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Removal of High Concentration of Ammonia from Wastewater by the Ion Exchange Resin

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ABSTRACT

Nitrogen (N) is an essential element for living organisms in aquatic ecosystem. However, excess nitrate in this ecosystem could degrade water quality due to eutrophication. Ammonia is usually found in aqueous environments. It affects fish and other aquatic life and recreational use of water. In this study, the acidic ion exchange resins were chosen as adsorbent to adsorb the high concentration of ammonia from wastewater. The experimental results showed that reaction of temperature, the amount of the ion exchange resins and reaction time had an important influence on the removal rate of high concentration of ammonia from wastewater. The experimental data correlated well with the Langmuir adsorption isotherm. It was also suggested that the adsorption process was homogeneous adsorption. The ammonia from aqueous solution adsorption on the acidic ion exchange resins was a monolayer adsorption.

INTRODUCTION

Nitrogen (N) is an essential element for living organisms in aquatic ecosystem. However, excess nitrate in this ecosystem could degrade water quality due to eutrophication. Ammonia is usually found in aqueous environments.

One of the most serious environmental problems concerning nitrate pollution is eutrophication of natural water bodies such as rivers and lakes; it affects fish and other aquatic life and recreational use of water (Lahav et al. 2013).

High nitrate levels in drinking water can also cause blue baby syndrome or methaemoglobinaemia, especially in infants. Severe methaemoglobinaemia can result in brain damage and death (Gendel & Lahav 2013.). The toxicity of ammonia to fish and other aquatic animals is severe when its concentration is in a range of 0.2-0.5 mg/L (Ward et al. 2005, Shafeeyan et al. 2015). Currently, many municipal and industrial wastewaters in part of China, after conventional treatments, remain relatively in high concentration of ammonia (Zhu et al. 2011, Fang et al. 2016). These concentrations exceed surface water standard limits in China and could pose a potential risk to receiving watersheds. Therefore, a need exists to develop an efficient means for removing ammonia from wastewaters.

Several nitrate removal technologies have been used in water treatment, for example, ion exchange, reverse osmosis, adsorption and chemical and biological methods (Bhatnagar & Sillanpää 2011, Zhao et al. 2015). At present, most of the processes that are used for ammonia-nitrogen removal from wastewater are coupled with the removal of organic matter. The most commonly-used technique for swine waste treatment to-date is anaerobic digestion, predominantly applied in anaerobic lagoons. Anaerobic treatment provides a convenient and simple method for stabilizing organic matter into less reactive compounds and biogas.

Among these methods, adsorption is the best choice because of its relatively low operational costs, simplicity, and minimal production of waste (Blaney et al. 2007, Milmile et al. 2011). However, this method's efficiency depends highly on the type of adsorbent. Nitrate removal studies have been conducted in the past with several adsorbents, such as ion exchange resins, zeolite, fly ash, red mud and agricultural wastes (Nur et al. 2012, Oladoja & Helmreich 2014).

In this study, the acidic ion exchange resins were chosen as adsorbent to adsorb the ammonia from wastewater. The influence of factors, such as reaction of temperature, the amount of the ion exchange resins and reaction time, were discussed through the adsorption experiments in details. Additional, the adsorption isotherm was also studied through the experimental data.

MATERIALS AND MATERIALS

The acidic ion exchange resins were obtained from the chemical group in Guangdong Province. In this adsorption experiment, the analytical reagents were used. The high concentration ammonia wastewater was confected according to the wastewater of chemical industry. The concentration of ammonia is 3125 mg/L.

Experiment

The preparation of the acidic ion exchange resins: The acidic ion exchange resins were washed 4-5 times with the deionized water. Then they were soaked for 4 h in 200 mL 1 mol/L HCl solution again. They were washed to the pH 6.0-8.0 in solution with the deionized water. The experimental adsorbent was prepared for the experiment.

The adsorption experiment: Adsorption experiments were conducted in a set of 250 mL Erlenmeyer flasks containing the acidic ion exchange resins and 100 mL of ammonia with various initial concentrations in aqueous solution. The flasks were placed in a shaker at a constant temperature of 308 K and 200 rpm. The samples were then filtered and the residual concentration of ammonia in solution was analysed.

Analytical Methods

The value of pH was measured with a pH probe according to APHA Standard Method. The concentration of ammonia was measured with Nash reagent colorimetric method.

