Supplementary Information

Efficiency, mechanism and application prospect of ammonium adsorption and desorption over a sodium-acetate-modified synthetic zeolite

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Text. S1

Synthetic zeolite was modified with different sodium acetate concentrations to explore the effect of sodium acetate concentrations on the NH_4^+ adsorption efficiency of modified synthetic zeolite. The experimental conditions were as follows: the adsorbent dosage was 10 g/L, initial NH_4^+ concentration was 100 mg/L, and agitation frequency was set at 150 rpm. The results are depicted in **Fig. S1**. With the increase of sodium acetate concentration, the adsorption effect of NH_4^+ was enhanced. However, when the concentration of sodium acetate surpassed 1 mol/L, the adsorption capacity for NH_4^+ tended to plateau. At this point, an excessively high concentration of sodium acetate solution limited the zeolite available for Na^+ exchange, leading to resource wastage. Considering the efficacy and cost-effectiveness of NH_4^+ removal, subsequent experimentation established 1 mol/L as the optimal zeolite modification concentration. The adsorption capacity of the synthetic zeolite modified with the optimal concentration of sodium acetate was nearly double that of the unmodified counterpart.

Text. S2

The sodium (Na) level in MSZ before to ammonium adsorption is 8.86%, but after adsorption, it decreased to 6.81%. During the adsorption process of 1 g of MSZ, 0.0205 grams of Na^+ (equivalent to 0.00089 mol) was ionically exchanged. Given that the pH was 7 and there were no other ions present in the simulated water that could cause interference, it could be concluded that the exchange of Na^+ exclusively occurred with ammonium. The amount of ammonium adsorbed by 1 g MSZ ion during exchange is 0.00089 mol (16.04 mg). Based on the adsorption isotherm at a temperature of 25℃, the adsorption capacity of MSZ at an initial concentration of 200 mg/L was 20.59 mg/g. So, the ion exchange ratio was calculated as 77.90% by dividing 16.04 by 20.49.

Furthermore, the Na^+ concentration in the solution exhibited a 77.49 ppm increase both before and after the adsorption of ammonium. The data indicated that 77.49 mg/L of sodium ions (equal to 3.37 mol/L) were substituted by ammonium ions via ion exchange. The change in ammonium concentration attributed to ion exchange amounts to 60.66 mg/L, calculated as the product of 3.37 and 18 (Molar mass of NH_4^+). Simultaneously, the ammonium concentration in the solution decreased by 82.78 mg/L. The ion exchange ratio can be calculated as 60.66/82.78=73.28%. The discrepancy was smaller than 5% between the outcomes computed based on the salt level in MSZ.

Text. S3

The breakthrough curve illustrates the impact of varying concentrations of ammonium on the adsorption process. **Fig. 5a** presents the breakthrough curves for different imported ammonium concentrations (10 mg/L, 50 mg/L, and 100 mg/L) under a constant flow rate of 10 mL/min and a fixed bed height of 2 cm. As the ammonium concentration increases, both the saturation time and breakthrough time decrease. For an input concentration of 10 mg/L, the saturation time is 126 minutes, while for an input concentration of 100 mg/L, the saturation time reduces to 90 minutes. Increasing the concentration of the adsorbent reduces the running time of the tower. This is because, at a specific tower height and solution flow rate, higher concentrations of imported ammonium result in greater adsorption by the tower.

To assess the effect on ammonium salt adsorption, the optimal bed height was determined by adjusting the height of the MSZ layer. **Fig. 5b** demonstrates the influence of a constant inlet concentration (50 mg/L) and flow rate (10 mL/min) on ammonium salt adsorption using MSZ films of different thicknesses (1, 2, and 3 cm). Increasing the height of the MSZ layer promotes crack formation and saturation, thereby enhancing the rate of ammonium removal. As the MSZ layer height increases from 1 cm to 2 cm and 3 cm, the corresponding saturation time also increases from 70 minutes to 120 minutes and 145 minutes, respectively. This trend aligns with the observed change in adsorption capacity (q_t), indicating that the height of the adsorbent in the packing fixed bed directly affects the effectiveness of ammonium salt adsorption. This relationship arises because a greater height of the MSZ layer provides a larger number of active adsorption sites.

Fig. 5c illustrates the impact of different flow rates on ammonium adsorption in MSZ packed bed towers. The experimental flow rates ranged from 5 to 15 mL/min, while maintaining a constant inlet concentration of ammonium salt solution (50 mg/L) and a fixed MSZ layer height (2 cm). The fixed bed saturation time increased from 90 minutes to 125 minutes and 200 minutes, respectively. The adsorption capacity of the fixed bed is directly proportional to the flow rate; however, the actual adsorption volume of ammonium decreases, resulting in a lower adsorption rate. These

observations can be attributed to an increase in the intensity of incoming air and a higher mass absorbed into the capillary through the fixed bed. The breakthrough duration is shortened due to the rapid saturation of the surfactant's active sites.

