**Supporting Information**

**Highly porous chitosan based magnetic polymeric nanocomposite (PNC) for the removal of radioactive, Cs(I) and Sr(II) ions from aqueous solution**

1. **Fabrication of NiFe2O4 nanoparticles**

The NiFe2O4 nanoparticles were synthesized via co-precipitation method. In a 500 mL flask, 2.37 g (0.01 mol) of NiCl2·6H2O and 5.4 g (0.02 mol) of FeCl3·6H2O were dissolved into 200 mL of distilled water. In this solution, 3–5 drops of dilute HCl was added under the flow of nitrogen, then aqueous solution of NH3(10%) was added drop-wise under continuous starring until the pH reached up to 10.0 and the colour of the mixture was changed black. The growth of magnetic particles can be observed using external magenta and then the black precipitate was collected by magnet, washed and dried at room temperature.

1. **Analytical techniques**

Fourier transform infrared (FT-IR) spectra were recorded on a Tensor-27 (Bruker) within the range 400–4000 cm−1, using KBr pellets. The thermal analytical curves for NiFe2O4, PNC and NiFe2O4@PNC were recorded using SDTQ 600 (TA instrument). The crystalline nature and purity of the synthesized materials was characterized by XRD, RigakuUltima IV diffractometer over an incident angle from 20° to 70° using Cu-Kα radiation. The morphologies of the nanocomposite were observed by a SEM (FESEM, JEOL, JSM-7600F) and TEM (TEM, JEOL JEM-2010F). The Brunauer - Emmett - Teller (BET) specific surface areas and porosity of the samples were measured on the basis of nitrogen adsorption isotherms using a gas adsorption apparatus (Micromeritics, System, ASAP, 2020). The surface properties of the photocatalysts was characterized by X-ray photoelectron spectroscopy (XPS) (Thermo ESCALAB 250, USA, Al Kα). The zeta potential of NDs in ultrapure water was measured by a zeta potential analyzer (Zetasizer, Malvern Instruments, Worcestershire, UK, model Nano ZS). Magnetic measurements of NiFe2O4 and NiFe2O4@PNC were performed at room temperature by a vibrating sample magnetometer, Cryogenic Limited PPMS.

1. **Batch experiments**

The adsorption of Sr(II) and Cs(I) on magnetic NiFe2O4@PNC was studied. Briefly, 0.2 gm of NiFe2O4@PNC were mixed with a freshly prepared different concertation solution of Sr(II) or Cs(I) in polycarbonate test tubes. After the pH was adjusted, the tubes were sealed and then reacted for an optimum time in a constant temperature over-end-over shaker. The pH in aqueous solutions was adjusted by adding 0.1 mol/L NaOH and HCl (Fisher Scientific). The concentration of Sr(II) and Cs(I) solution was analyzed by inductively coupled plasma atomic emission spectrometry (ICP-AES). The adsorption capacity of NiFe2O4@PNC were calculated using flowing equation (i) [1]:

(i)

WhereC0 (mg/L) and Ce (mg/L) represent the initial and equilibrium concentration of Cs(I) and Sr(II) respectively. m is the mass of NiFe2O4@PNC (g) and V is the volume of Cs(II) /Sr(II) solution in L. The desorption and the regeneration study were carried out using dil HCl solution and the concentration of desorbed metal ions were measured by ICP and the regenerated NiFe2O4@PNC was used for next adsorption cycles.

**4. Adsorption Kinetics**

The adsorption behavior of both the metal ions over NiFe2O4@PNC was further explained via adsorption kinetics, the experimental data were fitted via pseudo-first-order, pseudo-second-order model and Intraparticle diffusion kinetic models according to equation (ii-iv) [2, 3]:

(ii)

(iii)

(iv)

### Where qe(mg g−1) andqt (mg g−1) are the adsorption capacities at equilibrium and at time t (min), respectively.k1 (min−1) andk2 (g mg−1min−1) are the rate constants of the pseudo-first-order model and the pseudo-second-order model, respectively.ki is intra-particle diffusion rate constant and C is the thickness of the boundary layer.

**5. Adsorption Isotherms**

### The Langmuir model, Freundlich model and Temkin models were used to discuss the adsorption mechanism and conclude the adsorption tendency of the NiFe2O4@PNC for Cs(I) and Sr(II). The Langmuir isotherm model can be used for the monolayer adsorption process on the adsorbent surface[4]. The nonlinear equation for Langmuir model as below (v):

(v)

### Where, qeis the amount of metal ions adsorbed on the NiFe2O4@PNC (mg/g),Ceis the aqueous equilibrium concentration of metal ions (mg/L),the dimensionless constant separation factor, RL as equation (vi)

### (vi)

### The RL parameter denotes the isotherm shape either undesirable (RL> 1), linear (RL=1), desirable (0<RL< 1) or irreversible (RL=0).

