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Research paper

Arsenic(V) removal using an amine-doped acrylic ion exchange fiber: Kinetic, equilibrium, and regeneration studies

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HIGHLIGHTS

- A novel amine-doped acrylic fiber was suitable for the removal of As(V) from water.
- The amine doping reaction was complete within 60 min under catalysis at 100 °C.
- The maximum adsorption capacity (q_e) for As(V) was 205.3 ± 3.6 mg/g.
- This fiber can be an affordable and reusable ion exchange medium.

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ABSTRACT

This study investigates As(V) removal from aqueous solutions using a novel amine-doped acrylic ion exchange fiber. The amine doping reaction was confirmed using FT-IR, and the surface of the fiber was characterized using FEG-SEM. The synthesis process was completed within 60 min using an $AlCl_3 \cdot 6H_2O$ catalyst at 100 °C, and the resulting in a fiber with an ion exchange capacity of 7.5 meq/g. The removal efficiency of the A-60 fiber was affected by the solution pH, and the efficiency was optimum at pH 3.04. As(V) adsorption on the fiber was rapid in the first 20 min and reached equilibrium in 60 min. As(V) removal followed pseudo-first-order kinetics, and the Redlich-Peterson adsorption isotherm model provided the best fit of the equilibrium data. The fiber has an As(V) adsorption capacity (q_e) of 205.32 ± 3.57 mg/g, which is considerably higher than literature values and commercial adsorbents. The removal efficiency of the fiber was above 83% of the initial value after nine regeneration cycles.

1. Introduction

Arsenic is an abundant element in the environment and is present in air, soil, and water. Arsenic is introduced into water through both natural and anthropogenic activities, such as geological weathering, mining, pesticide application, and industrial activities. The presence of dissolved arsenic in water and groundwater has been reported in many countries, and it is especially serious in Bangladesh, India and other countries in Southeast Asia [1,2]. Arsenic is a carcinogen, and chronic exposure to contaminated drinking water increases the occurrences of skin, lung, bladder, and kidney cancers [2]. Because of the high toxicity of arsenic, the United States Environmental Protection Agency (US EPA) and World Health Organization (WHO) recommend a maximum contaminant level of 10 μg/L for arsenic in drinking water.

The US EPA announced several best available technologies (BATs) for arsenic removal; e.g., ion exchange, activated alumina, reverse osmosis, modified coagulation/filtration, modified lime softening, electrodialysis reversal, and oxidation/filtration [3]. Among the technologies, ion exchange is a physical/chemical process by which an ion on a solid phase is exchanged for an ion in a solution phase. A synthetic resin is typically used as the solid phase, and anion exchange resins can effectively remove arsenate (As(V)), which is the predominant species in aerobic surface waters

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[3]. To select the most appropriate treatment technology, the disposal options for residuals and costs should be considered along with treated water quality. The ion exchange process does not generate a large amount of waste and is affordable as the resins can be regenerated. Field studies applying the ion exchange process to arsenic removal have been reported [4–7].

The ion exchange fiber is a new type of ion exchange material and has several advantages over conventional ion exchange resins. The fiber has high adsorption/desorption rates and a better uptake capacity than ion exchange resins because of the short transit distance for ions and the number of functional groups present along the fiber. Furthermore, the compact configuration of the treatment module is easy to fabricate and relatively free from head loss [8,9]. Several studies have reported the synthesis of ion exchange fibers for the removal of arsenic from aqueous solutions using various polymers. Polyacrylonitrile (PAN) fiber was used as the raw material for the preparation of anion exchange fibers chemically cross-linked with hydrazine [10–12]. Polymer/inorganic hybrid fibrous ion exchangers prepared by impregnation of hydrated ferric oxide within a commercial ion exchanger fiber were used for arsenic removal from aqueous solutions [13,14]. Polyethylene-coated polypropylene fibers and cellulose fibers were also used for arsenic removal after graft modification using electron irradiation and chemicals [15–19]. However, research on the development of more affordable synthetic methods using cost-effective and easily obtained commercial fibers is still necessary to make water treatment more broadly accessible.

Acrylic fibers are well-known for their superior properties, such as bulk and insulating heat compared to other synthetic fibers, and they can serve as an alternative for natural fibers, such as wool [20]. The first acrylic fiber was created by DuPont in 1941 and was used for sweaters, tracksuits, boots' and gloves' linings and in furnishing fabrics and carpets. This fiber was also used as a precursor for PAN, as it contained at least 85% of the acrylonitrile monomer and produced large quantities at an affordable price [21,22]. The nitrile groups on the surface of the PAN polymer can participate in various chemical reactions and are easily cross-linked with polyamines [10,12]. Diethylenetriamine (DETA) is a polyamine widely used to increase the number of amine groups on sorbents for their ion exchange capacity [23,24]. In our previous study, DETA was successfully grafted onto a commercial acrylic fiber to synthesize an ion exchange fiber [8].

