# Electronic Supplementary Information

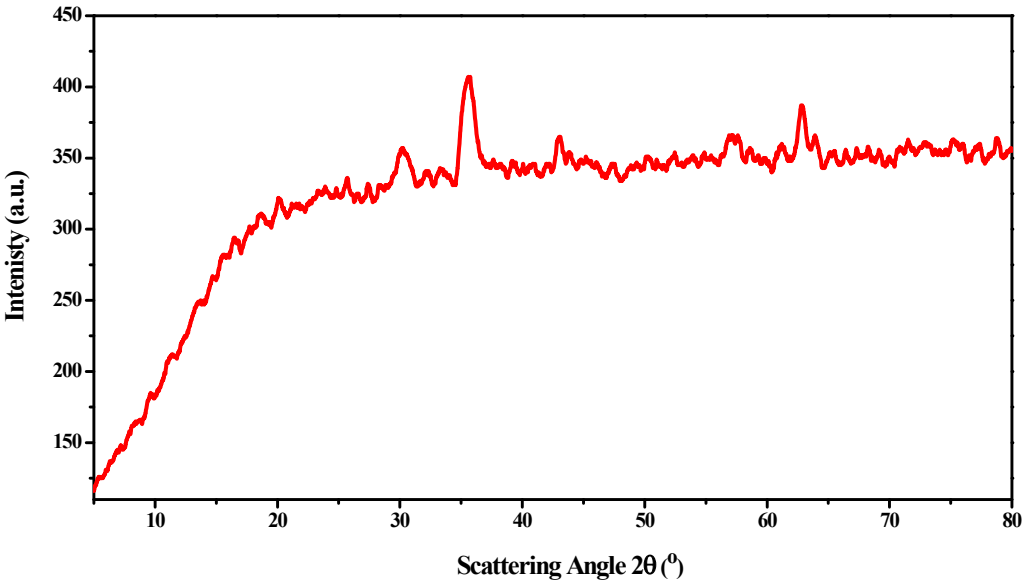


**Fig. S1.** XRD patterns of the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite.

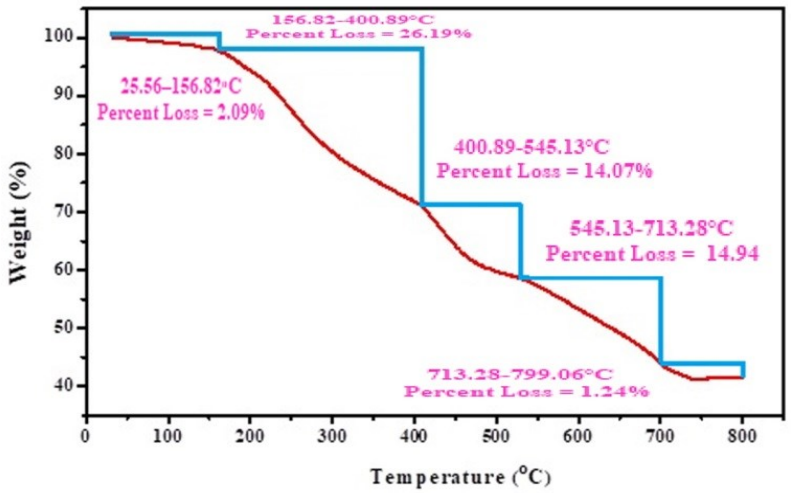


**Fig. S2.** TGA thermogram of the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite.

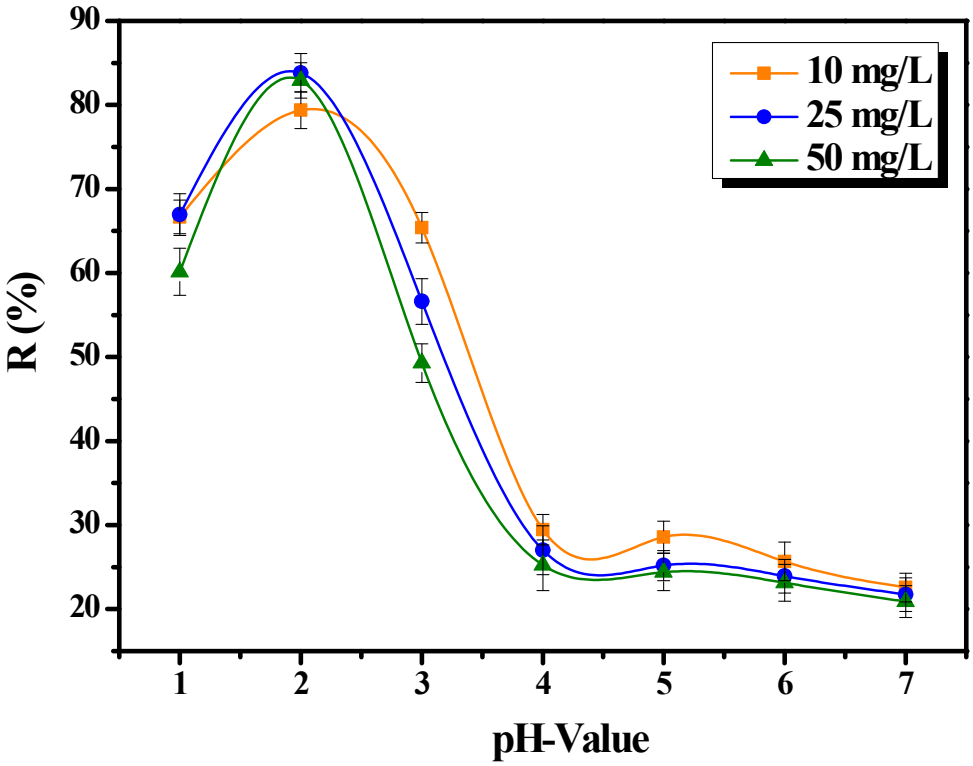


**Fig. S3.** Effect of initial solution pH on Cr(VI) ions removal percentage (%R) by the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite. (Sample volume = 10.0 mL; nanosorbent dose = 10.0±1.0 mg; Cr(VI) initial concentrations = 10.0, 25.0, and 50.0 mg/L; pH value = 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, and 7.0; shaking time = 60.0 min; temperature = 25.0°C; shaking speed = 250.0 rpm).

