Effect of Temperature Optimization on the Efficiency of Membrane Distillation for Removing Ammonia in Wastewater

Abstract

The most common nitrogenous water pollutant is ammonia. Excess ammonia levels in water can be problematic for aquatic organisms and human health. Membrane distillation is often considered as an alternative to conventional ammonia removal because it can be more productive while being operated at lower temperatures. Ammonia removal through membrane distillation at various temperatures was compared through an extensive review of available literature and data. It was found that higher temperatures allow for more efficient removal of ammonia. From this, future work on the optimization of membrane distillation should be focused on temperature conservation within the system to produce greatest efficiency at the lowest cost.

Purpose

Determine optimal temperatures for membrane distillation in order to reduce ammonia pollution from wastewater treatment plants.

Hypothesis

Alternative:Temperature optimization will increase the efficiency of MD for removing ammonia in wastewater.

Null:Temperature optimization will not affect the efficiency of MD for removing ammonia in wastewater.

Introduction

Wastewater is composed of 99.9% water and 0.1% of organic matter, microorganisms, and inorganic compounds. Organic matter, like nitrogen and other compounds, can be broken down into inorganic compounds, causing pollution that is only partially taken care of in current water treatments methods. The main source of this pollution can be attributed to nitrogen and ammonia.

Removal of ammonia and nitrogen pollutants is desirable due to its negative effect on the environment, economy, and human health. Ammonia leads to eutrophication, or the excessiveness of nutrients, and harms food sources, habitat, water quality, and decreases oxygen levels in the water, causing death and sickness.

The most common method employed for nutrient removal is activated sludge which breaks down ammonia, giving it off as nitrogen gas, however concentrations of ammonia still remain in wastewater discharge. A new method, ammonia removal by membrane distillation (MD) has gained attention because of the low energy it requires, low cost, and overall minimal footprint. It works through filtering the contaminated, or feed solution, with heat through a membrane to a receiving solution that is cold. A membrane acts as a barrier between the two solutions, and as the feed solution vaporizes, specific vapor molecules can move through the membrane, allowing for the removal of pollutants such as ammonia. By optimizing the methods of MD, a cost-effective alternative can be established, ultimately removing ammonia and preventing nitrogen pollution.

Figure 1. Eutrophication as a result of nutrient pollution

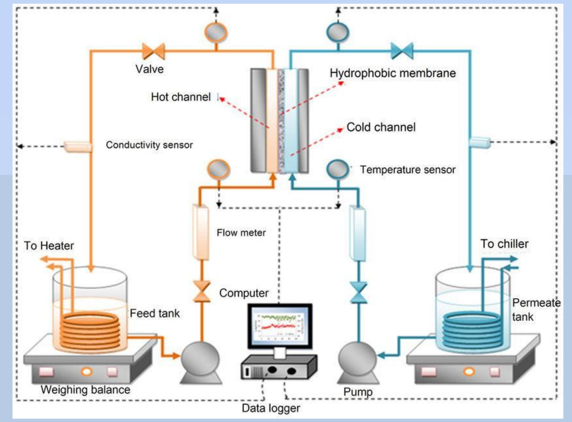

Figure 2. Overview of the membrane distillation process, with the feed solution in orange and the receiving solution in blue

Methods

Data of nitrogen discharge at feed temperatures within a range of 50 to 80℃ was taken from various peer reviewed studies. Nitrogen is measured in ppm after MD treatments. Data was then interpreted to determine the temperature that resulted in the most efficient removal of ammonia. Temperature optimized MD was compared to conventional methods of treatment, to determine if MD can become a more competitive option for ammonia removal.

Statistical analysis was completed on each study separately by calculating the correlation value to determine the relationship between the data points recorded by each study. Based on the correlation value, it was decided as to whether the study should be included in the final findings or not. Also, the relation between temperature and ammonia removal was evaluated by comparing graphical trends.

Results

Treatment Type	Total Nitrogen (ppm)	Location
None	40	EPA Average
Primary Treatment	37	EPA Average
Activated Sludge	25	EPA Average
Activated Sludge	17.8	Bozeman, MT
Activated Sludge	7.85	Crewe, VA
Activated Sludge	18.62	Tampa, FL
Activated Sludge	8.93	Victor Valley, CA
Activated Sludge	6.32	Wolfeboro, NH

Chart 1. Total nitrogen concentrations based using activated sludge measured in ppm. Averages established by the EPA after each treatment are shown as well as actual data from wastewater treatment plants.

