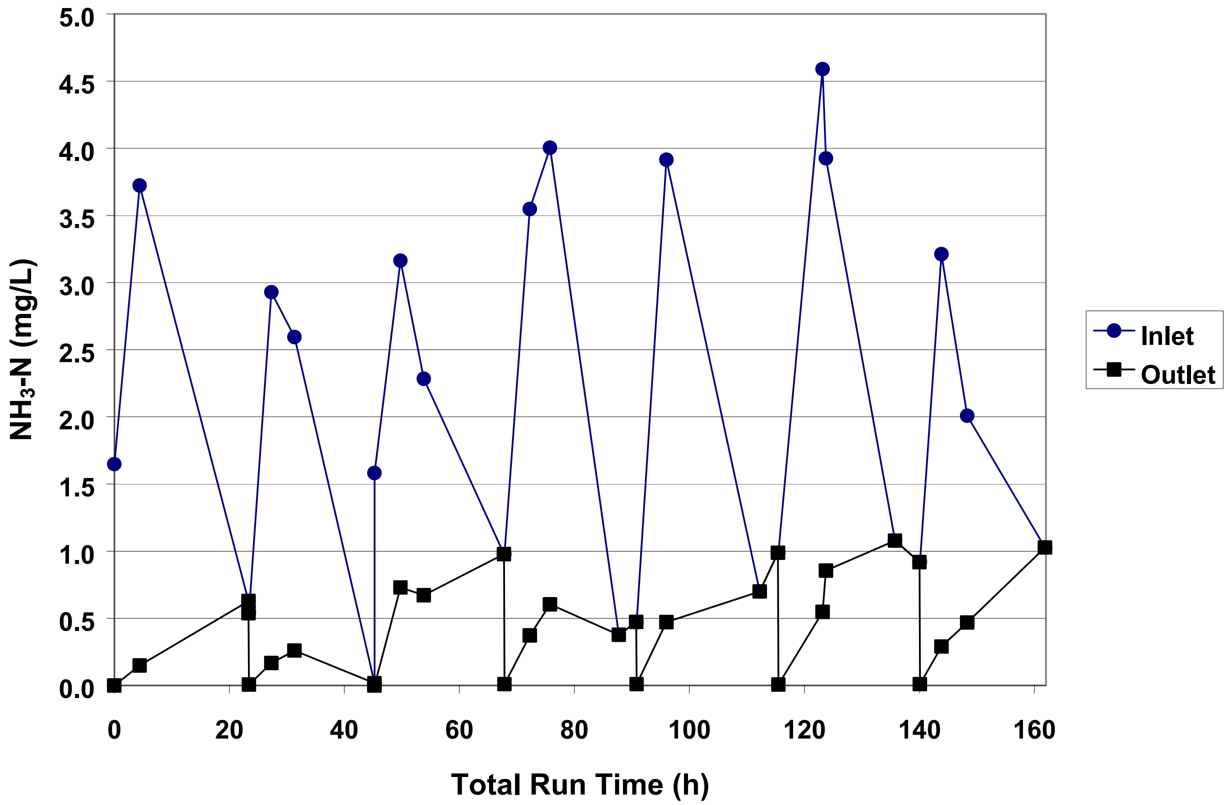

Figure 5: Treatment of Clarified Secondary Effluent