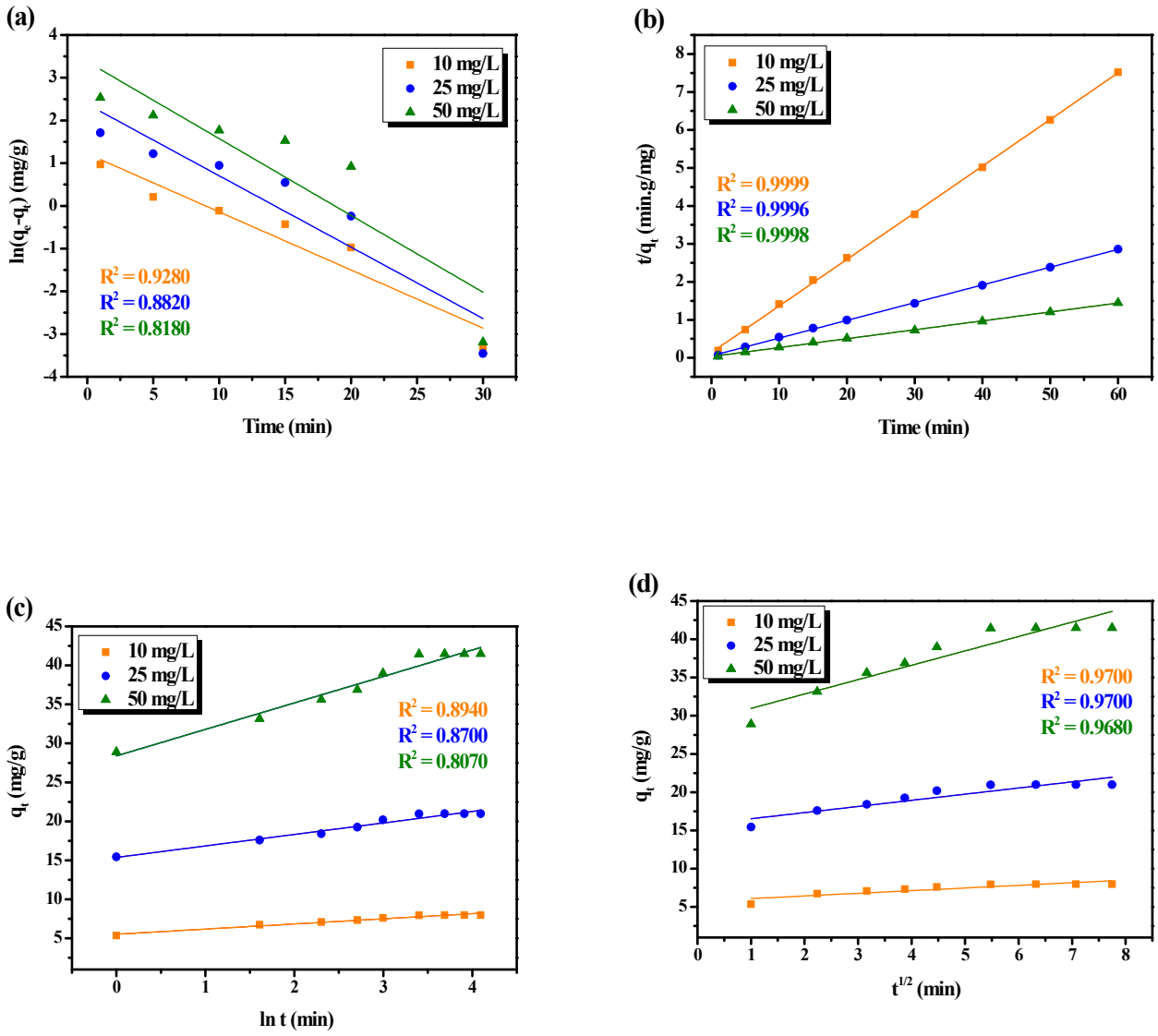


**Fig. S4.** **(a)** *Pseudo*-first order, **(b)** *Pseudo*-second order, **(c)** Intra-particle diffusion, and **(d)** Elovich kinetic models, for Cr(VI) ions (concentration = 10.0, 25.0, and 50.0mg/L) adsorption onto the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite at 25.0°C.

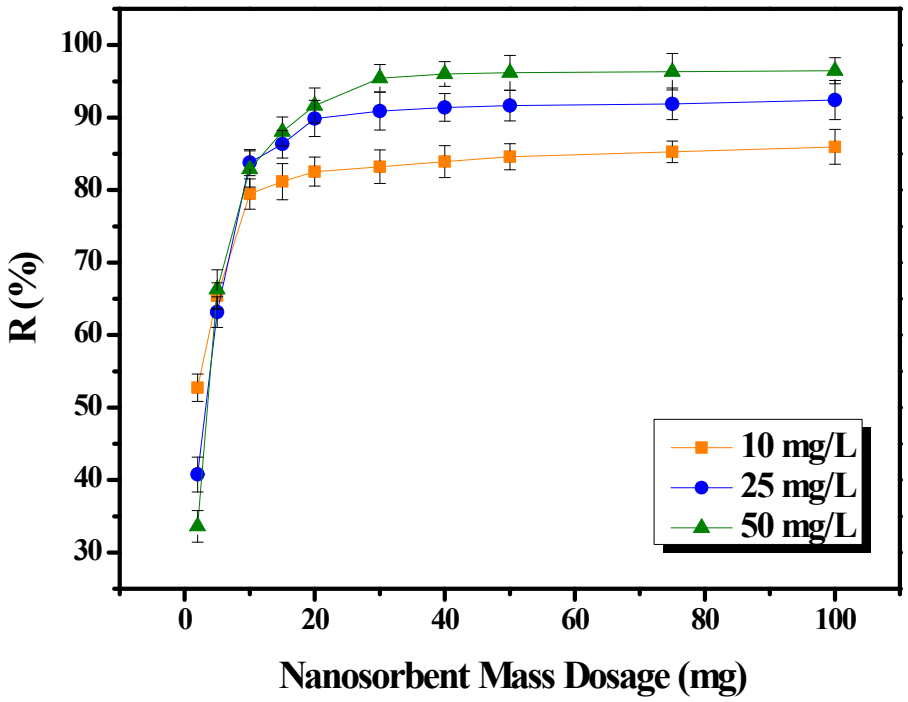


**Fig. S5.** Effect of dosage on Cr(VI) ions removal percentage (%R) by the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite. (Sample volume = 10.0 mL; nanosorbent dose = 2.0, 5.0, 10.0, 15.0, 20.0, 30.0, 40.0, 50.0, 75.0, and 100.0±1 mg; Cr(VI) initial concentrations = 10.0, 25.0, and 50.0 mg/L; pH value = 2.0; shaking time = 60.0 min; temperature = 25.0°C; shaking speed = 250.0 rpm).