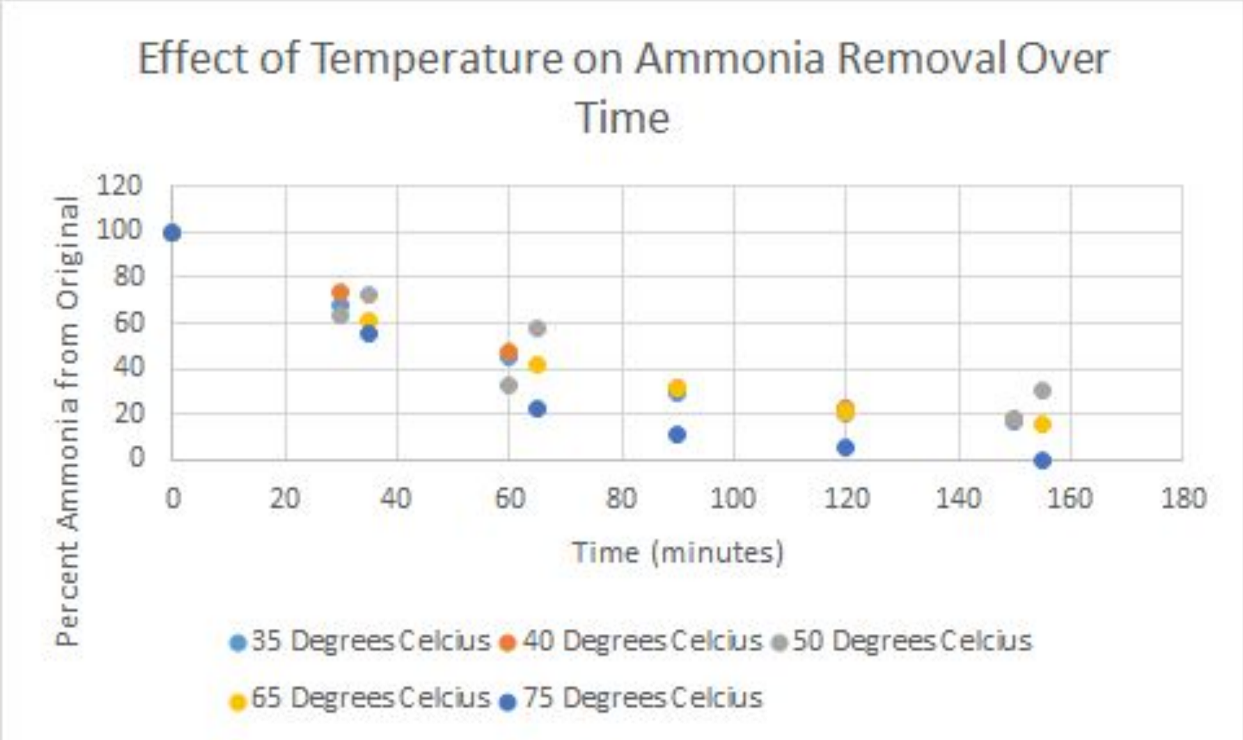

Chart 2. Combined data displaying the ammonia percentage remaining in solution after MD treatment over time at various temperatures

Discussion

The overall trend observed demonstrates that at higher temperatures more ammonia is removed, supporting the alternative hypothesis. MD is dependent on the phase change of the contaminated solution into a gaseous state. With higher temperatures, the kinetic energy of the liquid solution increases eventually allowing for a phase change to gas.Because of the role evaporation plays in the success of MD, it is reasonable to think that conditions that promote faster evaporation rates will allow for greater success in ammonia removal.

Although activated sludge does remove much of the ammonia that is found in the original contaminated solution, there is still substantial amounts of ammonia present in water after it has completed treatment. However, this is also the case for MD, as in no cases was 100% of ammonia removed. Even so, the value of this review has shown that temperature can be used as an effective optimization technique in MD for ammonia removal, meaning that as MD continues to be developed, the importance of temperature must be impressed upon those that seek to make the process a competitive method for ammonia removal.

A more comprehensive approach that involves determining if the average values of each temperature group were statistically significant would further explain any variance seen in the research and analysis and overall deliver a greater understanding of the temperature optimization process.

Further Work

Previous research suggests that one of the main benefits of MD is that it can be operated at lower temperatures than conventional methods. However, these results suggest that in order to make MD most effective, higher temperatures should be used. And while this may optimize the process, it is still not enough to make MD competitive with conventional methods and overall decrease ammonia discharge from wastewater treatment plants. For the process to be further optimized, the conservation of heat in a system could be further investigated to make the process low cost, while still being able to be run at higher temperatures.

Conclusion

As a result of my analysis, I accept the alternative hypothesis and reject the null. By determining that ammonia removal through membrane distillation becomes increasingly more efficient as temperature increases, the research is able to provide a basis for optimization, which is essential to improving ammonia removal of municipal wastewater at treatment plants. Overall, with the development of MD the adverse effects on the environment, economy, and human health can be reduced.

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