ISSN 1001-0742
CN 11-2629/X

JES JOURNAL OF ENVIRONMENTAL SCIENCES

January 1, 2013 Volume 25 Number 1
www.jesc.ac.cn

ELSEVIER
Science Press

Sponsored by
Research Center for Eco-Environmental Sciences
Chinese Academy of Sciences

ISSN 1001–0742 **Journal of Environmental Sciences** Vol. 25 No. 1 2013

CONTENTS

Serial parameter: CN 11-2629/X*1989*m*235*en*P*26*2013-1

Available online at www.sciencedirect.com

ScienceDirect

Journal of Environmental Sciences 2013, 25(1) 105–113

JOURNAL OF ENVIRONMENTAL SCIENCES
ISSN 1001-0742
CN 11-2629/X
www.jesc.ac.cn

Effect of dissolved organic matter on nitrate-nitrogen removal by anion exchange resin and kinetics studies

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Received 05 April 2012; revised 13 July 2012; accepted 23 July 2012

Abstract

The effects of dissolved organic matter (DOM) on the removal of nitrate-nitrogen from the model contaminated water have been investigated utilizing the strong base anion exchange resins. With the increase of gallic acid concentration from 0 to 400 mg/L, the adsorption amount of nitrate-nitrogen on the commercial resins, including D201, Purolite A 300 (A300) and Purolite A 520E (A520E), would significantly decrease. However, the presence of tannin acid has little impact on nitrate-nitrogen adsorption on them. Compared to D201 and A300 resins, A520E resin exhibited more preferable adsorption ability toward nitrate-nitrogen in the presence of competing organic molecules, such as gallic acid and tannin acid at greater levels in aqueous solution. Attractively, the equilibrium data showed that the adsorption isotherm of nitrate-nitrogen on A520E resin was in good agreement with Langmuir and Freundlich equations. The rate parameters for the intra particle diffusion have been estimated for the different initial concentrations. In batch adsorption processes, nitrate-nitrogen diffuse in porous adsorbent and rate process usually depends on $t^{1/2}$ rather than the contact time. The pseudo first- and the second-order kinetic models fit better for nitrate-nitrogen adsorption onto A520E resin. The observations reported herein illustrated that A520E resin will be an excellent adsorbent for enhanced removal of nitrate-nitrogen from contaminated groundwater.

Key words: dissolved organic matter; strong base anion exchange resin; selectivity; nitrate-nitrogen

DOI: 10.1016/S1001-0742(12)60035-7

Introduction

High nitrate-nitrogen concentration is frequently detected in the surface water and groundwater recently due to the excessive use of agricultural fertilizers, septic tank systems and animal waste disposal. Excess nitrate-nitrogen in drinking water would cause the serious environmental and health problems, even cancer (Bhatnagar and Sillanpää, 2011).

Several technologies have been developed in order to effectively remove nitrate-nitrogen, such as adsorption, ion exchange, electrodialysis, reverse osmosis, chemical treatment (Gašparovičová et al., 2007; Hoek et al., 1988; Wang et al., 2006, 2009; Mikami et al., 2003; Song et al., 2012a). However, considering low cost, practical application and operability, adsorption is always regarded as the most promising and effective approach. Therefore, adsorbent resins with higher chemical stability have caught the global attention, because of their attractive ability to reduce, even completely remove nitrate-nitrogen from water (Bae et al., 2002).

Meanwhile, dissolved organic matter (DOM) also exists in various natural water systems commonly, they would greatly compete with nitrate-nitrogen for the active sites of the adsorbents. So, it is still challenging task for deep removal of nitrate-nitrogen from combined contaminated water (Wang et al., 2009; Huo et al., 2008; Lapworth et al., 2008). For example, gallic acid and tannin acid, which could result in the formation of disinfection by-products and bacterial re-growth in natural water sources would be considered as the typical components among DOMs (Wang et al., 2009; Huo et al., 2008; Lapworth et al., 2008).

Until now, some systems about nitrate-nitrogen removal by anion exchange method had been reported in the previous literatures (Heredia et al., 2005; Chabani et al.,

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2007; Milmile et al., 2011). However, few researches on the impact of DOM for the absorption behavior of nitrate-nitrogen onto resin were reported. In fact, how to remove the nitrate-nitrogen from polluted water systems containing DOM effectively is an interesting and important issue for practical application utilizing the commercial resins.

In this article, the kinetic behaviors and adsorption properties for nitrate-nitrogen removal were investigated by the corresponding kinetic models and equilibrium adsorption experiments using three commercial anion exchange resins. The impacts of DOMs for the absorption ability were studied in detail.