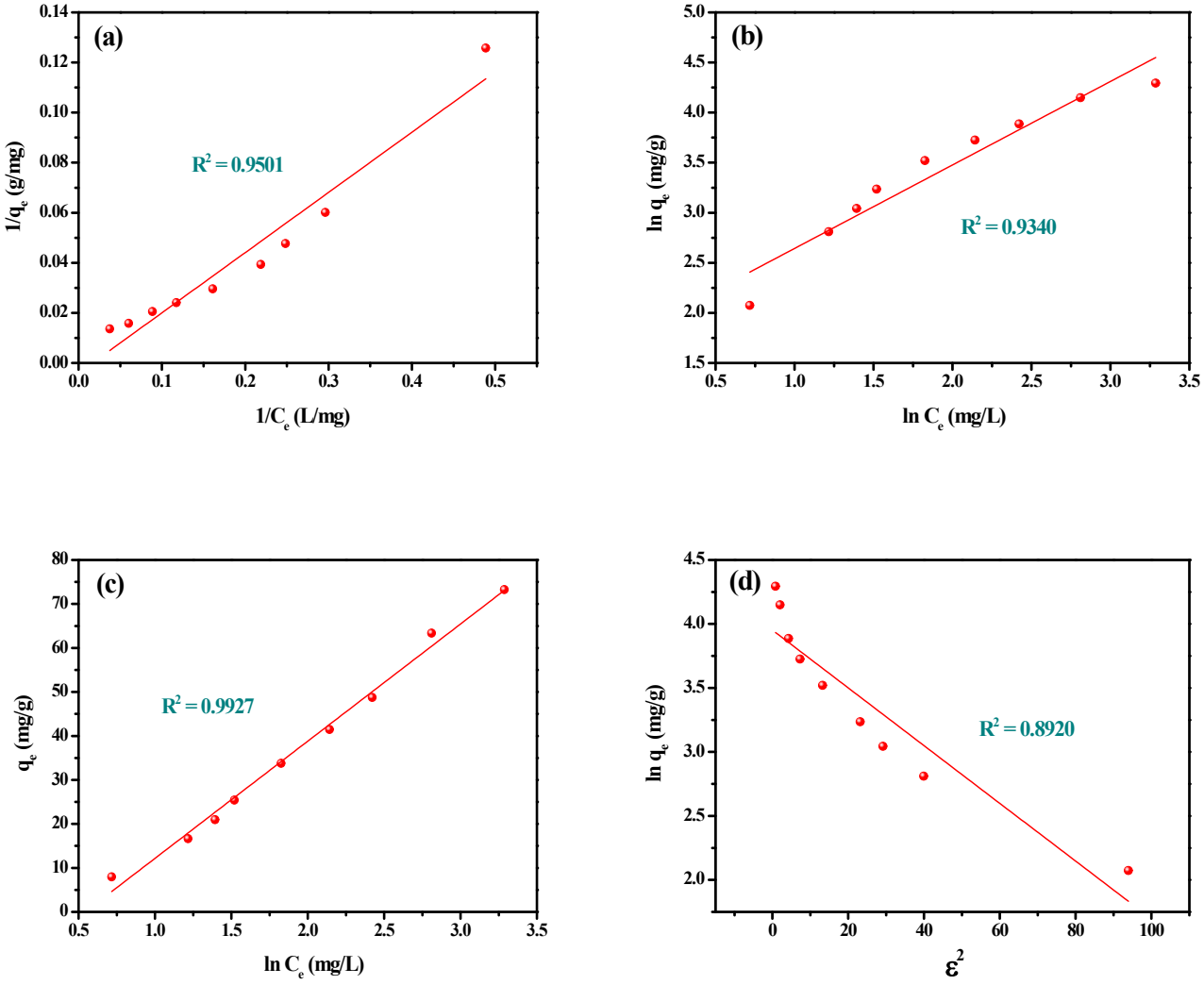


**Fig. S6. (a)** Langmiur, **(b)** Freundlich, **(c)** Temkin, and **(d)** D-R isotherm models for Cr(VI) ions (concentration = 10.0, 25.0, and 50.0mg/L) adsorption onto the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite at 25.0°C.

