

1 **Supplementary**

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3 **Investigating the Absorption of Quaternary Ammonium Salt-**
4 **functionalized Silica towards Vanadium in Hydrochloric Acid**

5 **Solution**

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19 **Experimental**

20 **Analytical methods and materials**

21 Thermogravimetric analyzer (TGA; NETZSCH, 209F3A) was employed to assess variations in
22 weight loss across distinct temperature conditions. Fourier-transform infrared (FTIR) spectroscopy
23 (Perkin-Elmer, Frontier Mid-IR FTIR/STA6000-TL9000-Clarus SQ8 spectrometer) was utilized to
24 determine the functional groups present on the adsorbent surface. Spectra were recorded in the frequency
25 range of 400-4000 cm^{-1} . A scanning electron microscope (SEM) model FEI Quanta FEG 250 equipped
26 with an energy-dispersive X-ray spectrometer (EDS) was used for qualitative detection of surface
27 morphology and elemental constituents. Inductively coupled plasma mass spectrometry (ICP-MS;
28 Thermo Fisher Scientific, ICAP RQ) for the determination of metals in solution. X-ray photoelectron
29 spectroscopy (XPS, Thermo Scientific, ESCALAB250Xi).

30 Silica (SiO_2 , 100-200 mesh); 3-Chloropropyltriethoxysilane ($\text{C}_9\text{H}_{21}\text{O}_3\text{SiCl}$); *N*-benzyl-*N*-
31 methylethanolamine ($\text{C}_{10}\text{H}_{15}\text{NO}$); Sodium Metavanadate (NaVO_3); Sodium Hydroxide (NaOH);
32 Acetonitrile (CH_3CN); Manganese(II) Chloride (MnCl_2) were purchased from Tianjin Heowns OPDE
33 Technologies, LLC. Sodium Chromate Tetrahydrate ($\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$); Sodium Nitrate (NaNO_3); Toluene
34 (C_7H_8); Hydrochloric Acid (HCl); Nitric Acid (HNO_3); Sulfuric Acid (H_2SO_4) were obtained from
35 Sinopharm Chemical Reagent Co., Ltd. All chemicals are of analytical grade and the experimental used
36 water was distilled and does not require further purification before use.

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38 **Table S1** Quantitative and qualitative analysis of different SiO_2 analyzed by EDS (5 μm) (20 mL
39 solution of V(V), $C_0 = 2 \times 10^{-3} \text{ mol L}^{-1}$, BMEA-SD = 3.5 g L^{-1} , pH = 3, t = 60 min, T = 298 K)

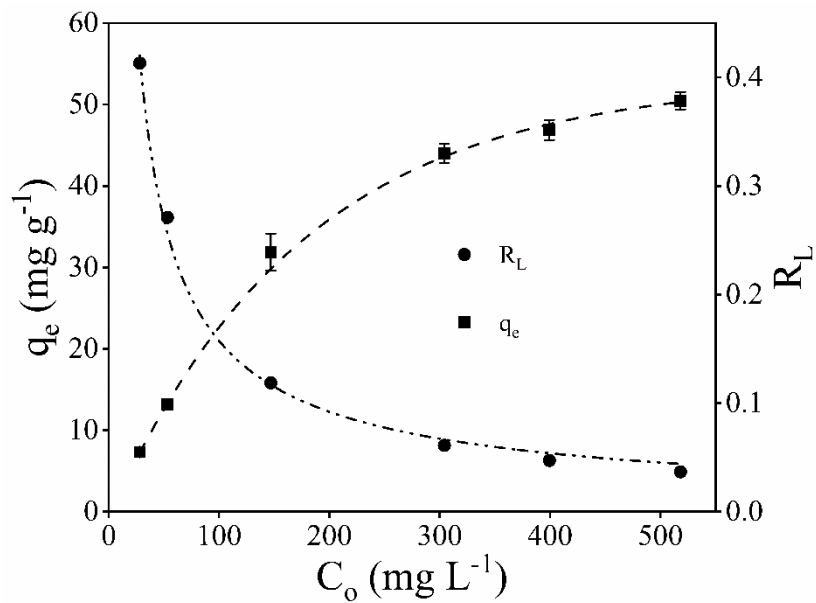
Types of SiO_2	Detected Elements (%)					
	Si	O	C	N	Cl	V
SD	47.12	52.88	-	-	-	-
CTPES-SD	32.15	56.03	10.60	-	1.22	-
BMEA-SD	38.31	40.47	15.89	5.33	-	-
BMEA-SD(V)	42.18	41.02	12.51	2.12	-	2.17

40 ⁻ Indicates Elements Not Selected for Testing

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45 **Figure S1** Effect of initial V(V) concentrations on adsorption onto BMEA-SD and separation factor

46 (R_L) (20 mL solution of V(V), pH = 3, BMEA-SD = 3.5 g L⁻¹, t = 60 min, T = 298 K)

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