1 Experimental

1.1 Materials and methods

Purolite A 300 (A300) and Purolite A 520E (A520E) were strong anion exchange resins provided by Purolite Int. Ltd., which were functionalized by reactions with -$(CH_3)_2(C_2H_4OH)N^+$ and -$(C_2H_5)_3N^+$ groups, respectively, to create quaternary ammonium exchange sites (Gu et al., 2004; Berbar et al., 2008). D201, which was functionalized by reactions with -$(CH_3)_3N^+$ group, was kindly provided by Nan & Ge Inc. (China). The physicochemical properties and specifications of resins are given in **Table 1**. Before experiments the resins were extracted with ethanol for 9 hr in a soxhlet apparatus, and dried in vacuum at 333 K for 10 hr (Wang et al., 2010). Then, the resins were washed in distilled water to remove the adhering dirt until the pH reached 7 and dried at 333 K. After drying, the resins were screened to obtain the free-flowing resin particles (Wang et al., 2010; Song et al., 2012b).

Inorganic chemicals were supplied by Beijing Chemistry Company as analytical grade reagents. Gallic acids ($C_7H_6O_5$, MW = 170) and tannin acids ($C_{76}H_{52}O_{46}$, MW =1701) were purchased from Sigma (Sweden). The model solutions were prepared using deionized water. Under the experimental conditions, the nitrate-nitrogen sorption isotherm determination was carried out (Dron and Dodi, 2011). The equilibrium, kinetics, batch-mode sorption, batch-mode stripping and column-mode sorption-elution have been studied to evaluate the nature of interaction between nitrate-nitrogen and the resins. The detailed experimental procedures were similar to the processes reported by Chabani et al. (2007). The resin (0.2 g) was contacted with nitrate in solution (100 mL) with different concentrations for adsorption isotherm study at 293 K separately.

1.2 Analysis

The analyses of nitrate-nitrogen were performed using a Shimadzu model 1800 UV-Vis spectroscopy (Shimadzu, Japan) and the Dionex ICS-1000 ion chromatography equipment (Dionex, USA).

2 Results and discussion

2.1 Influence of DOM

The removal behaviors of nitrate-nitrogen by D201, A520E and A300 resins have been investigated in the binary co-existence compound model solution containing nitrate-nitrogen and DOM (gallic acid and tannin acid), (**Fig. 1**). The adsorption capacity of nitrate-nitrogen onto three adsorbents would decrease with the variation of the DOM concentration from 0 to 400 mg/L. The decreased speed of equilibrium capacity for A520E is obviously slower than that of other two resins. The results indicated that A520E is very suitable for removal nitrate-nitrogen in such binary competing systems. The influence of gallic acid for the nitrate-nitrogen removal is higher than that of tannin acid. The mechanism of selective removal by ion exchange approach could be explained with the size of molecule and the hydration energy of the target ion (Wang et al., 2009; Gu et al., 2004). The adsorption drop is possibly caused by the nonspecific adsorption interaction between resins and nitrate-nitrogen, and gallic acid greatly competed for functional groups of resins.

2.2 Adsorption kinetic studies

2.2.1 Effect of resin type

The kinetic adsorption experiments were performed by measuring the removal amount of nitrate-nitrogen at different times from each aqueous solution with the initial concentration of 22.57 mg nitrate-nitrogen/L at 293 K (**Fig. 2**). Initially, the large amounts of nitrate-nitrogen could be removed rapidly to approximately 60 min, and then plateau gradually to 120 min. A further increase in contact time had a negligible effect on nitrate-nitrogen sorption. The results revealed that the sorption of A520E

Table 1 Physicochemical property of the resins*

Property	A520E	A300	D201
Skeleton	Macroporous styrene-divinylbenzene	Polystyrene crosslinked with divinyl benzene	Macroporous styrene-divinylbenzene
Granulometry (mm)	0.3–1.2	0.3–1.2	0.3–1.2
Moisture retention (%)	50–56	40–45	50–60
Limit of temperature (°C)	100	77	80
Total anion-exchange capacity (meq/g)	2.8	3.5	3.8

* The data were cited from literature (Gu et al., 2004; Berbar et al., 2008).