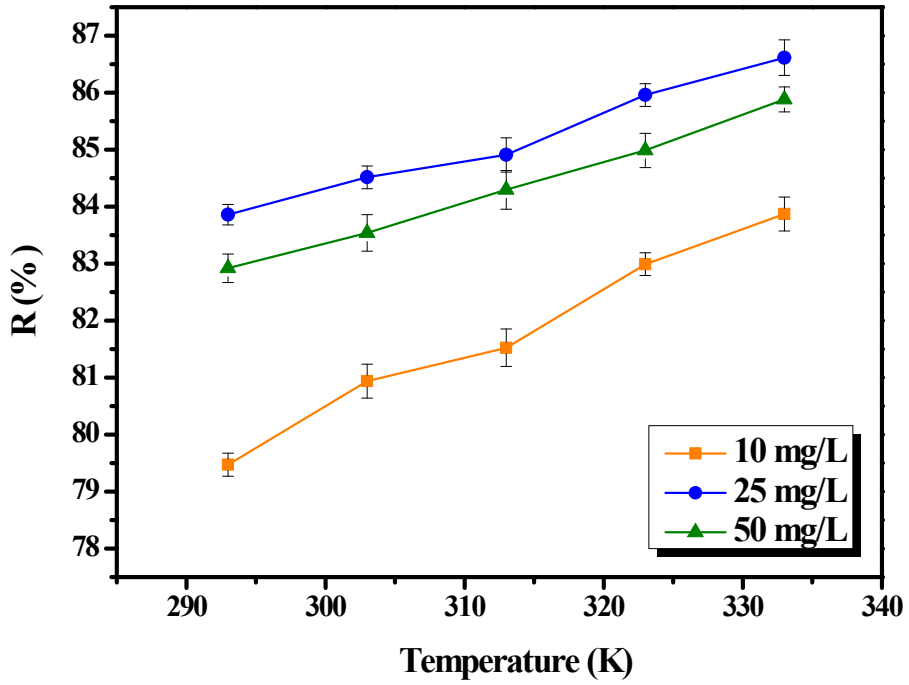


**Fig. S7.** Effect of reaction temperature on Cr(VI) ions removal percentage (%R) by the $NFe_3O_4$Starch-Glu-$NFe_3O_4$ED nanocomposite. (Sample volume = 10.0 mL; nanosorbent dose = 10.0 ±1 mg; Cr(VI) initial concentrations = 10.0, 25.0 and 50.0 mg/L; pH value = 2.0; shaking time = 60.0 min; temperature = 293.0, 303.0, 313.0, 323.0, and 333.0 K; shaking speed = 250.0 rpm).