The amount of adsorbed ammonia q_t (mg/g) at different time, was calculated as follows:

$$q_t = \frac{(C_0 - C_t) \times V}{m} \quad ...(1)$$

Where C_0 and C_t (mg/L) are the initial and equilibrium liquid-phase concentrations of ammonia respectively. V (L) is the solution volume and m (g) is the mass of adsorbent used.

Statistical Analyses of Data

All experiments were repeated in duplicate and the data of results were the mean and the standard deviation (SD). The value of the SD was calculated by the Excel Software. All error estimates given in the text and error bars in figures are the standard deviation of the means (mean±SD). All statistical significance was noted at α=0.05 unless otherwise noted.

RESULTS AND DISCUSSION

The effect of reaction time: In order to investigate the effect of reaction time on the removal of ammonia in solution, the following tests were carried out. Adsorption experiments were conducted in a set of 250 mL Erlenmeyer flasks containing 10.0 g of acidic ion exchange resins and 100 mL of 3125 mg/L ammonia in aqueous solution. The value of pH in the solution was adjusted to 7 with 1 mol/L HCl or 1 mol/L NaOH. The flasks were placed in a shaker at a constant temperature of 308 K and 200 rpm. The experimental results are shown in Fig. 1.

From Fig. 1, it can be seen that the removal rate of ammonia increased with the increasing of reaction time. When the reaction time reached to 90 min, the adsorption process reached equilibrium.

The effect of the doze of acidic ion exchange resins: Adsorption experiments were conducted in a set of 250 mL Erlenmeyer flasks containing the acidic ion exchange resins with various initial concentrations (2g, 4g, 6g, 8g, 10g, 12g and 14g) and 100 mL of 3125 mg/L ammonia in aqueous solution. The value of pH in solution was adjusted to 7 with 1 mol/L HCl or 1 mol/L NaOH. The flasks were placed in a shaker at a constant temperature of 308 K and 200 rpm. The reaction time was 120 min. The results are shown in Fig. 2.

As seen from Fig. 2, the effect of acidic ion exchange resins was important. When the doze of ion exchange resins was increasing, the removal rate of high ammonia from solution was also increased. The increase in the doze of ion exchange resins is beneficial for the increase in surface and adsorption place. So, the ion exchange resins can behold more ammonia from aqueous solution and the removal rate of ammonia is increasing. When the adsorption process reached equilibrium, the removal rate of ammonia began to keep stabilization. The adsorption of ammonia from wastewater by the acidic ion exchange resins reached saturation.

The effect of temperature: The reaction temperature had an important role in the removal rate of high ammonia from wastewater. In this work, the effect of reaction temperature was investigated in details. Adsorption experiments were conducted in a set of 250 mL Erlenmeyer flasks containing 10 g acidic ion exchange resins and 100 mL of 3125 mg/L

Table 1: The adsorption parameters for high concentration ammonia from aqueous solution adsorption on the acidic ion exchange resins by Langmuir adsorption isotherm and Freundlich isotherm.

Langmuir parameters			Freundlich parameters		
q_{max} (mg/g)	K_L (L/mg)	R^2	n	K_F	R^2
202.6	0.0312	0.9812	0.1102	3.24	0.7215

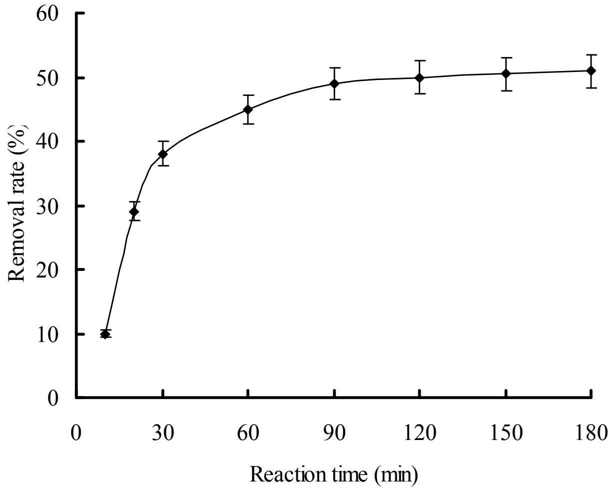

Fig. 1: The effect of reaction time.