This study focuses on the synthesis of amine-doped acrylic ion exchange fibers and their application to the removal of As(V) from aqueous solutions in batch systems. The synthesis of the fibers was confirmed using Fourier-transform infrared (FT-IR) spectroscopy, and the surface of the fiber was characterized using field emission gun scanning electron microscopy (FEG-SEM). As(V) removal experiments were performed to examine the effects of solution pH, contact time, initial arsenic concentration, and regeneration cycles. Adsorption kinetics and isotherms were used to analyze the experimental data, and the adsorption capacity was compared to that of PAN-based commercial anion exchange fiber, Fiban AK-22 (Institute of Physical Organic Chemistry), which exhibits maximum Cr(VI) removal efficiency in the pH 3–4 range [38]. In addition, titanium- and iron-based commercial adsorbents that are commonly used to remove As(V) removal from water were also used to benchmark the performance of our novel ion exchange fiber under similar test conditions.

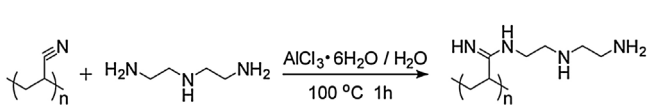

Fig. 1. Synthesis procedure for the amine-doped acrylic ion exchange fiber.

2. Materials and methods

2.1. Materials

Acrylic fiber (consisting of about 90% acrylonitrile) was purchased from Taekwang Industrial Co., Ltd., Korea. This fiber was extracted with ethanol to remove impurities and dried at 60 °C under vacuum for 18 h. Diethylenetriamine (ACROS Organics Co., 98.5%) was dried at 40 °C under vacuum to remove any adsorbed water. PAN-based Fiban AK-22 fibrous ion exchanger and titanium-based ADSORBSIA™ adsorbent were obtained from the Institute of Physical Organic Chemistry and the DOW Chemical Company, respectively. Iron oxide nanoparticle was synthesized by a co-precipitation method [34]. Aluminum trichloride hexahydrate ($AlCl_3 \cdot 6H_2O$, Junsei Chemical Co., 99%), phenolphthalein ($C_{20}H_{14}O_4$, Yakuri Pure Chemicals Co., Extra pure), and sodium arsenate dibasic heptahydrate ($Na_2HAsO_4 \cdot 7H_2O$, Sigma-Aldrich Chemical Co., 98–102%) were used without further purification. Ultra-pure water (DI, 18.2 MΩ) was used for all dilutions and reagent preparations.

2.2. Synthesis of amine-doped acrylic ion exchange fiber

Acrylic fibers (6 g), diethylenetriamine (500 g), and distilled water (50 mL) containing $AlCl_3 \cdot 6H_2O$ (10 g) were placed in a three-neck round-bottomed flask with stirring at 100 °C for various times (30 min to 60 min). The amine functionalized fibers were named A-30 and A-60, indicating the reaction time. After the reaction, the modified fibers were washed with 0.1 M HCl, 0.1 M NaOH, and distilled water in sequence. The modified fibers were dried at 60 °C under vacuum for 18 h. The product was characterized using FT-IR spectroscopy, and a schematic diagram of the synthesis procedure for the amine doped acrylic ion exchange fiber is shown in Fig. 1.

2.3. Measurements

Fourier-transform infrared (FT-IR) spectroscopy (Frontier, PerkinElmer, Waltham, USA) was used to confirm the synthesis. The surface morphology of the samples was observed using field emission gun scanning electron microscopy (FEG-SEM, Quanta 250 FEG, FEI, Oregon, USA), and the chemical compositions of the samples were analyzed using an energy dispersive spectrometer (EDS) embedded in an FEI Quanta 250 FEG device. The number of amine sites on the sample surface was quantified using back titration [25]. The titration procedure is as follows: 0.01 g of acrylic fiber (as raw material), A-60 and AK-22 were each added into 20 mL solutions of 0.1 M HCl and stirred for 30 min. The fibers were separated by syringe filters, and 10 mL of the filtered solutions was titrated with a standardized 0.1 M NaOH solution in the presence of phenolphthalein indicator. Based on the difference in the HCl concentration after treatment with the fibers, the molar concentrations of the amine sites on the ion exchange fibers were calculated. This value was converted into a total ion exchange capacity (meq/g) for the ion exchange fibers. The arsenic concentration in the water was analyzed using inductively coupled plasma-optical emission spectrometry (ICP-OES, Prodigy ICP, Teledyne Leeman Labs, USA), and the solution pH was measured using a pH probe (8302BNUMD, Orion, USA).