**Table S1.** Chemicals and their specifications

| Chemical Name | Molecular Formula (MF) | Formula weight (FW) (g/mol) | Assay | CAS Reg. No. | Company |
|---|---|---|---|---|---|
| Starch (amylose 17.5%, amylopectin 82.5%, moisture content 12.0%, total ash 0.3%) | $(C_6H_{10}O_5)_n$ | 692.70 | 99.0% | 9005-25-8 | Sigma Aldrich, USA |
| Ethylenediamine | $C_2H_8N_2$ | 60.10 | 99.0% | 107-15-3 | |
| Glutaraldehyde | $C_5H_8O_2$ | 100.12 | 50.0 wt. % in $H_2O$ | 111-30-8 | |
| Anhydrous ferric chloride | $FeCl_3$ | 162.20 | 99.9% | 7705-08-0 | |
| Ferrous chloride | $FeCl_2$ | 126.75 | 99.9% | 7758-94-3 | |
| Hydrochloric acid | HCl | 36.46 | 37.0% | 7647-01-0 | |
| Potassium chloride | KCl | 74.55 | 99.0-100.5% | 7447-40-7 | BDH, UK |
| Sodium hydroxide | NaOH | 40.00 | 99.0% | 1310-73-2 | |
| Ammonium chloride | $NH_4Cl$ | 53.49 | 99.5% | 12125-02-9 | |
| Ethanol | $C_2H_5OH$ | 46.07 | 99.8% | 64-17-5 | |
| 1,5-Diphenylcarbazide | $C_{13}H_{14}N_4O$ | 242.29 | 99.0% | 140-22-7 | |
| Potassium dichromate | $K_2Cr_2O_7$ | 294.19 | 99.8% | 7778-50-9 | |
| Sodium acetate anhydrous | $CH_3COONa$ | 82.00 | 99.0% | 127-09-3 | Merck, Germany |
| Formaldehyde | $CH_2O$ | 30.03 | 34.5% | 50-00-0 | |
| Sodium chloride | NaCl | 58.44 | 99.9% | 5-14-7647 | Riedel de Haën, Germany |
| Calcium chloride dihydrate | $CaCl_2.2H_2O$ | 147.01 | 99.0% | 10035-04-8 | |
| Magnesium chloride hexahydrate | $MgCl_2.6H_2O$ | 203.30 | 99.0% | 6-18-7791 | |

**Table S2.** Instruments and their specifications.

| Instrument Name | Model | Data | Conditions |
|---|---|---|---|
| Fourier-transform infrared spectrophotometer **FT-IR** | A BRUKER VERTEX 70 | FT-IR spectrum | 400–4000 $cm^{-1}$ |
| **TGA**-7 thermobalance | A Perkin-Elmer | Thermogram | Pure atmospheric nitrogen, flow rate = 40 mL/min, heating rate = 10°C/min, sample mass in the range of 5.0–6.0 mg, heating temperature 25°C – 800°C |
| X-ray diffraction **(XRD)** | Shimadzu lab x 6100, Kyoto, Japan | XRD spectrum | The XRD generator works at 40 kV, 30 mA, λ = 1 Å, using target Cu-Kα with secondary Monochromatic X-ray, 2θ from 10° to 80°, recording steps of the diffraction data of 0.02°, at a time of 0.6 s, at room temperature (25°C). |
| Scanning electron microscope **(SEM)** | JSM-lT200, JEOL Ltd Sputtering coating (JEOL-JFC-1100E) | SEM images | Imaging mode |
| High-resolution transmission electron microscope **(HR-TEM)** | JEOL- JSM-1400 plus | HR-TEM image | Imaging mode |
| Brunauer–Emmett–Teller **(BET)** surface area | BELSORP-mini II, BEL, Japan | Surface area, pore volume and pore size distribution | The required data were determined by nitrogen adsorption–desorption isotherm measurements at adsorption temperature 77 K and saturated vapor pressure of 102.48 kPa for 24 h. |
| UV-Vis-spectrophotometer | UV-Vis-7200 single beam | Absorbance | 1.0 cm cell, wave length 540 $cm^{-1}$ wavelength range 190–1100 nm |
| Microwave oven | KOG-1B5H, Korea | Microwave irradiation | 1400-W, 2.45GHZ |
| pH meter | Orion pH meter model 420Afitted with an Orion combined glass electrode | pH-measurement | Calibrated using standard buffers of pH 4.01, 7.00, and 10.00 |

