Animal Rendering Wastewater Treatment Process Utilizing Zeolite Based Ammonium Capture

Jacob Blinkoff, Shakti Arumugam, Paige Wells, Rohan Sarnaik, Morgan Tinsley
Chemical and Biomolecular Engineering, University of Maryland

Abstract

Animal Rendering Condensate Wastewater (RCWW) produced by slaughterhouses is rich with ammonia, oils, phosphorus, and other components. When RCWW is dumped into a body of water, algal blooms and dead zones are likely to form and cause significant environmental damage. This project presents an approach of utilizing zeolite ion exchange for ammonium removal in the downstream processing stages of the RCWW treatment process and makes a comparison to other common methods such as distillation and reverse osmosis. Aspen was used to simulate the zeolite exchange and distillation, and reverse osmosis data was used to compare. The zeolite column is shown to be the cheapest by about $25k per year compared to the next best (rev. osmosis)

Introduction and Background

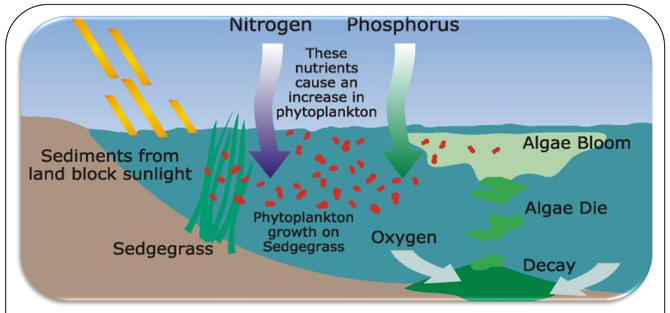

Figure 1: Eutrophication Process in freshwater[1]

- Illegal disposal of RCWW into the Chesapeake Bay has caused widespread eutrophication[2].
- RCWW contains high levels of pollutants (COD> 10,000 mg/L, Ammonia >850 mg/L)[3]

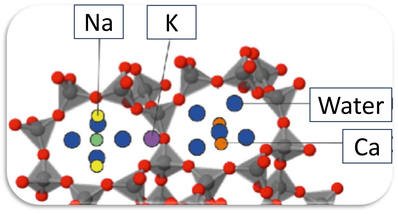

Figure 2: Clinoptilolite (zeolite) molecular structure and ion formation (Na, K, Ca, etc.) within its structure[4]

- Clinoptilolite is a zeolite that has a high affinity for ammonium compared to other ions
- Columns an be regenerated with concentrated salt brines, and are cheap to maintain

Methodology

- Ammonia Separation Processes simulated utilizing Aspen Adsorption
- Modeled using equations: Convection Dispersion Model, Solid Film Model, and Stoichiometric Equilibrium Isotherm[5,6]
- Specifications: constant density/velocity, no pressure drop, isothermal, fixed MTC[5,6]
- Column performs ion exchange within the zeolites then NH3 elution is driven with elevated levels of NaCl

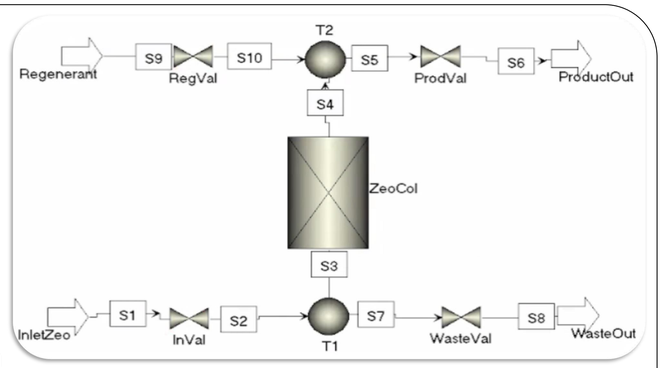

Figure 3: Aspen Adsorption Zeolite PFD

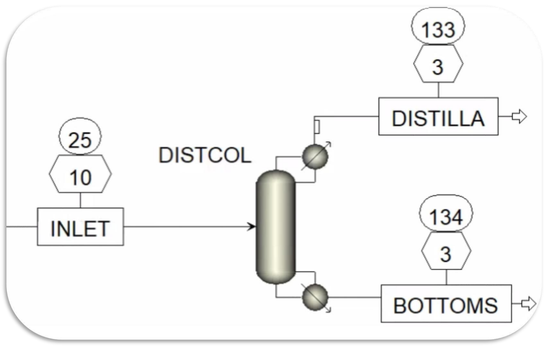

Figure 4: Aspen Plus RadFrac model for distillation

- Aspen Plus RADFRAC block enables regeneration of the zeolite column by separating ammonia from a brine regenerant stream
- Added enough energy to reboiler to result in an effluent containing low levels of NH_3 at 1 mg/L
- Sensitivity analyses on distillate-to-feed and reflux ratios identified optimal operating ranges (D:F = 0.1–0.3, Reflux = 0.4–0.6) to maximize NH_3 purity while minimizing energy usage

Zeolite Column Simulation Results

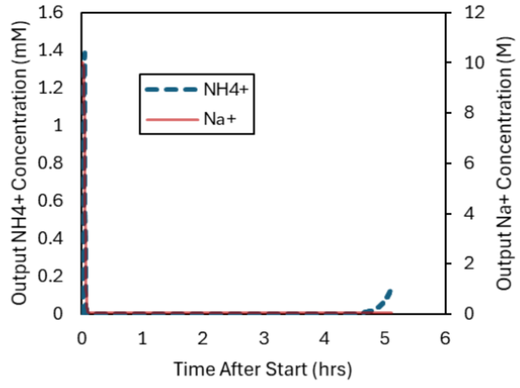

Figure 5: Product stream output concentration over 5-hr period.