2.4. As(V) removal experiments

Arsenic (As(V)) removal experiments were conducted in batch systems. The desired concentrations of As(V) were prepared by diluting the stock solution (1000 mg/L), which was made using sodium arsenate dibasic heptahydrate ($Na_2HAsO_4 \cdot 7H_2O$). All experiments were performed in duplicate under ambient conditions. The first experiment was conducted to examine the effect

Table 1
Physicochemical properties of the fibers used in this study.

Properties	Acrylic fiber	A-60	AK-22
Physical form	staple	staple	non-woven
Color	white	gold yellow	light yellow
Diameter (μm)	29–32	37–54	17–22
Ion exchange capacity (meq/g)	0.0	7.5	4.0
Functional groups	≡N	=NH, —NH_2	≡N, =NH,—NH_2, —COOH

of solution pH on the removal of As(V) by the acrylic fiber, A-30, and A-60 (initial arsenic concentration = 10 mg/L; solution pH = 2.05–7.51). The pHs of the solutions were adjusted using 1 N HCl or 1 N NaOH. The experiments were performed in 50 mL polypropylene conical tubes containing 0.2 g/L of the fibers with 40 mL of diluted arsenic solution. The conical tubes were shaken using a rotary shaker at 20 rpm for 2 h. After shaking, the solutions were sampled using 0.45 μm syringe filters. Next, the residual arsenic concentrations were analyzed using ICP-OES.

The second and third experiments were conducted to evaluate the effect of the contact time (initial arsenic concentration = 10 mg/L; solution pH = 3.04; contact time = 5–120 min) and initial concentration (initial arsenic concentration = 5–50 mg/L) on As(V) removal. The fourth set of experiments was performed to examine the removal of As(V) by A-60 after regeneration cycles. Adsorption tests were performed using 40 mL of diluted arsenic solution (initial concentration = 10 mg/L; solution pH = 3.04) containing 8 mg of A-60. After 2 h, the adsorbed arsenic was desorbed with 50 mL of 0.1 N HCl, treated with 50 mL of 0.1 N NaOH, and washed with ultra-pure water. Additional adsorption tests were carried out using the same procedure.

Various adsorption kinetic (i.e., pseudo-first-order, pseudo-second-order, and Elovich) and isotherm models (i.e., Freundlich, Langmuir, and Redlich-Peterson) were used to fit and analyze experimental data. Model parameters were estimated along with their respective standard errors using Sigma Plot 10.0 software. Pearson's chi-square (χ^2) tests and determination coefficients (R^2) were used to assess the goodness-of-fit of the models.

3. Results and discussion

3.1. Characterization of the prepared fibers

The physicochemical properties of the fibers used in this study are presented in Table 1. The staple form of the acrylic fiber was used as the raw material, and the color of the fiber changed from white to a gold yellow after reaction with diethylenetriamine for 60 min. Specific morphologies and chemical compositions of the fibers' surfaces are shown in Fig. 2. After reaction, the diameters of the acrylic fibers increased from 29–32 μm to 37–54 μm, and the nitrogen content on the surface of the fibers increased from 23.4 wt% to 31.7 wt%. This is attributed to the reaction between diethylenetriamine and the fibers, which modifies the nitrile group [26,27]. The reaction was also confirmed by the FT-IR spectra (Fig. 3). The absorption peaks of the nitrile group (C≡N, 2242 cm^{-1}) decreased with increasing reaction time and disappeared after 60 min of reaction (A-60). New peaks for amidine (N—C=N, 1640 cm^{-1}) and strong broad bands for the amine groups (NH_2, 3500–2000 cm^{-1}) were visible after the reaction [7,28].

The total ion exchange capacity of A-60 for amine sites, which was calculated using the back titration method, was 7.5 meq/g. This value falls within the range of reported ion exchange capacity for commercial products such as Fiban K-4 ion exchange fiber (4–5 meq/g) and poly(acrylo-amidino diethylenediamine) chelating fiber (11.4 meq/g) [7,13].