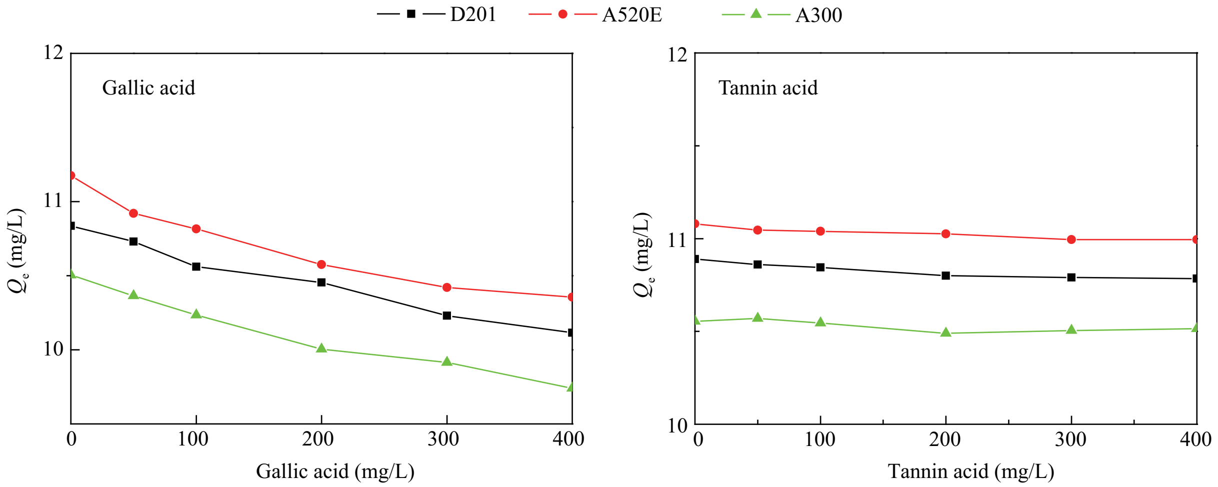

Fig. 1 Effect of DOM (gallic acid and tannin acid) on nitrate-nitrogen retention by D201, A520E and A300 resins at 293 K. Initial nitrate-nitrogen 22.57 mg /L; solid to liquid ratio 2.00 g/L.

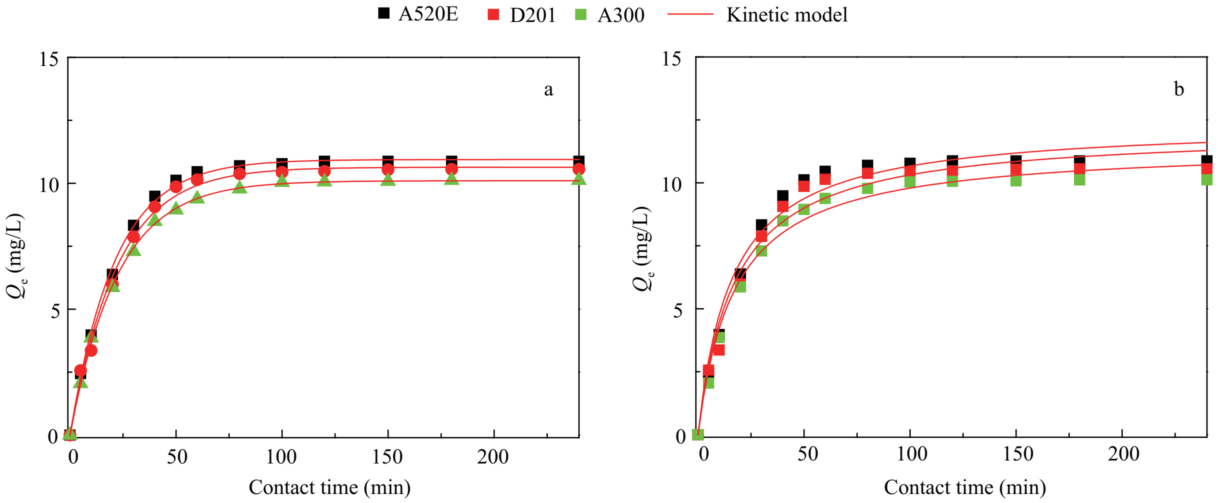

Fig. 2 Nitrate-nitrogen removal by A520E, D201 and A300 resins as a function of reaction time, and the fittings of pseudo first- (a) and second-order (b) kinetic models. Experimental condition: pH 6.28, initial nitrate-nitrogen concentration 22.57 mg/L, 293 K.

resin is very fast and effective on nitrate-nitrogen removal.

Several models can be used to express the mechanism of solute sorption onto a sorbent. In order to investigate the mechanism of sorption, some characteristic constants of sorption are determined using kinetic models (Garcia-Delgado et al., 1992; Ho et al., 1996) based on solid capacity. A pseudo first-order equation (Eq. (1)) based on solution concentration, and a pseudo second-order equation (Eq. (2)) based on solid phase sorption (Chabani et al., 2006; Bhattacharya and Venkobachar, 1984; McKay et al., 1985; Bilgili et al., 2006; Mohan et al., 2007; Nemr et al., 2009) were applied.

$$\log(Q_e - Q_t) = \log(Q_e) - \frac{K_{ad}}{2.303}t \tag{1}$$

$$\frac{t}{Q_t} = \frac{1}{K_t Q_e^2} + \frac{t}{Q_e} \tag{2}$$

where, Q_t (mg/g) is the nitrate-nitrogen amount of adsorption at time t and Q_e (mg/g) is the nitrate-nitrogen amount of adsorption at equilibrium; K_{ad} (min^{-1}) is the first-order adsorption kinetic constant and K_t (min^{-1}) is the intra-particle diffusion constant. The constants evaluated by application of Eqs. (1) and (2) are summarized in **Table 2**. **Figure 2** shows that the experiment results were in good agreement with the pseudo first- and the second-order kinetic models with the relatively high correlation coefficients (R^2 > 0.98). It suggested that the studied sorption system was based on the assumption that the rate limiting step might be chemical sorption (Wang et al., 2010).