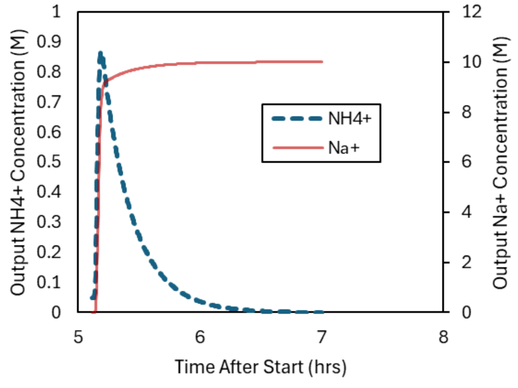

Figure 6: Backwash stream utilizing salt brine regenerant (10M NaCl) after column saturation.

- Shows a 5-hour adsorption time followed by a 2-hour regeneration time
- During regeneration high concentration of NaCl displaces NH_4^+ from column via another ion exchange and NH_4^+ sharply increases
- Output NH_4^+ limit for the product stream set to 1 mg/L
- Optimization of temperature, grain size, and pH was completed

Economic Analysis

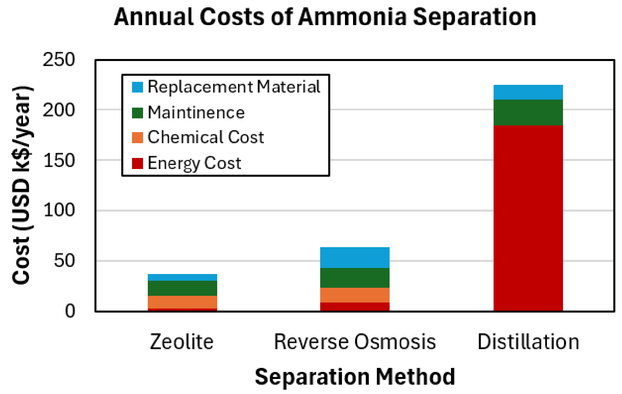

Figure 7: Economic analysis of annual cost of each method

Conclusions/Recommendations

- The system with zeolite treatment provides a more cost-effective removal of ammonia compared to the competitors
- The zeolite column operates most effectively and cheapest at a neutral pH with grain sizes in the 1mm range, and at warmer warm temperatures 25-35 C
- Other configurations could be optimal depending on the variation of RCWW content. More rigorous separation methods might be needed

Future Work

- Simulating zeolite regeneration for multiple cycles with updated component concentrations
- Measuring the accumulation of ammonia in the regeneration stream when recycled, and analyzing when the zeolite effectiveness starts to drop off

References

1. Netsol Water. *How Can We Control Eutrophication, Its Causes and Control?* Netsol Water. Accessed April 22, 2025.
2. Chesapeake Bay Foundation. Maryland Environmental Organizations Seek Judicial Review of New Valley Proteins Wastewater Permit; Chesapeake Bay Foundation: Annapolis, MD, 2023. https://www.cbf.org/ (accessed Apr 17, 2025).
3. Mahmud, S.; Kalamdhad, A. S. Potential Viable Products Identified from Characterisation of Agricultural Slaughterhouse Rendering Wastewater. ResearchGate 2021. https://www.researchgate.net/publication/348911290 (accessed Apr 17, 2025).
4. Miądlicki, P.; Wróblewska, A.; Kiełbasa, K.; Koren, Z.; Michalkiewicz, B. Sulfuric Acid Modified Clinoptilolite as a Solid Green Catalyst for Solvent-Free α-Pinene Isomerization Process. *Microporous Mesoporous Mater.* **2021**, *324*, 111266. https://doi.org/10.1016/j.micromeso.2021.111266.
5. Upadhyay, U.; Gupta, S.; Agarwal, A.; Sreedhar, I.; Anitha, K. L. Process Optimization at an Industrial Scale in the Adsorptive Removal of Cd^{2+} Ions Using Dolochar via Response Surface Methodology. Res. Sq. 2021, doi: 10.21203/rs.3.rs-811892/v1.
6. Tosun, İ. Ammonium Removal from Aqueous Solutions by Clinoptilolite: Determination of Isotherm and Thermodynamic Parameters and Comparison of Kinetics by the Double Exponential Model and Conventional Kinetic Models. Int. J. Environ. Res. Public Health 2012, 9 (3), 970–984. https://doi.org/10.3390/ijerph9030970.