AK-22 is a commercial product that is light yellow and comes in a non-woven form. The diameter of AK-22 is in the range of 17–22 μm, which is thinner than the acrylic fiber, and the surface of the AK-22 is mainly composed of carbon (59.0 wt%), nitrogen (23.4 wt%), and oxygen (17.11 wt%). In our laboratory experiment, the total ion exchange capacity of AK-22, which was also calculated using the back titration method, was 4.0 meq/g.

3.2. Effect of solution pH on As(V) removal

The effects of the solution pH on As(V) removal by raw, A-30, and A-60 fibers are shown in Fig. 4(a). As(V) removal by A-30 and A-60 was clearly affected by the solution pH. These results are related to the speciation of As(V). The chemical speciation of As(V) based on the solution pH was calculated using a computer program for geochemical modeling (arsenic concentration = 10 mg/L, temperature = 25 °C, calculation performed using the Visual MINTEQ 3.0 code):

$$H_3AsO_{4(aq)} \leftrightarrow H_2AsO_4^- + H^+ \quad pK_{a1} = 2.28 \tag{1}$$

$$H_2AsO_4^- \leftrightarrow HAsO_4^{2-} + H^+ \quad pK_{a2} = 6.97 \tag{2}$$

At low solution pH, the amine groups on the adsorbent surface are protonated to form —NH_3^+, and the surface of the adsorbent is more positively charged [19,29]. Therefore, the maximum sorption capacity of A-60 was at pH 3.04, when anionic species such as $H_2AsO_4^-$ predominate. The sorption of As(V) at pH 2.05 was negligible because the nonionic species are dominant at solution pH values lower than 2.28, as indicated by Eq. (1). In the case of A-30, the shorter synthesis time of 30 min did not allow for as many nitrile groups to convert to amine groups (Fig. 3), which decreased As(V) sorption capacity. Optimum As(V) removal occurred at pH 3 for A-60 and at pH 4 for A-30. In both cases, the predominant As(V) species was anionic $H_2AsO_4^-$ (Fig. 4(b)), which is electrostatically attracted the positively-charged protonated amines. Apparently, A-60 may need a lower pH for protonation of all amine groups, and the lower abundance of amines on A-30 may require less acidity (higher pH) for complete protonation. Note that at pH 4, near all of the dissolved As(V) is present in easier-to-sorb anionic form (Fig. 4(b)). Similar behavior for As(V) adsorption based on solution pH is reported in the literature. Zhang et al. [10] reported that the maximum adsorption capacity of arsenate on RPFA-I was at pH 4.1, whereas Yu et al. [19] showed that the optimal pH for the removal of arsenate by Cellulose-g-GMA-b-TEPA was 5.0. The adsorption of As(V) on the surface of the acrylic fiber was negligible over the tested pH range (2.05–7.51). This agrees with the back titration results (Table 1).

3.3. Adsorption kinetics

The effect of contact time on As(V) removal by A-60 fibers is shown in Fig. 5. The adsorption capacity of As(V) rapidly reached 49.99 ± 0.23 mg/g in the first 20 min and further increased to 53.00 ± 0.06 mg/g after 120 min. The As(V) adsorption reached equilibrium after 60 min with a removal efficiency of 98.5%. Rapid adsorption is a characteristic of fibrous adsorbents and is due to the

