Supplementary Information for

Removal of ammonium from swine wastewater using synthesized zeolite from fly ash

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Number of supplemental tables: 2
Number of supplemental figures: 4

Section 1. Description of adsorption kinetics model

The adsorption kinetics can typically determine the contact time required for the adsorbent to reach its maximum adsorption capacity during the equilibrium phase. The results of our kinetics experiment were analyzed using pseudo-first-order (Equation 1) and pseudo-second-order kinetics models (Equation 2): [1,2]

$$ln(q_e - q_t) = ln\, q_e - k_1 t \tag{1}$$

$$\frac{t}{q_t} = \frac{t}{q_e} + \frac{1}{k_2 q_e^2} \tag{2}$$

where qe and qt are adsorption capacity (mg/g) at equilibrium, and time t (min), and k_1 (1/min) and k_2 (g/(mg/min)) are the adsorption rate constant of the pseudo-first-order and pseudo-second-order models, respectively.

Section 2. Description of adsorption isotherms model

Adsorption isotherm refers to a curve that reflects the relationship of amount of solute q_e, at constant temperature in a certain volume of solution, adsorbed on the unit mass by adsorbent and the corresponding equilibrium concentration of the solution C_e [3]. The Freundlich isotherm model [4] explains that the surface properties of the adsorbent is heterogeneous and the multilayer adsorption occurs on the surface. The Langmuir model [5] illustrates the surface properties of the adsorbent is homogeneous and the monolayer adsorption occurs on the surface. The ammonium adsorption equilibrium isotherm was analyzed by the Freundlich mathematical models (Equation 3) and Langmuir (Equation 4), which are expressed as follows:

$$q_e = k_f C_e^{1/n} \tag{3}$$

$$q_e = \frac{q_m k_l C_e}{1 + k_l C_e} \tag{4}$$

$$R_L = \frac{1}{1 + k_l C_0} \tag{5}$$

where q_m is the the maximum ammonium adsorption capacity (mg/g), C_e is the equilibrium concentration (mg/L), n is the heterogeneity factor, R_L is a dimensionless separation factor, and k_f, k_l are the Freundlich, Langmuir constants, respectively.

Section 3. Description of adsorption thermodynamics

The thermodynamics parameters, including Gibbs free energy ($\Delta G°$), enthalpy variation ($\Delta H°$), and entropy variation ($\Delta S°$) can be calculated by Gibbs and Van't Hoff equations according to the experimental data for ammonium adsorption onto zeolite at different temperatures [6,7]:

$$K_c = \frac{C_{ad,e}}{C_e} \tag{6}$$

$$\Delta G° = -RT\ln K_c \tag{7}$$

$$\ln K_c = \frac{\Delta S°}{R} - \frac{\Delta H°}{RT} \tag{8}$$

In which k_c is the equilibrium constant; $C_{ad,e}$ (mg/L) denotes the NH_4^+ amount adsorbed on the adsorbent per liter of the solution at equilibrium; R (8.314 J/mol/K) is the universal gas constant and T(K) is the temperature. A straight line will yield when ($\ln K_c$) was plotted against (1/T), $\Delta H°$ and $\Delta S°$ can be obtained from its slope and intercept.

Section 4. Supplementary Table and Figure of contents

Table S1. The kinetic model parameters for ammonium adsorption of synthetic zeolite.

Parameters		Initial Ammonium Concentration (mg/L)			
		20	100	300	500
Pseudo-first-order	q_e	1.85	7.70	17.50	20.91
	k_1 (1/min)	0.060	0.120	0.260	0.200
	r^2	0.420	0.376	0.213	0.930
Pseudo-second-order	q_e (mg/g)	2.00	8.36	18.54	21.29
	k_2 (g/(mg/min))	0.041	0.014	0.008	0.008
	r^2	0.999	0.999	0.999	0.999

Table S2. Ammonia nitrogen adsorption capacities of various zeolites.

Types	The Ammonium Adsorption Capacity (mg/g)	Thermodynamic Model	Reference
Natural zeolite	13.32	Langmuir	[8]
Modified zeolite	11.83	Langmuir	[9]
Modified zeolite	9.66	Langmuir	[11]
ZFA	28.65	Langmuir	[12]
ZFA	25.13	Langmuir	[13]
ZFA	23.15	Langmuir	[14]
ZFA	32.16	Langmuir	This research

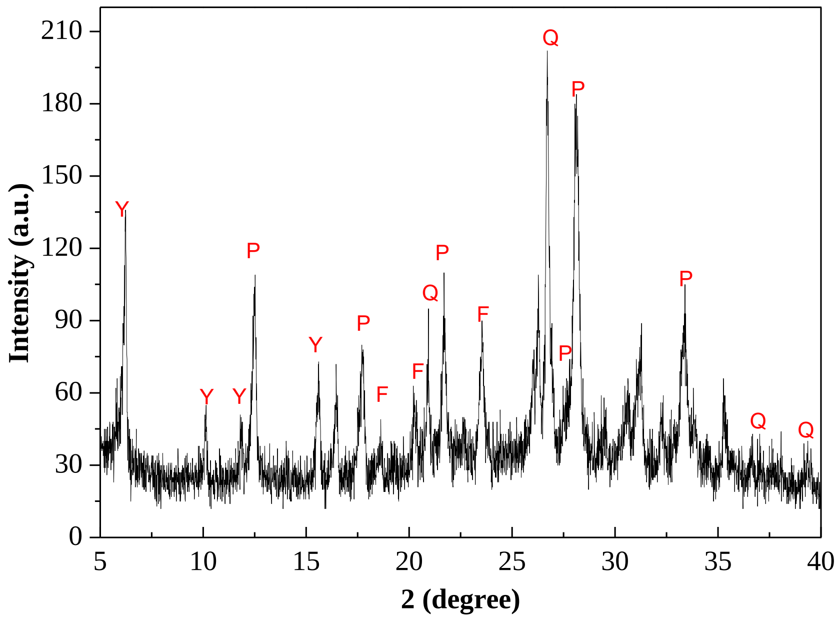

Figure S1. XRD of synthetic zeolite. (Y) zeolite Y, (P) zeolite P, (F) faujasite, (Q) quartz.