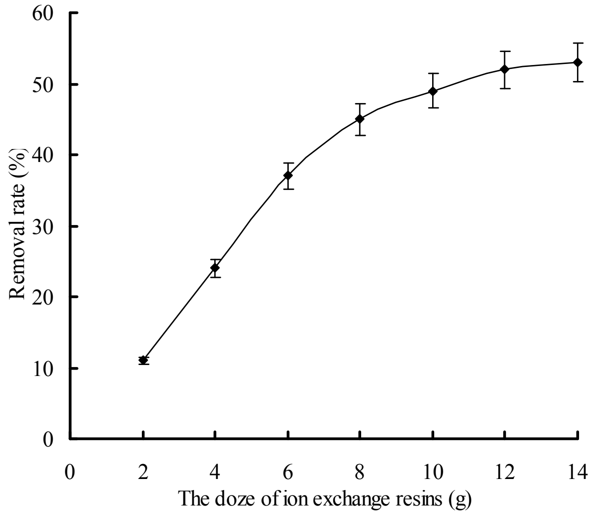

Fig. 2: The effect of acidic ion exchange resins.

ammonia in aqueous solution. The value of pH in the solution was adjusted to 7 with 1 mol/L HCl or 1 mol/L NaOH. The flasks were placed in a shaker at a constant temperature (293K, 308 K and 318 K) and 200 rpm. The experimental results are shown in Fig. 3.

As shown from Fig. 3, it can be known that the reaction temperature had an important influence on the removal rate of ammonia from wastewater. When the reaction temperature is increased, the removal rate of ammonia is also increased. It was shown that the reaction temperature had a benefit for the adsorption of ammonia from wastewater.

Adsorption isotherm: The adsorption isotherm was described with Langmuir isotherm and Freundlich isotherm. The Langmuir isotherm equation is represented by the following Eq. (2):

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \quad ...(2)$$

Where C_e is the equilibrium concentration of ammonia (mg/L), q_e is the amount of ammonia adsorbed (mg/g), q_m is the maximum adsorption capacity of ammonia (mg/g), and K_L is the Langmuir adsorption equilibrium constant (L/mg) related to the affinity of the binding sites (Langmuir 1918).

The Freundlich isotherm equation is described by the following Eq. (3):

$$q_e = K_F C_e^{\frac{1}{n}} \quad ...(3)$$

Where K_F and n are the Freundlich adsorption isotherm constants, which are indicators of adsorption capacity and adsorption intensity respectively (Freundlich 1906).

According to the experimental data, the adsorption parameters were obtained from the Langmuir adsorption isotherm and Freundlich adsorption isotherm. They are listed in Table 1.

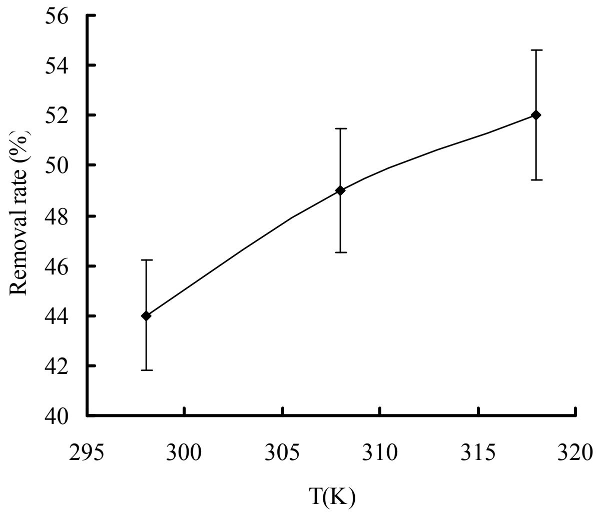

Fig. 3: The effect of reaction temperature.

It was shown that the Langmuir adsorption isotherm model was more suitable for the ammonia from aqueous solution than the Freundlich adsorption isotherm model. It was also suggested that the adsorption process was homogeneous adsorption. The ammonia from aqueous solution adsorption on the acidic ion exchange resins was monolayer adsorption.

CONCLUSION

In this study, the acidic ion exchange resins were chosen as adsorbent to adsorb the ammonia from wastewater. The experimental results showed that the influence of factors, such as reaction of temperature, the amount of the ion exchange resins and reaction time, had an important influence on the removal rate of high ammonia from wastewater. The Langmuir adsorption isotherm model was more suitable for the ammonia from aqueous solution than the Freundlich adsorption isotherm model. It was also suggested that the adsorption process was homogeneous adsorption. The ammonia from aqueous solution adsorption on the acidic ion exchange resins was monolayer adsorption.

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