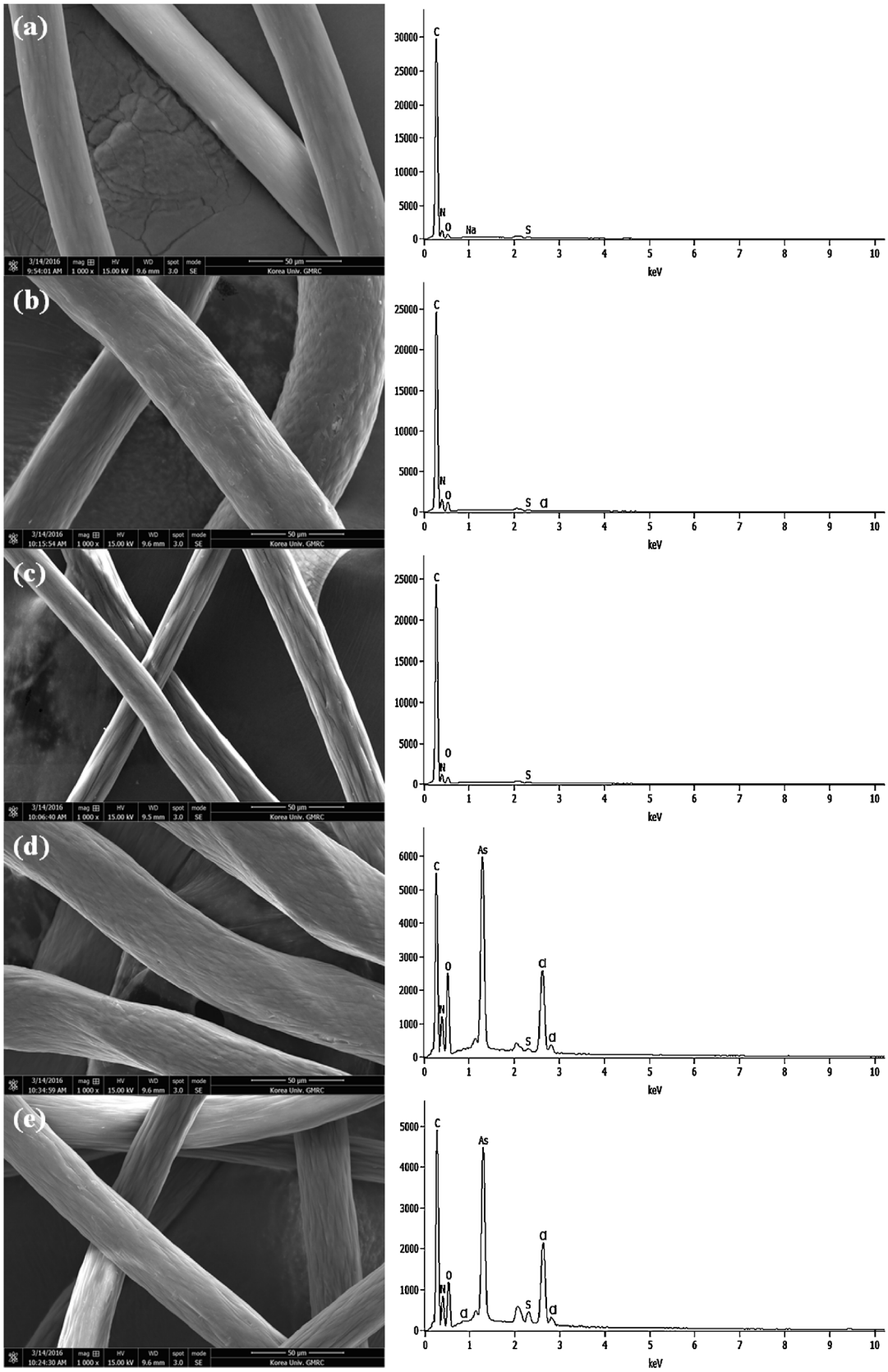

Fig. 2. SEM images and EDS patterns of the fibers: (a) acrylic fiber; (b) A-60; (c) AK-22; (d) A-60 after As(V) adsorption; (e) AK-22 after As(V) adsorption (adsorbent dosage = 0.2 g/L, initial concentration = 10 mg/L, contact time = 2 h, solution pH = 3.04).

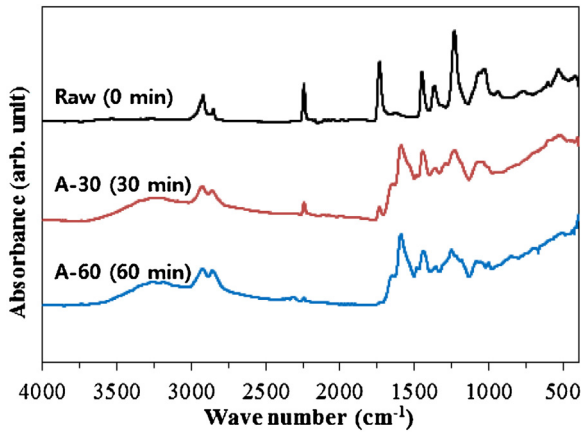

Fig. 3. FT-IR spectra of the synthesized fibers after different reaction times.