2.2.2 Effect of initial nitrate-nitrogen concentration

The adsorption capacities for different initial nitrate-nitrogen concentrations were investigated. As shown in **Fig. 3**, the adsorption rate constants increased with increasing initial nitrate-nitrogen concentrations. The adsorption capacities of nitrate-nitrogen at equilibrium were 4.78, 10.42, 19.14 and 24.20 mg/g with the initial concentrations of 11.29, 22.57, 45.15, and 67.72 mg/L, respectively.

Table 2 Kinetic parameters of nitrate-nitrogen adsorption on A520E, D201 and A300 resins at 293 K

Adsorbent	Pseudo first-order model			Pseudo second-order model		
	K_{ad}	Q_e (mg/g)	R^2	K_t	Q_e (mg/g)	R^2
A520E	0.047	10.94	0.99	0.0050	12.38	0.98
D201	0.045	10.64	0.99	0.0048	12.09	0.99
A300	0.045	10.10	0.99	0.0051	11.48	0.99

Pseudo first- and second-order equations were used to fit the results (**Table 3**).

2.2.3 Adsorption kinetics of different initial nitrate-nitrogen concentrations

The process of adsorbate molecules diffused in porous during nitrate-nitrogen removal from aqueous solution could be investigated using Eq. (3), which shows the rate of adsorption (Chabani et al., 2007; Weber and Morris, 1987):

$$Q_t = k_i t^{1/2} \tag{3}$$

where, Q_t (mg/g) is the nitrate-nitrogen amount of adsorption at time t (min); k_i is the rate parameter for the intra particle diffusion.

The intraparticle model assumed that the external diffusion is negligible, and intraparticle diffusion is on the only rate-controlling step. The initial kinetic data were used to plot the relationship of Q_t versus $t^{1/2}$ for different initial nitrate-nitrogen concentrations (Ahmaruzzaman and Sharma, 2005). From **Fig. 4**, linear adsorption was obtained for various initial concentrations that showed fast uptake of nitrate-nitrogen during the first several minutes (Chaani et al., 2006). **Table 4** shows the rate parameters for intra particle diffusion. The values of k_i increased with increasing initial concentrations. The rapid increase of the intra particle diffusion has obviously presented with the increase in the concentration gradient between bulk solution and adsorbent surface. The correlation relationships between Q_t and $t^{1/2}$ illustrated that the adsorption kinetics for the resin favored its use in a continuous column application.

Table 4 Intraparticle diffusion constant values for the adsorption of nitrate-nitrogen on A520E resin at different concentrations.

Nitrate-nitrogen concentration (mg/L)	Intrapaticle diffusion	
	R^2	k_i (mg/(g·min$^{1/2}$))
11.29	0.90	1.58
22.57	0.93	3.54
45.15	0.94	6.54
67.72	0.95	8.25

2.2.4 First order reversible model

To further understand the sorption kinetic process of nitrate-nitrogen on A520E resin, experimental data were analyzed using the reversible-first order kinetic model (Ho and Mckay, 1999). Equation (4) shows the ion exchanger

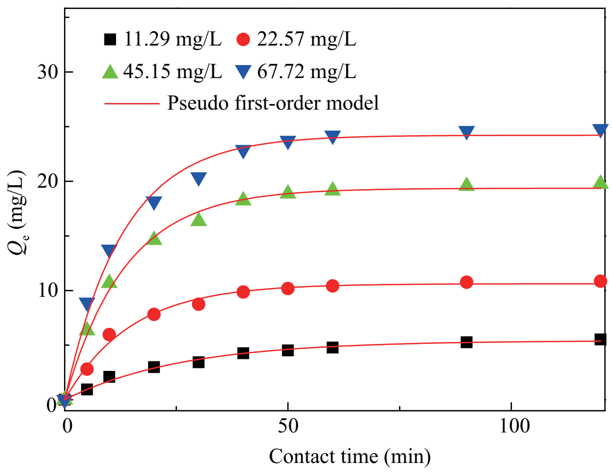

Fig. 3 Effect of initial concentrations on the adsorption of nitrate-nitrogen on A520E resin, and the fitting of pseudo first-order kinetic model. Experimental condition: pH 6.28, 293 K.

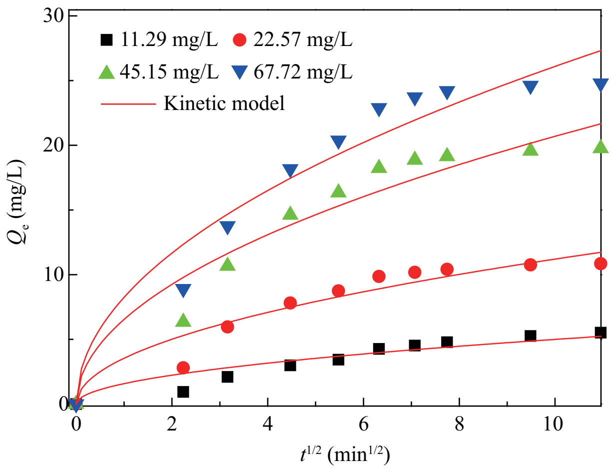

Fig. 4 Intraparticle diffusion plots for the sorption of nitrate-nitrogen on A520E resin, and the fittings of the kinetic model.