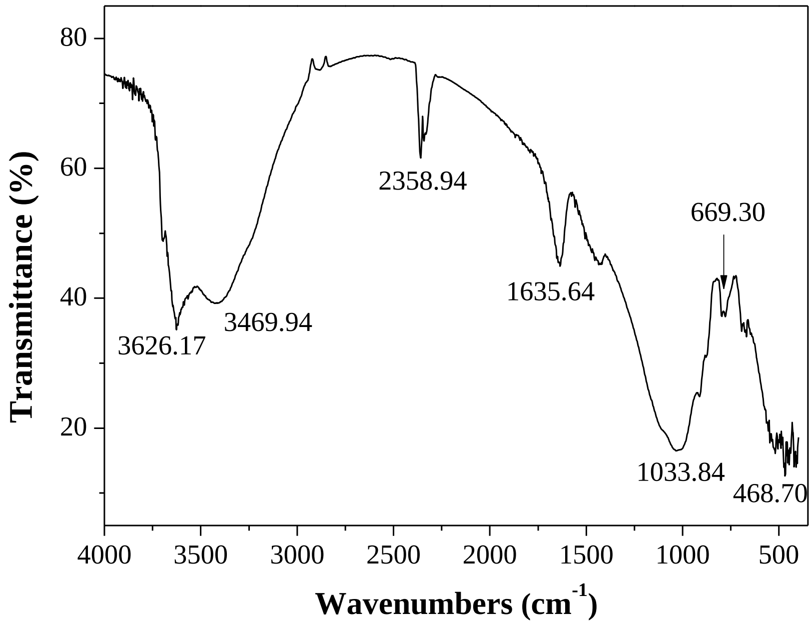

Figure S2. FTIR spectrum of synthetic zeolite.

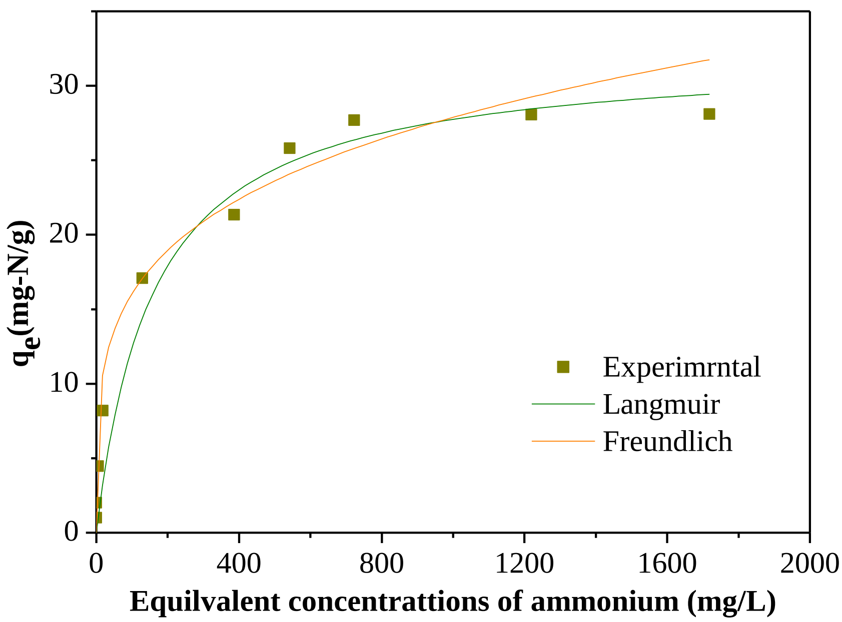

Figure S3. Equilibrium isotherm fitted to the Langmuir and the Freundlich models (25 °C).

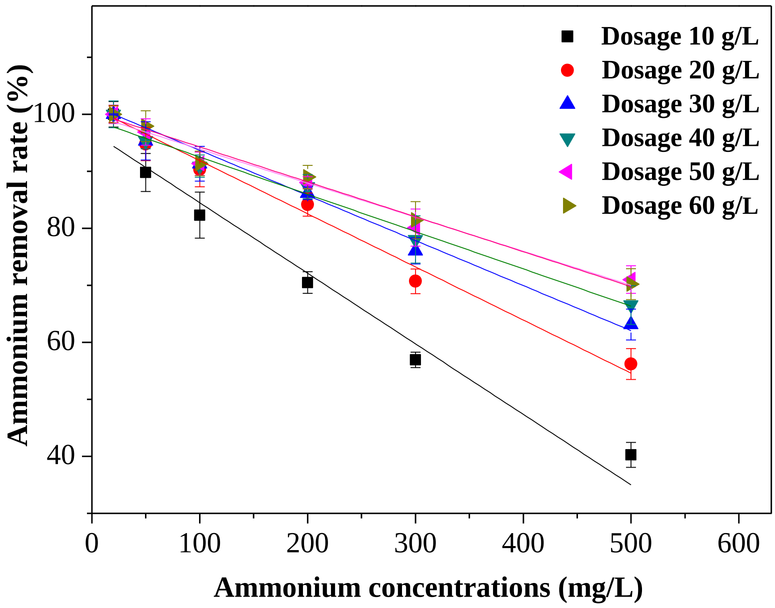

Figure S4. Fitting of ammonium removal efficiency in simulated wastewater.

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