Sustainable practice of ammonium removal and recovery using the combination of ion exchange and air stripping method

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이온 교환 및 에어 스트리핑 방법을 사용한 암모늄 제거 및 회수의 지속 가능한 실행

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Abstract

This study provides an investigation on the feasibility of running the adsorption-desorption of ammonium using natural zeolites with the combination of air stripping method. The air stripping technique was done separately using our developed reactor. This preliminary experiment is useful to evaluate the efficiency of the system and eventually arrange a better technical approach for system optimization if necessary. The adsorption was terminated after breakthrough was reached at Ct/C0 = 10% which also equaled 5 mg/L. The calculated total ammonium adsorbed during the first cycle was 4,225.7 mg in 1.3 kg zeolites. In the second cycle, total ammonium adsorbed was 10,823.6 mg in packed zeolites. In the first cycle of desorption with the combination of air stripping, the efficiency was 62% and for the second cycle, the efficiency increased as high as 69.77%. We notice that during the air stripping process, calcites were sporadically produced and this significantly increased the disturbance for regeneration. Thus, we would like to try sodium hydroxide for the substitute of regenerant solutions.

1. Introduction

Ion exchange using natural zeolite has been the promising alternative for removing ammonium ions from water or wastewater since the application of natural zeolites enables several advantages e.g., ease of operation and maintenance, abundant availability, and possibility for species recovery. Numerous factors such as contact time, type of zeolites, initial ammonium concentrations, zeolite loading, and particle sizes; influence the characteristics of natural zeolites as ion exchangers. One of challenging parts in the application of ion exchange is the regeneration phase. Once the natural zeolites get saturated, regeneration of natural zeolites is commonly selected instead of using the fresh natural zeolites. Regeneration of natural zeolites allows the sustainable use of zeolites for continuos cycles without the needs of using the new natural zeolites.

Typically, a large volume of fresh regenerant is used for regenerating natural zeolites. However, using air stripping method, zeolite regeneration without additional fresh solvent is plausible. Thus, air stripping method is usually coupled during regeneration to remove ammonia in the solvent. After the ammonia is completely removed, the remaining solvent can be reused for another cycle of regeneration. Ellersdorfer (2018) observed the advantages in combining the air stripping technique during regeneration phase. Prevention against excess amount of fresh regeneration solutions, a decrease of operational cost, and lower demand of energy are of the benefits.

In this study, we carried out an investigation on the feasibility of running the adsorption-desorption of ammonium using natural zeolites with the combination of air stripping method. The air stripping technique was done separately using our developed reactor. This preliminary experiment is useful to evaluate the efficiency of the system and eventually arrange a better technical approach for system optimization if necessary.

2. Methods

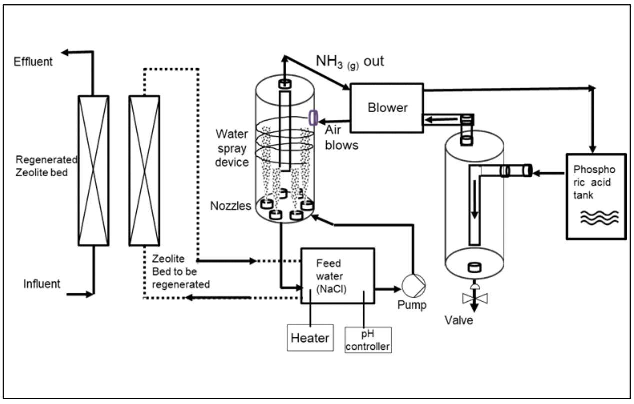
2.1 Experimental set-up

The adsorption of ammonium ions was done in an acrylic column packed with natural zeolites (1.3 kg) of 85 cm in height and inner diameter of 5 cm. The ammonium concentration was set to 50 mg/L using synthetic grey water (Table 1). The influent was fed into the column using peristaltic pump with the upward direction (vertical velocity = 5 m/h). The adsorption was terminated after breakthrough was reached at C_t/C_0 = 10% which also equaled 5 mg/L.

[Table 1] Composition of synthetic greywater

Compound	mg/L
Kaolin	3.75
Cellulose	3.75
Humic acid	1.25
$MgSO_4$	0.5
KH_2PO_4	3.25
$FeCl_3$	0.075
H_3BO_3	0.150
$MnCl_2$	0.006
$ZnSO_4$	0.050
$CuSO_4$	0.005
NH_4Cl	50

The regeneration phase started by flowing the sodium chloride (0.5 M) solution into the zeolite bed. Total solution used was 25 Liter. The direction of flow was downward with vertical velocity at 5 m/h. The overall experimental set-up is illustrated in the Figure 1 below.