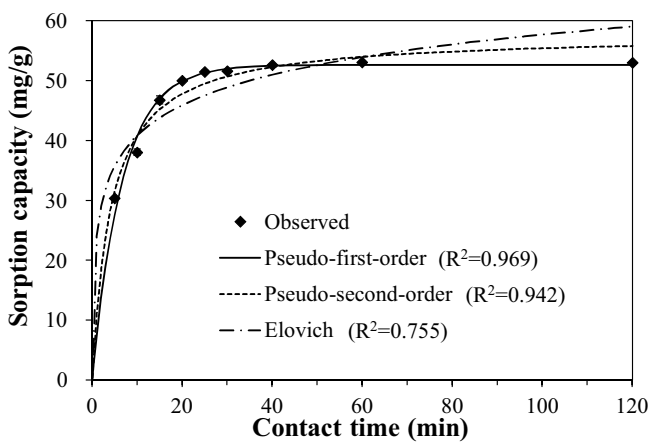

Fig. 4. (a) Effect of solution pH on As(V) removal by the synthesized fibers, and (b) distribution of As(V) species as a function of solution pH (adsorbent dosage = 0.2 g/L, initial concentration = 10 mg/L, contact time = 2 h, solution pH = 2.05–7.51).

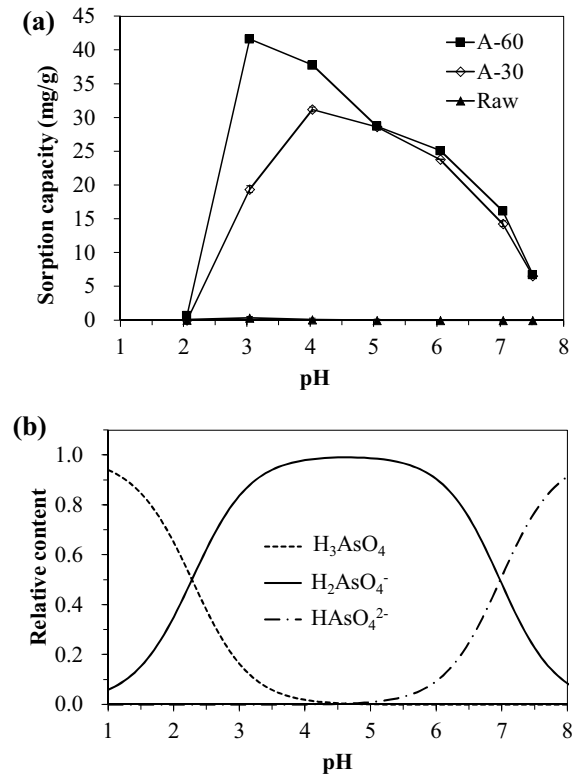

Fig. 5. Effect of contact time on As(V) removal by A-60 (adsorbent dosage = 0.2 g/L, initial concentration = 10 mg/L, contact time = 5–120 min, solution pH = 3.04).

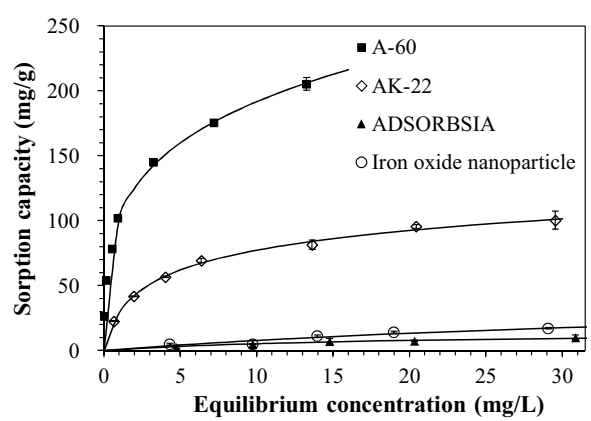

Fig. 6. Effect of equilibrium concentration on As(V) removal by fibrous ion exchangers and alternative adsorbents tested in this study (adsorbent dosage = 0.2 g/L, initial concentration = 5–50 mg/L, contact time = 2 h, solution pH = 3.04).

easily accessible sites on the fiber surface. Zhang et al. [10] reported that arsenate adsorption on an ion-exchange fiber reached equilibrium after 30 min with a removal ratio of 93%, and Ruixia et al. [11] showed that the equilibrium of As(V) on an ion exchange fiber was reached after 5 min.

The experimental data in Fig. 5 were analyzed using the following pseudo-first-order (Eq. (3)), pseudo-second-order (Eq. (4)), and Elovich (Eq. (5)) kinetic models:

$$q_t = q_e\left(1 - e^{-k_1 t}\right) \tag{3}$$

$$q_t = \frac{k_2 q_e^2 t}{1 + k_2 q_e t} \tag{4}$$

$$q_t = \beta \ln\left(\alpha\beta\right) + \beta \ln t \tag{5}$$

where q_e is the amount of arsenic adsorbed at equilibrium, q_t is the amount of arsenic adsorbed at time t, k_1 is the pseudo-first-order rate constant, and k_2 is the pseudo-second-order rate constant. In Eq. (5), α and β are the initial adsorption rate constant and the Elovich adsorption constant, respectively [30].