Table 3 Kinetic parameters of adsorption for nitrate-nitrogen on A520E at 293 K

Nitrate-nitrogen concentration (mg/L)	Pseudo first-order equation			Pseudo second-order equation		
	K_{ad}	Q_e (mg/g)	R^2	K_t	Q_e (mg/g)	R^2
11.29	0.038	5.42	0.99	0.0059	6.73	0.99
22.57	0.047	10.64	0.99	0.0050	12.38	0.99
45.15	0.073	19.36	0.99	0.0041	22.34	0.99
67.72	0.077	24.21	0.99	0.0036	27.74	0.99

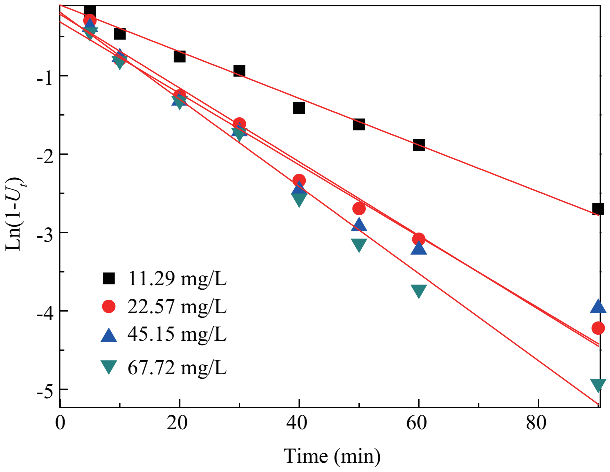

Fig. 5 Adsorption kinetics for different initial concentrations in term of the reversible-first order model.

and the heterogeneous equilibrium for the adsorption of solute in the solution (Ho and Mckay, 1999):

$$\mathrm{A} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \mathrm{B} \tag{4}$$

where, k_1 (min^{-1}) and k_2 (min^{-1}) are the forward and reverse reaction rate constant, respectively.

Equation (5) shows the adsorption rate for the initial concentration of nitrate-nitrogen and the amount transferred from liquid phase to solid phase at time t,

$$\frac{\mathrm{d}Q_t}{\mathrm{d}t} = \frac{-\mathrm{d}(C_0 - Q_t)}{\mathrm{d}t} = k(C_0 - Q_t) \tag{5}$$

where, C_0 (mg/L) is the initial concentration and Q_t (mg/g) is the amount transferred from liquid phase to solid phase at a time t; k is the overall reaction rate constant. Equation (6) shows the rate formula:

$$\frac{\mathrm{d}Q_t}{\mathrm{d}t} = k_1(C_0 - Q_t) - k_2 Q_t \tag{6}$$

If Q_e (mg/L) is the amount of the nitrate-nitrogen adsorbed at equilibrium. Equation (7) shows the formula at equilibrium:

$$k_1(C_0 - Q_e) - k_2 Q_e = 0 \tag{7}$$

$$\frac{\mathrm{d}Q_t}{\mathrm{d}t} = (k_1 + k_2)(Q_e - Q_t) \tag{8}$$

Rearrange Eq. (8) by integration:

$$\mathrm{Ln}(1 - U_t) = -(k_1 + k_2) = -kt \tag{9}$$

where, U_t is the fractional attainment of nitrate-nitrogen removal equilibrium.

and

$$U_t = \frac{Q_t}{Q_e} \tag{10}$$

Table 5 Rate constants for the nitrate-nitrogen removal with A520E resin using reversible-first order model

Nitrate-nitrogen concentration (mg/L)	R^2	$K = k_1 + k_2$ (min^{-1})	k_1 (min^{-1})	k_2 (min^{-1})
11.29	0.99	0.030	0.029	0.001
22.57	0.98	0.047	0.045	0.002
45.15	0.98	0.046	0.040	0.004
67.72	0.99	0.056	0.042	0.014

then,

$$U_t = \frac{C_0 - C_t}{C_0 - C_e} \tag{11}$$

where, C_e (mg/L) is the equilibrium concentration and C_t (mg/L) is the equilibrium concentration at time t.

Figure 5 shows that the overall rate constant k for a given concentration corresponding to the slope of the straight line of the plot ln(1–U_t) versus t. **Table 5** shows that the equilibrium constant, the forward and backward constant rates. The relatively high correlation coefficients showed that the reversible-first order kinetic model could be applied for the entire sorption process well. The similar results have been reported previously (Milmile et al., 2011; Bilgili, 2006).

2.2.5 Diffusion process

The pore diffusion and film diffusion coefficients of the adsorption process can illustrate that the nature of the diffusion process is responsible for nitrate-nitrogen removal by the A520E resin. The value of film diffusion coefficient (D_f) should be in the range of 10^{-6} to 10^{-8} cm^2/sec when film diffusion is to be the rate determining step in the adsorption of nitrate-nitrogen on the surface of resin, and the value of pore diffusion (D_p) rated limiting step should be in the range of 10^{-11} to 10^{-13} cm^2/sec (Chaani et al., 2006). If the geometry of the resin was assumed to be spherical, the overall rate constant could be correlated with corresponding diffusion coefficient (Chaani et al., 2006).

