Supporting Information (SI) on

Direct synthesis of bacteria-derived carbonaceous nanofibers as highly efficient material for radionuclides elimination

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Submitted to ACS Sustainable Chemistry & Engineering

Supporting Information, 7 pages with 4 Figures and 2 Tables

S1. Preparation of XPS analysis

The samples for XPS analysis was prepared as followed procedures: 3.0 mL of 0.1 mol/L NaClO₄ solution and 15 mL of 20.0 mg/L Sr(II) or Cs(I) were added into 50 mL polycarbonate tubes, and then 12 mL of 0.4 g/L CNFs were added into the aforementioned solution. The pH values of suspension were adjusted to be 4.5 by adding negligible volume of 0.1-5.0 mol/L HClO₄ or NaOH solution. Then the suspension was agitated on a shaker for a reaction time of 24 h. The solid and liquid phases were separated by centrifugation at 7104 ×*g* for 30 min. The samples for XPS analysis were obtained by drying them in vacuum oven overnight.

S2. Adsorption kinetics

The pseudo-first-order and pseudo-second-order kinetic models can be described by Eqns. S1 and S2, respectively:

$$\ln(q_e - q_t) = \ln q_e - k_f \times t \tag{S1}$$

$$\frac{t}{q_t} = \frac{1}{k_s \times q_e^2} + \frac{t}{q_e}$$
(S2)

where q_e and $q_t(mg/g)$ are the amounts of radionuclides adsorbed at equilibrium and at time t, respectively. k_f and k_s are the pseudo-first order and pseudo-second order kinetic rate constant, respectively. The fitted results and the corresponding kinetic parameters are shown in Figure S1 and Table S1, respectively.



Figure S1. The fitted results of pseudo-first-order kinetic models of Sr(II) and Cs(I) sorption on the CNFs

Table S1. The parameters of pseudo-first-order and pseudo-second-order kinetic

Adsorbates	Pseudo-first-order			Pseudo-second-order		
	q _e (mg/g)	$k_{f}(min^{-1})$	R ²	q _e (mg/g)	$k_s(g/(mg^{\cdot}h))$	R^2
Sr(II)	9.1431	0.0013	0.818	21.739	0.0573	0.9996
Cs(I)	9.5984	0.0007	0.837	13.514	0.0757	0.9999

model of Sr(II) and Cs(I) sorption on the CNFs

S3. Calculation of surface site concentration

The surface site concentration of the CNFs was calculated according to data of acid-base titration. The acid-base titration of the CNFs at 0.01 mol/L NaClO₄ solution was performed at 298 K with a DL50 Automatic Titrator (Mettler Toledo, Switzerland). Briefly, 40 mL of 0.16 g/L the CNFs with 0.01 mol·L⁻¹ NaClO₄ background electrolyte was purged with argon gas (< 1 ppm CO₂) for 60 min under vigorous stirring to exclude atmospheric CO₂(g). The initial suspensions were

adjusted to pH 3.0 by adding 0.1 mol/L HNO₃ solution gradually. The base titrations were conducted to pH 11.0 with 0.01 mol/L NaOH titrant at a variable increment and the equilibration time conditions. The values of Gran function (G) at acid and base side can be calculated by *Eqns*. S3 and S4, respectively:^{S1}

At acid side:
$$G_a = (V_0 + V_a + V_b) \times 10^{-pH} \times 100$$
 (S3)

At base side:
$$G_b = (V_0 + V_a + V_b) \times 10^{-(13.8-pH)} \times 100$$
 (S4)

where G_a and G_b are the Gran functions at the acid and base sides, respectively; V_0 is the initial volume of the suspension. V_a and V_b represent the total volume of acid added and base added at different titration points, respectively. The linear regression analysis of Gran plots at acid side (V_{eb1}) and at base side (V_{eb2}) can be considered as the neutralization with excess H⁺ cations. As shown in Figure S2, the value of V_{eb1} and V_{eb2} were calculated to be 0.55 and 2.2 mL at 0.01 mol/L NaClO₄ solution.



Figure S2. Gran plots of the CNF titration at 0.01mol/L NaClO₄, $V_0 = 40$ mL, m/v =

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0.16 g/L and T = 298 K.
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The total surface site concentration of the CNFs per solid weight (H_{s} , mmol/g) calculated from the two equivalence points on the Gran plot (V_{eb1} and V_{eb2}) is defined by the Eqn. (S5):^{S2}

$$H_{s} = \frac{(V_{eb2} - V_{eb1}) \times C_{b}}{m_{s}}$$
(S5)

where C_b and m_s refer to the concentration of NaOH (0.01 mol/L) and mass of the CNFs (0.0064 g), respectively. Therefore, the total surface site concentration of the CNFs was calculated to be 2.578 mmol/g.

S4. Distribution of Sr(II) and Cs(I) in aqueous solutions

The distribution of Sr(II) and Cs(I) in aqueous solutions were calculation by visual MINTEQ mode (Figure S3).^{S3}

Reactions Log K Ref. Sr(II) $Sr^{2+} + H_2O = SrOH^+ + H^+$ -13.29 (S4) $Sr^{2+} + 2H_2O = Sr(OH)_{2(aq)} + 2H^+$ -28.51 (S5) Cs(I) $Cs^+ + H_2O = CsOH + H^+$ -14.32 (S6) $Cs^{+} + 2H_2O = Cs(OH)_2^{-} + 2H^{+}$ -30.25 (S6)Distribution of radionuclides (mmol/L) B 0.16- Sr^{2+} А 0.14 Cs^+ 0.12 0.10 0.08 0.06 **SrOH** 0.04 0.02 CsO Sr(OH), Cs(OH), 0.00 5 7 8 pH 7_{pH} 8 ġ 10 11 1 ż Å 6 Ż ż Ś 6 9 10 11 12 4

Table S2. The equilibrium constants of Sr(II) and Cs(I) species in aqueous solution

Figure S3. The relative distribution of radionuclides as a function of pH in aqueous solutions, $C_0 = 10.0 \text{ mg/L}$, $P_{CO_2} = 10^{-3.5} \text{ atm}$, $I = 0.01 \text{ mol} \cdot \text{L}^{-1} \text{ NaClO}_4$, T = 298 K.

S5. Adsorption isotherms

The Langmuir and Freundlich models can be expressed by Eqns. (S6) and (S7), respectively:

$$Q_{e} = \frac{q_{m} \times K_{L} \times C_{e}}{1 + K_{L} \times C_{e}}$$
(S6)

$$Q_e = K_F \times C_e^{1/n} \tag{S7}$$

where $C_e (mg/L)$ and $Q_e (mg/g)$ refer to the equilibrium solute concentration and the amount of adsorbate adsorbed per unit mass of adsorbent, respectively. $K_L (L/mg)$ and $K_F ((mg^{1-n}L^ng^{-1}))$ are the equilibrium constants of Langmuir and Frenudlich models, respectively. $q_m (mg/g)$ represents the maximum adsorption capacity.

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