The kinetic parameters obtained from model fitting are provided in Table 2. Based on the Pearson's chi-square test, there were no significant differences ($p < 0.05$) between the simulated and the observed data. The pseudo-first-order model yielded the best fit ($R^2 = 0.969$), suggesting that the overall rate of As(V) adsorption on A-60 is controlled by a first-order reaction such as ion exchange [35]. A similar phenomenon was also observed for As(V) removal using cellulosic-ferric oxide and iron(oxy)hydroxide impregnated granular activated carbon [36,37].

3.4. Adsorption isotherms

Isotherm studies were carried out at various initial arsenic concentrations using fibrous ion exchangers (A-60 and AK-22) and adsorbents (ADSORBSIA™ and iron oxide nanoparticle) that there are well known for As(V) removal from water. As shown in Fig. 6, the sorption capacity of A-60 increased rapidly compared to AK-22, and the difference in the sorption capacity between the two adsorbents also increased based on the initial concentration. At the highest initial concentration of 50 mg/L, the sorption capacity of A-60 (205.32 ± 3.57 mg/g) was 2 times larger than that of the AK-22 (100.35 ± 8.80 mg/g), and an intense arsenic peak was observed

Table 2
Kinetic parameters for the adsorption of As(V) on A-60.

Pseudo-first-order				Pseudo-second-order				Elovich			
q_e (mg/g)	k_1 (/min)	R^2	χ^2	q_e (mg/g)	k_2 (g/mg/min)	R^2	χ^2	α (g/mg/min)	β (mg/g)	R^2	χ^2
52.60 ± 0.69	0.15 ± 0.01	0.969	0.471	57.72 ± 1.44	0.004 ± 0.001	0.942	0.632	3.69 ± 5.98	7.31 ± 1.57	0.755	2.725

*Critical value for the Pearson's Chi-square test (Degrees of freedom = 8, Significance level = 0.05) = 15.507.

Table 3
Isotherm parameters for the adsorption of As(V) on A-60 and AK-22.

	Langmuir				Freundlich				Redlich-Peterson				
	Q_m (mg/g)	K_L (L/mg)	R^2	χ^2	K_F (L/g)	1/n	R^2	χ^2	K_R (L/g)	a_R (L/mg)	g	R^2	χ^2
A-60	199.79 ± 14.57	1.28 ± 0.38	0.945	60.693	98.04 ± 3.11	0.30 ± 0.02	0.991	3.632	1708.27 ± 590.99	15.66 ± 5.93	0.75 ± 0.02	0.998	0.620
AK-22	108.40 ± 4.16	0.30 ± 0.04	0.983	2.138	34.25 ± 2.72	0.33 ± 0.03	0.974	2.750	56.08 ± 12.22	0.92 ± 0.32	0.83 ± 0.04	0.996	0.233

*Critical value for the Pearson's Chi-square test (Degrees of freedom = 6, Significance level = 0.05) = 12.592.

Table 4
Comparison of the adsorption capacity (q_e) of different fibrous ion exchangers and adsorbents for As(V) adsorption.

Adsorbents	Conditions	q_e (mg/g)	Reference
RPFA-I	Initial concentration = 5 mg/L; pH = 7.00; contact time = 12 h	9.19[a]	[10]
FIBAN-As	Initial concentration = 500 mg/L; pH = 7.70; contact time = 24 h	75.67[a]	[14]
QDMAEMA-g-PE/PP	Initial concentration = 500 mg/L; pH = 7.00; contact time = 240 min	82.66	[17]
Cellulose-g-PDMAEMA	Initial concentration = 8.9 mg/L; pH < 10; contact time = 1 min	27.93[a]	[18]
FIBAN AK-22	Initial concentration = 50 mg/L; pH = 3.04; contact time = 120 min	100.35 ± 8.80	This study
Poly(acrylo-amidino diethylenediamine) (A-60)		205.32 ± 3.57	This study
ADSORBSIA™		10.70 ± 0.51	This study
Iron oxide nanoparticle		22.91 ± 0.49	This study

[a] Langmuir adsorption capacity.

on the surface of both adsorbents after adsorption (Fig. 2d and e). While, the sorption capacity of ADSORBSIA™ (10.70 ± 0.51 mg/g) and iron oxide nanoparticle (22.91 ± 0.49 mg/g) were about nine times smaller than that of fibrous ion exchanger at same initial concentration (50 mg/L) in our experimental conditions. The adsorption capacity of various materials are presented in Table 4 along with the tested conditions. Based on these data, the A-60 synthesized in this study exhibits superior adsorption capacity than the tested commercial materials and literature values.