Equations (12) and (13) shows D_f and D_p, respectively:

$$D_f = 0.23\frac{R_p \tau Q_t}{t_{1/2} C_0} \tag{12}$$

$$D_p = 0.03\frac{R_p^2}{t_{1/2}} \tag{13}$$

where, R_p (0.06 cm) is the radius of the adsorbent, τ (10^{-3} cm) is the thickness of the film. **Table 6** shows the D_f and D_p for various concentrations of nitrate-nitrogen by A520E resin. The results in the range 10^{-6} to 10^{-8} cm^2/sec showed that the diffusion process is controlled by film diffusion.

Figure 6 shows the double nature of intra particle diffusion plot and pore diffusion at different initial nitrate-nitrogen concentrations. Equation (14) can be used to fit

Table 6 Diffusion coefficients for removal of nitrate-nitrogen by A520E resin

Nitrate-nitrogen concentration (mg/L)	D_f ($\times10^{-8}$ cm^2/sec)	D_p ($\times10^{-7}$ cm^2/sec)
11.29	0.20	0.36
22.57	0.27	0.45
45.15	0.33	0.60
67.72	0.33	0.72

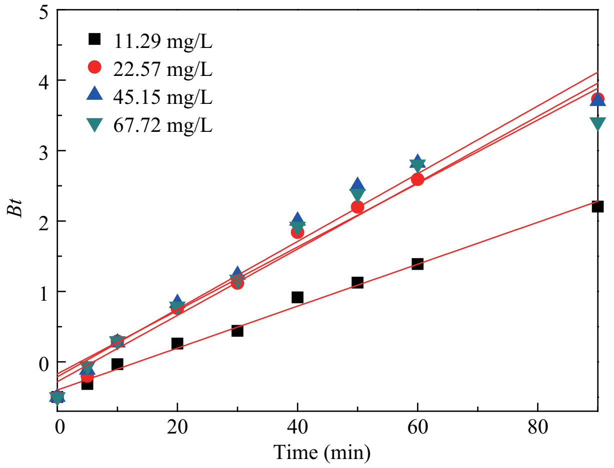

Fig. 6 Correlation between Bt and t for nitrate-nitrogen adsorption on A520 resin for different initial concentrations.

the adsorption kinetic data of nitrate-nitrogen removal on A520E resin.

$$U_t = 1 - \frac{6}{\pi^2}\exp(-Bt) \tag{14}$$

where, B is time constant, and can be calculated by Eq. (15)

$$B = \frac{\pi D}{r^2} \tag{15}$$

where, D is the effective diffusion coefficient of adsorbates in adsorbent phase and r the radius of adsorbent particle assumed to be spherical. Substituting $U_t = Q_t/Q_e$ into Eq. (14), the kinetic expression became Eq. (16):

$$Bt = -0.4977 - \ln(1 - \frac{Q_t}{Q_e}) \tag{16}$$

A comparison of the results showed that the plots do not pass through the origin at different initial concentrations (**Fig. 6**). The results implied that external mass transfer was mainly governs the rate control process (Boyd et al., 1947).

2.2.6 Effect of resin dosage

Figure 7 shows the influence of A520E resin dosage on nitrate-nitrogen adsorption at initial nitrate-nitrogen concentrations of 22.57 mg/L. The equilibrium adsorption capacities were 17.22, 10.93 and 8.65 mg/g with resin dosage 0.15, 0.25 and 0.35 g, respectively. **Table 7** shows the results fitted by two kinetic modes. It indicated that very fast superficial sorption was observed at higher concentration ratio of A520E resin dosage and nitrate-nitrogen. It implied that the anion exchange resin could remove only a certain amount of nitrate-nitrogen (Milmile et al., 2011).

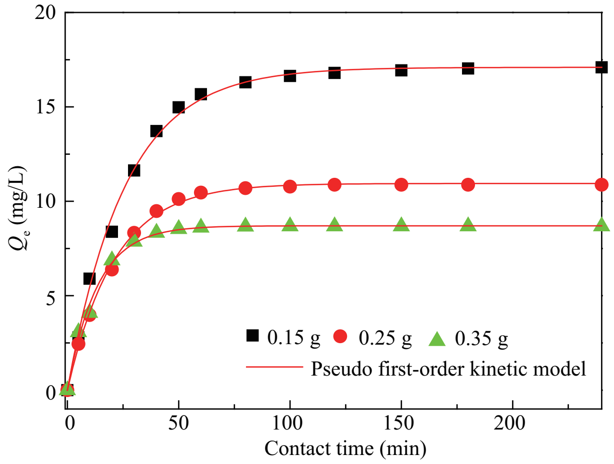

Fig. 7 Effect of A520E resin dosage on removal of nitrate-nitrogen from the system. Experimental condition: 293 K, initial nitrate-nitrogen concentration 22.57 mg/L.