**Table S3.** Equations and parameters of kinetic models

| Kinetic Model | Equation | Plot | Kinetic Parameter | Cr(VI) Concentration (mg/L) | | |
|---|---|---|---|---|---|---|
| | | | | 10 | 25 | 50 |
| **Pseudo-First Order** | $Ln (q_e - q_t) = Ln (q_e) - k_1 t$ | ln ($q_e - q_t$) versus time (t) $q_e$ and $q_t$ are the sorption capacity at equilibrium and at time t (min), respectively, $k_1$ is the first order rate constant | $q_e$ (mg/g) (exp) | 7.9800 | 20.9800 | 41.4900 |
| | | | $q_e$ (mg/g) (calc) | 3.3906 | 10.6867 | 29.1659 |
| | | | $K_1$ ($min^{-1}$) | 0.1360 | 0.1660 | 0.1790 |
| | | | $R^2$ | 0.9280 | 0.8820 | 0.8180 |
| **Pseudo-Second Order** | $t/q_t = 1/k_2 q_e^2 + t/q_e$ | $t/q_t$ versus time (t) $K_2$ is the second order rate constant | $q_e$ (mg/g) (exp) | 7.9800 | 20.9800 | 41.4900 |
| | | | $q_e$ (mg/g) (calc) | 8.1967 | 21.7391 | 42.6076 |
| | | | $K_2$ (g/mg min) | 0.1146 | 0.0454 | 0.0173 |
| | | | $R^2$ | 0.9999 | 0.9996 | 0.9998 |
| **Intra-particle Diffusion** | $q_t = k_{id} t^{1/2} + C$ | $q_t$ versus ($t^{1/2}$) C is the thickness of the adsorption layer, $K_{id}$ is the intra-particle order rate constant | $K_{id}$ (mg/g $min^{1/2}$) | 0.3460 | 0.8040 | 1.8790 |
| | | | C | 5.7420 | 15.7200 | 29.0700 |
| | | | $R^2$ | 0.8070 | 0.8700 | 0.8940 |
| **Elovich** | $q_t = 1/\beta Ln(\alpha\beta) + 1/\beta Ln (t)$ | $q_t$ versus ln t α is the initial adsorption rate, β is related to the extent of surface coverage and the activation energy for the chemisorption | α (mg/g min) | 2916.4027 | 50100.6158 | 14539.1641 |
| | | | β (mg/g) | 1.5198 | 0.6789 | 0.2945 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | process | | | | |

**Table S4.** Linear equations and their parameters for different adsorption isotherm models

| Isotherm Model | Linear Equation | Linear Plot | Isotherm Parameter | Value of Isotherm Parameter |
|---|---|---|---|---|
| **Langmuir** | $C_e/q_e = 1/q_{max} K_L + C_e/q_{max}$ | $C_e/q_e$ versus $C_e$ slope = $1/q_m$ and intercept = $1/(K_L q_{max})$ $K_L$ is the Langmiur constant, $q_{max}$ is the maximum adsorption capacity | $q_{max}$ ( mg/g) | 210.7410 |
| | | | $K_L$ (L/mg) | 0.0274 |
| | | | $R_L$ | 0.2676-0.6463 |
| | | | $R^2$ | 0.9501 |
| **Freundlich** | $Ln(q_e) = Ln(K_F) + 1/n\ Ln(C_e)$ | ln $q_e$ versus ln $C_e$ slope = 1/n and intercept = ln $K_F$ $K_F$ is the Freunlish constant related to the affinity of the adsorbate to the binding sites of the adsorbent, n is the intensity of the adsorbent | n | 1.2007 |
| | | | $K_F$ (L/mg) | 6.1176 |
| | | | $R^2$ | 0.9340 |
| **Temkin** | $q_e = (RT/b_T) Ln(a_T) + (RT/b_T) ln(c_e)$ | $q_e$ versus ln $C_e$ slope = B and intercept = B ln $a_T$ $a_T$ is Temkin isotherm equilibrium binding constant corresponding to the maximum binding energy, $b_T$ is the Temkin isotherm equilibrium binding constant related to the heat of adsorption | $a_T$ (L/g) | 0.5810 |
| | | | $b_T$ ( KJ/mol) | 0.0914 |
| | | | B | 26.6384 |
| | | | $R^2$ | 0.9927 |
| **Dubinin-Radushkevich (D–R)** | $Ln(q_e) = Ln(q_s) - (K_{ad}\varepsilon^2)$ | ln $q_e$ versus $\varepsilon^2$ slope = $K_{ad}$ and intercept = Ln ($q_s$) ε is the *polanyi* potential (ε = RT ln (1+(1/$C_e$)), $q_s$ is the theoretical saturation capacity, $K_{ad}$ is the D-R isotherm constant | $q_s$ (mg/g) | 52.0090 |
| | | | $K_{ad}$ ($mol^2/J^2$) | 225.5934 |
| | | | $E_s$ (KJ/mol) | 0.0470 |
| | | | $R^2$ | 0.8920 |