The adsorption data for A-60 and AK-22 as a function of the initial concentration were analyzed using the Freundlich (Eq. (6)), Langmuir (Eq. (7)), and Redlich-Peterson (Eq. (8)) isotherm models:

$$q_e = K_F C_e^{\frac{1}{n}} \tag{6}$$

$$q_e = \frac{Q_m K_L C_e}{1 + K_L C_e} \tag{7}$$

$$q_e = \frac{K_R C_e}{1 + a_R C_e^{g}} \tag{8}$$

where C_e is the equilibrium concentration of arsenic in the aqueous solution, K_F is the Freundlich constant related to the adsorption capacity, $1/n$ is the Freundlich constant related to the adsorption intensity, Q_m is the maximum adsorption capacity, K_L is the Langmuir constant related to the binding site affinity, K_R is the Redlich-Peterson constant related to the adsorption capacity, a_R is the Redlich-Peterson constant related to the binding site affinity, and g is the Redlich-Peterson constant related to the adsorption intensity.

The best-fitting isotherm model parameters are presented in Table 3. Most of the models adequately fit the A-60 data ($\chi^2 < 12.592$), except for the Langmuir model ($\chi^2 = 60.693$). Both fibrous ion exchangers were best fitted by the Redlich-Peterson isotherm model. This is a hybrid model that combines the Freundlich and Langmuir isotherms, and can be applied to either homogeneous or heterogeneous systems to describe adsorption over a wide range of concentrations [31].

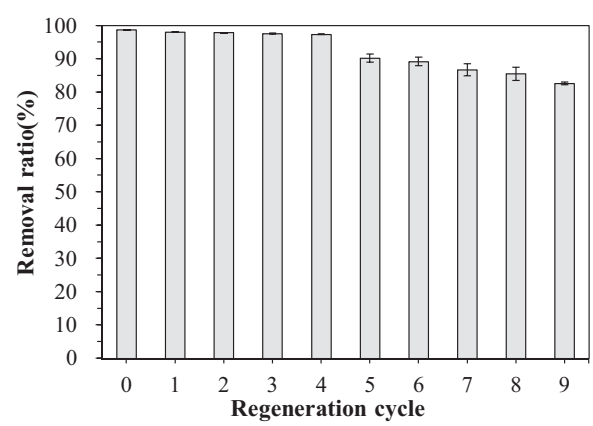

Fig. 7. Removal efficiency of As(V) onto A-60 during 9 regeneration cycles (adsorbent dosage = 0.2 g/L, initial concentration = 10 mg/L, contact time = 2 h, solution pH = 3.04).

3.5. Regeneration studies

Several chemicals and their combinations, such as HCl, NaOH, and NaCl, were tested for the regeneration of the fibrous ion exchange materials [13,15–17]. Acids and bases were used to complete the regeneration of the fiber in this study. The fiber can be effectively regenerated by rinsing the adsorbent with 0.1 N HCl, 0.1 N NaOH, and ultra-pure water in sequence. The removal efficiency of the A-60 fibers remained above 83% of the initial value during nine regeneration cycles (Fig. 7). The decrease in removal efficiency was related to fiber degradation via the regeneration chemicals [32,33]. Nonetheless, the results indicate that A-60 fibers have an excellent reusability for As(V) removal, and the fibers can be used as an affordable ion exchange technology with the use of regeneration.

4. Conclusions

The removal of As(V) from aqueous solutions was investigated using a synthesized ion exchange fiber. The amine doping reaction with an acrylic fiber using DETA was complete within 60 min using a $AlCl_3 \cdot 6H_2O$ catalyst at 100 °C. The total ion exchange capacity of A-60 was calculated using a back titration method and was 7.5 meq/g. The As(V) removal efficiency of the fiber was affected by the solution pH, and the maximum sorption capacity for A-60 was found at pH 3.04. The pseudo-first-order model was the most suitable for describing the kinetic data, and the equilibrium data fitted well to the Redlich-Peterson model. A-60 has a high adsorption capacity compared to literature values for other fibers, and the removal efficiency of the fiber was mostly maintained over nine regeneration cycles. These results demonstrate that amine-doped acrylic ion exchange fibers can be used as one of the BATs for arsenic removal from aqueous solutions.

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