Table 7 Kinetic parameters of adsorption for nitrate-nitrogen on A520E at 293 K

Resin dosage (g)	Pseudo first-order equation			Pseudo second-order equation		
	K_{ad}	Q_{e1} (mg/g)	R^2	K_t	Q_{e2} (mg/g)	R^2
0.15	0.038	17.09	0.99	0.002	19.73	0.98
0.25	0.047	10.94	0.99	0.005	12.38	0.98
0.35	0.075	8.70	0.99	0.012	9.52	0.98

2.3 Equilibrium adsorption assay of different adsorbents

Mechanism of sorption which has intimate relation to ion-change is actually complex. Generally sorption capacity of nitrate-nitrogen can be evaluated by equilibrium isotherm (Wang et al., 2010). In order to compare the influence of adsorbent on nitrate-nitrogen adsorption, the equilibrium adsorption isotherms of nitrate-nitrogen on D201, A520E and A300 resins had been investigated. The batch equilibrium test ran continuously over 24 hr ensured that the adsorption equilibrium was completely reached. Equation (16) shows the formula of the equilibrium adsorption capacity (Q_e).

$$Q_e = \frac{V(C_0 - C_e)}{W} \tag{17}$$

where, V (L) is the volume of solution; W (g) is the weight of dry resin. Each experiment was repeated for 3 times, and the results discussed here were mean values. **Figure 8** shows that the adsorption capacity of D201 was slightly higher than that of A520E and A300 at 293 K in model nitrate-nitrogen solution, which was possibly attributed to the different resin structures.

The Freundlich and Langmuir adsorption isotherm models were further investigated to clearly express the distribution of nitrate-nitrogen between liquid phase and the solid phase at equilibrium (Mittal et al., 2007). The former is used when assuming that maximum adsorption occurred, and the latter is believed as purely empirical. This moment, the homogeneous surface was covered by the functional groups (Wang et al., 2010). However, the Langmuir adsorption isotherm model was usually valid for monolayer sorption onto a surface with a finite number of identical sites (Bubba et al., 2003; Treybal, 1981; Chern and Chien, 2002). Equations (18) and (19) show Langmuir and Freundlich adsorption isotherm models, respectively:

$$Q_e = \frac{Q_0 b C_e}{1 + bC_e} \tag{18}$$

$$Q_e = K_f C_e^{(1/n)} \tag{19}$$

where, b is the Langmuir constants related to energy of adsorption; K_f and $1/n$ are Freundlich constants related to adsorption capacity and adsorption intensity, respectively.

The isotherm plots of Q_e vs. C_e indicated the applicability of Freundlich and Langmuir adsorption isotherm for A520E, D201 and A300 resins, respectively (**Fig. 8**).

Table 8 lists the results of nitrate-nitrogen removal using three resins. Q_0 is the maximum uptake value. The fitting of the models to the experimental data was evaluated through the coefficients of correlation (R^2). The Freundlich and Langmuir isotherms fairly fit with the experimental results with $R^2 > 0.98$ (Dron and Dodi, 2011). The major mechanism of sorption is electrostatic interaction. The use of large alkyl quaternary ammonium groups sacrifices the anion-exchange capacity due to a limited bead-surface area (Gu et al., 2004).

2.4 Column removal of nitrate-nitrogen from aqueous solutions

The preliminary column studies were performed using 22.57 mg nitrate-nitrogen/L solution. **Figure 9a** shows the breakthrough curve of nitrate-nitrogen obtained using

Table 8 Parameters for nitrate-nitrogen adsorption onto different resins

Resin	Langmuir equation			Freundlich equation		
	Q_0 (mg/g dry resin)	b (L/mg)	R^2	n	K_f (mg/g)	R^2
A520E	36.15	0.32	0.99	2.77	8.98	0.98
A300	34.92	0.27	0.99	2.60	7.55	0.99
D201	38.46	0.32	0.99	2.63	8.71	0.99

A520E resin (Xing et al., 2011; Hosseini et al., 2011; Westerhoff and James, 2003). Breakthrough capacity could be calculated by accepting the breakthrough point as a concentration which was just before than 1.0 mg/L. Breakthrough point was obtained after passing 488 bed volumes as shown in **Fig. 9a**.

Figure 9b presents the elution profile. The column utilization efficiency which was defined as the ratio between the total amount of solute retained by the resin and the total amount passed through the column until saturation was about 70%. NaCl solution (0.6 mol/L) can removal nitrate effectively and nitrate-nitrogen loaded onto A520E resin was quantitatively eluted with 120 bed volumes.