[Fig. 1] Experimental set up of ammonium adsorption and desorption

The operational conditions for air stripping technique were stated below (Table 2).

[Table 2] Operational conditions of stripping process

Conditions	Values
Temperature	28^0C
Air flow rate	120 L/min
Water flow rate	10 L/min
pH	11

2.2 Calculation

The calculation of regeneration efficiency is as follows.

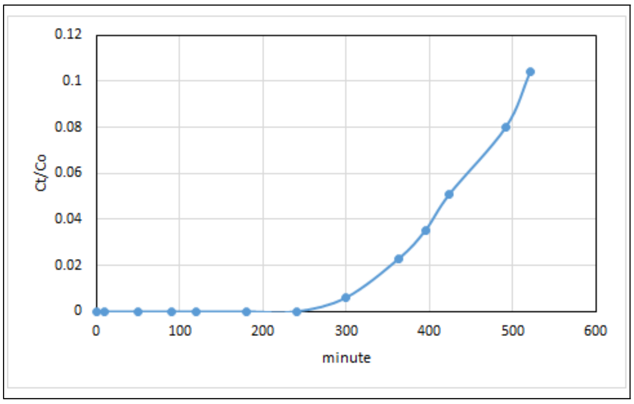
$$\text{Efficiency} = (X_1/X_2)*100\%$$

X_1 equals the amount of ammonium in the natural zeolites (mg) whereas X_2 is the amount of ammonium in the regenerant solutions (mg).

3. Results

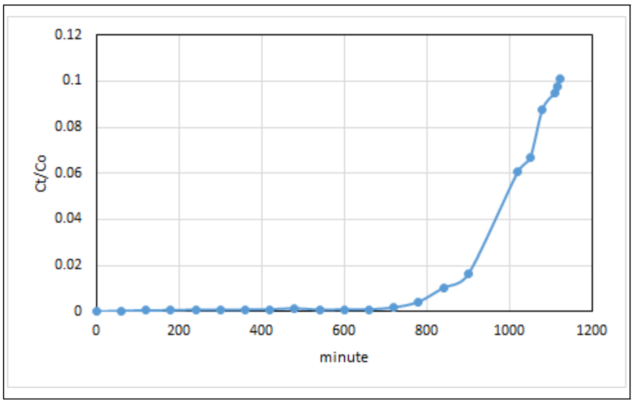
3.1 Adsorption

The first cycle of ammonium adsorption was done in total of almost 9 hour run. In the first cycle (Figure 2), we stopped the adsorption after 10% of C_t/C_0 was reached.



[Fig. 2] First cycle of ammonium adsorption at 50 mg/L

The calculated total ammonium adsorbed during the first cycle was 4,225.7 mg in 1.3 kg zeolites. The second cycle of adsorption was started after the desorption or regeneration cycle was promoted (Figure 3). In the second cycle of adsorption phase, the adsorption was stopped after 1,123 minutes as soon as the breakthrough of 10% was met.



[Fig. 3] Second cycle of ammonium adsorption at 50 mg/L

In the second cycle, total ammonium adsorbed was 10,823.6 mg in packed zeolites. The increase of adsorbed ammonium was due to more vacant sites in the zeolites after an intense cycle of regeneration phase. We also noticed that there was small portions of remaining ammonium ions trapped in active sites of the zeolites and could not be released during first cycle of regeneration phase.

3.2 Desorption

In the desorption stage, we did flush the packed zeolites with sodium chloride 0.5 M around 25 L and as soon as the desorption ended, air stripping was carried to remove the ammonium recovered from the desorption phase. The desorption phase took about 2.5 hours and air stripping of ammonia was done in 7 hours to remove ~90% of dissolved ammonia in the regenerant so that the solvent could be reused for many cycles of regeneration.

In the first cycle of desorption with the combination of air stripping, the efficiency was 62% and for the second cycle, the efficiency increased as high as 69.77%.

We notice that during the air stripping process, calcites were sporadically produced and this significantly increased the disturbance for regeneration. High calcites might clog the column. Thus, we would like to try sodium hydroxide for the substitute of regenerant solutions.

Acknowledgement

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References

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