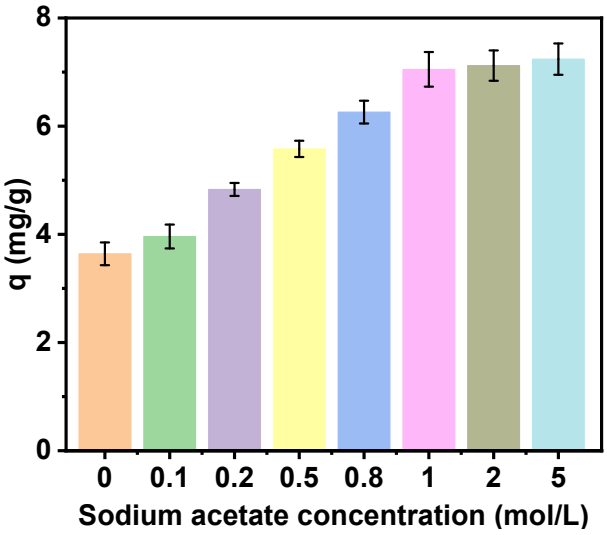


Fig. S1 Adsorption capacity of zeolite for NH_4^+ at different concentrations of sodium acetate

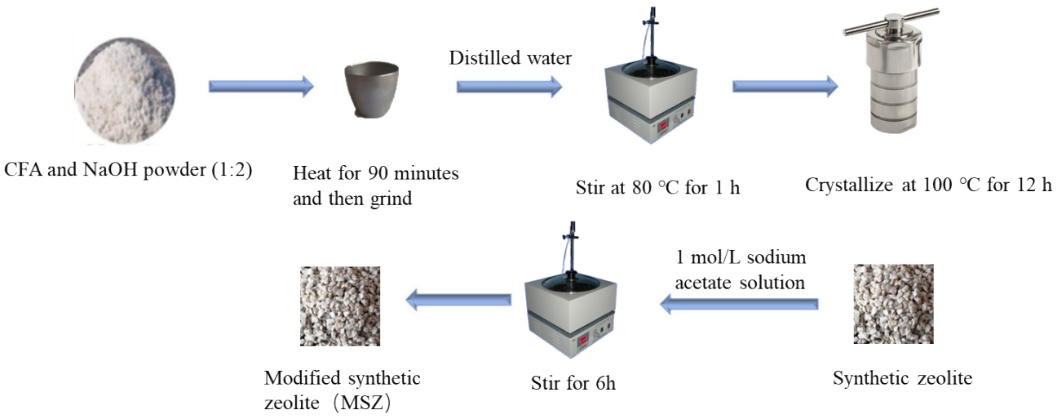
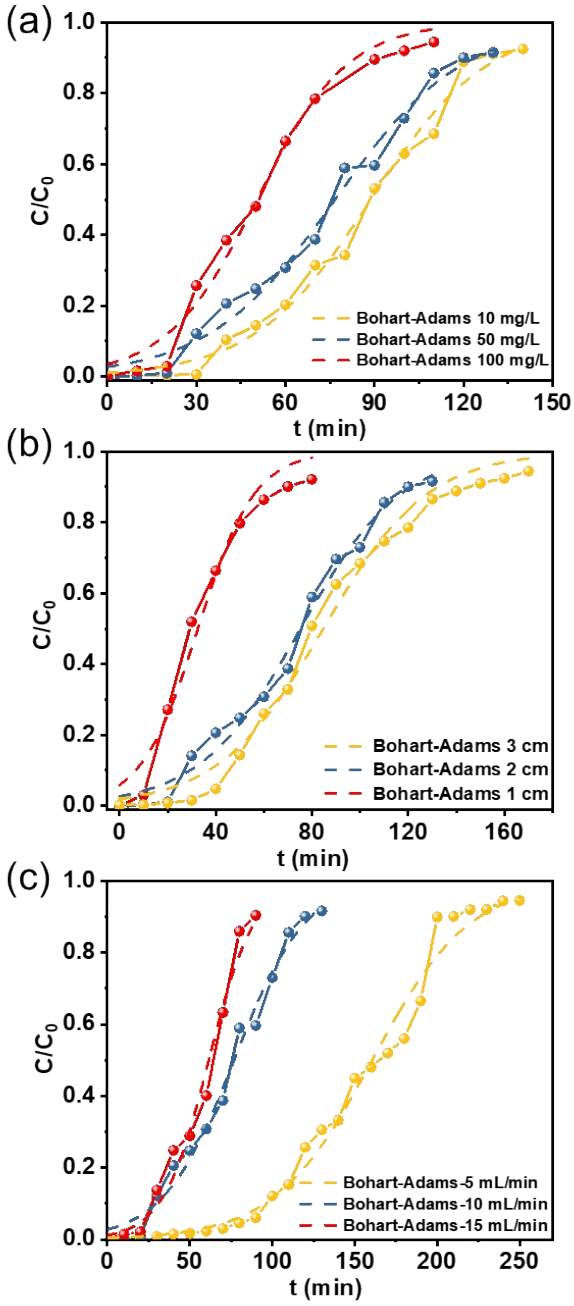


Fig. S2 Schematic diagram of the material synthesis process.



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88 **Fig. S3** (a) The influence of inlet ammonium concentration on the breakthrough curve (H = 2 cm,

89 Q = 10 mL/min), (b) the influence of fixed bed height on the ammonium adsorption breakthrough

90 curve of MSZ (C_0 = 50 mg/L, Q = 10 mL/min), (c) Effect of flow rate (C_0 = 50 mg/L, H = 2 cm)

91 on ammonium adsorption breakthrough curve.

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93 **Table S1** Details of plant growth in pot experiment.

Add NH_4^+-MSZ			
Germination rate (%)	Stem length (cm)	Root length (cm)	Fresh weight (g)
83.33	7.429	4.921	0.2852
Not add			
Germination rate (%)	Stem length (cm)	Root length (cm)	Fresh weight (g)
73.33	5.888	3.516	0.2261

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