3 Conclusions

The commercial A520E resin exhibits a higher absorption capacity for the nitrate-nitrogen than other two commercial A300 and D201 resins while the gallic acid or tannin acid appears in solution. The phenomenon is attributed to its long quaternary ammonium groups. Attractively, the fast adsorption process would reach the adsorption equilibrium within 120 min. The kinetic of nitrate-nitrogen removal using A520E resin fitted well with the pseudo-first order and the pseudo-second order models. The commercial A520E resin could be considered as the more effective sorbent to remove nitrate-nitrogen contamination during water supply treatment, especially for complex-polluted water resources.

Acknowledgments

This work was supported by the Program for Changjiang Scholars Innovative Research Team in University and NSFC (No. 50938004, 51178215, 51008152) and the Jiangsu Nature Science Foundation for Distinguished Scientists

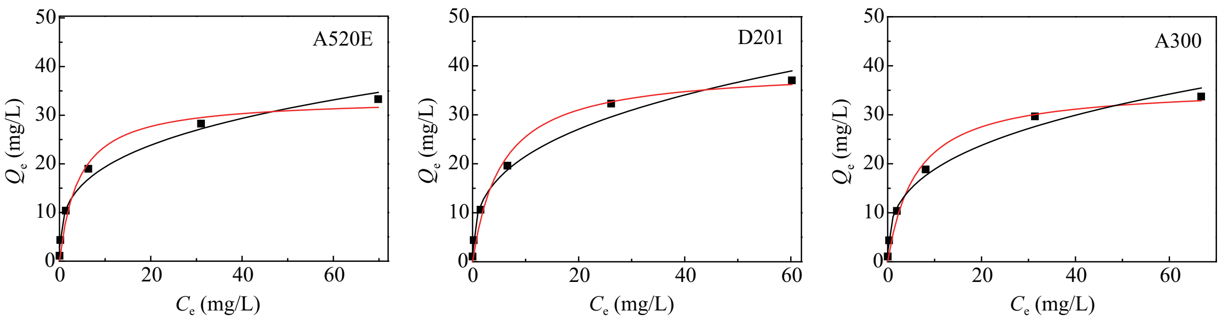

Fig. 8 Freundlich and Langmuir isotherm for nitrate-nitrogen sorption using A520E, D201 and A300 resins.

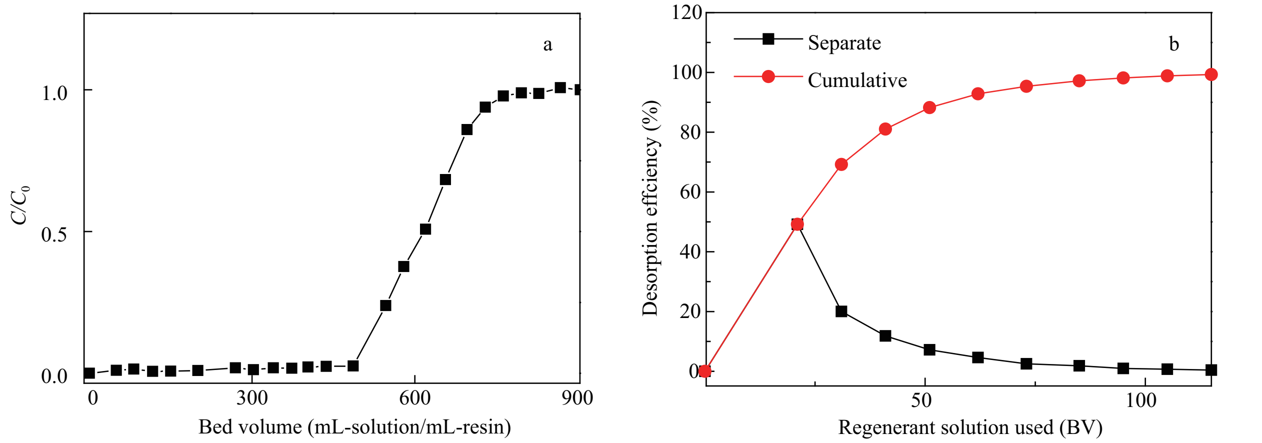

Fig. 9 Breakthrough (a) and elution curves of nitrate-nitrogen (b) are obtained by A520E resin using model solution. Experimental condition: nitrate-nitrogen 22.57 mg/L, superficial liquid velocity 0.5 m/hr, empty bed contact time 10 min, temperature 293 K, reagent 0.6 mol/L NaCl.

(No. BK2010006, BK2011032) and the Scientific Research Starting Found for Postdoctors, Nanjing University (No. 0211003046, 021114340069). We thank Purolite Int. Ltd., Nan & Ge Inc. (China) for supplying resins.

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Journal of Environmental Sciences (Established in 1989)
Vol. 25 No. 1 2013

Supervised by	Chinese Academy of Sciences	**Published by**	Science Press, Beijing, China
Sponsored by	Research Center for Eco-Environmental		Elsevier Limited, The Netherlands
	Sciences, Chinese Academy of Sciences	**Distributed by**	
Edited by	Editorial Office of Journal of	Domestic	Science Press, 16 Donghuangchenggen
	Environmental Sciences		North Street, Beijing 100717, China
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ISSN 1001-0742

9 771001 074130 01>