### The Freundlich adsorption isotherm describes the multilayer adsorption behavior over the surface of NiFe2O4@PNC, the nonlinear Freundlich adsorption isotherm model is described in equation (vii)

(vii)

### Where, Kf (mg/g (mg/L)−1/n) is the Freundlich distribution coefficient, and 1/n is empirical constant of the Freundlich describing the adsorption intensity or surface heterogeneity[5]. The Temkin isotherm model contains a factor that explicitly shows adsorbate-adsorbent interactions, it is assumed that heat of adsorption of all molecules in the layer would decrease with adsorption and the nonlinear model for Temkin isotherm is given below equation (viii)

(viii)

Where, kt is the Temkin isotherm constant, bt was related with the maximum bond energy; the bt value lower than 40 kJ/mol indicates a physical adsorption process. When the bt is higher than 40 kJ/mol, it directs a chemical adsorption process.

### 6. Thermodynamic parameters

### It was observed that the adsorption tenancy of Cs(I) and Sr(II) over NiFe2O4@PNC decreased with with increasing temperature from 296 to 336 K, suggesting that the adsorption metal ions was promoted at lower temperature. Thermodynamic parameters such as free energy (ΔGo), enthalpy (ΔHo), and entropy (ΔSo) change of adsorption were determined by the van’t Hoff equation. These parameters are calculated by the following equations:

(ix)

(x)

Where, K is the equilibrium constant, R is the universal gas constant (8.314 J/mol K); and T is the solution temperature (K). The linear plot between lnK and 1/T (K) help to calculate the parameters [6].

**Supporting Table S 1.** Comparison of adsorption capacities of Sr(II) and Cs(I) by various adsorbents.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Adsorbents** | **Metals** | **Adsorption capacity (mg/g)** | **Conditions** | **References** |
| FJSM-SnS/PAN | Sr(II) | 62.88 | pH 7.1 | [7] |
| FJSM-SnS | Sr(II) | 65.15 | pH UM | [8] |
| KMS-1 | Sr(II) | 77 | pH UM | [9] |
| KMS-2 | Sr(II) | 86.89 | pH UM | [10] |
| KTS-3 | Sr(II) | 102 | pH 6 | [11] |
| NiFe2O4@PNC | Sr(II) | 212.5 | pH UM | This Work |
| FJSM-GAS-1 | Sr(II) | 79.79 | pH 7 | [7] |
| FJSM-SnS/PAN | Cs(I) | 89.29 | pH 2.5 | [7] |
| FJSM-SnS | Cs(I) | 408.91 | pH UM | [8] |
| KMS-1 | Cs(I) | 226.3 | pH 5 | [9] |
| KMS-2 | Cs(I) | 531.74 | pH 4 | [10] |
| CHCF-PAN | Cs(I) | 25.52 | pH 8 | [12] |
| NiFe2O4@PNC | Cs(I) | 232.12 | pH UM | This Work |

**References:**

[1] T. Ahamad, M. Naushad, Ruksana, A.N. Alhabarah, S.M. Alshehri, N/S doped highly porous magnetic carbon aerogel derived from sugarcane bagasse cellulose for the removal of bisphenol‑A, International Journal of Biological Macromolecules, 132 (2019) 1031-1038.

[2] J. Yang, J. Dai, L. Wang, W. Ge, A. Xie, J. He, Y. Yan, Ultrahigh adsorption of tetracycline on willow branche-derived porous carbons with tunable pore structure: Isotherm, kinetics, thermodynamic and new mechanism study, J Taiwan Inst Chem E, 96 (2019) 473-482.

[3] C.P. Okoli, A.E. Ofomaja, Degree of time dependency of kinetic coefficient as a function of adsorbate concentration; new insights from adsorption of tetracycline onto monodispersed starch-stabilized magnetic nanocomposite, J Environ Manage, 218 (2018) 139-147.

[4] A. Xie, J. Cui, Y. Chen, J. Lang, C. Li, Y. Yan, J. Dai, Simultaneous activation and magnetization toward facile preparation of auricularia-based magnetic porous carbon for efficient removal of tetracycline, J Alloy Compd, 784 (2019) 76-87.

[5] M.T. Islam, A.H.M.G. Hyder, R. Saenz-Arana, C. Hernandez, T. Guinto, M.A. Ahsan, B. Alvarado-Tenorio, J.C. Noveron, Removal of methylene blue and tetracycline from water using peanut shell derived adsorbent prepared by sulfuric acid reflux, Journal of Environmental Chemical Engineering, 7 (2019) 102816.

[6] M.J. Ahmed, M.A. Islam, M. Asif, B.H. Hameed, Human hair-derived high surface area porous carbon material for the adsorption isotherm and kinetics of tetracycline antibiotics, Bioresource Technology, 243 (2017) 778-784.

[7] Z.T. Abd Ali, L.A. Naji, S.A. Almuktar, A.A. Faisal, S.N. Abed, M. Scholz, M. Naushad, T. Ahamad, Predominant mechanisms for the removal of nickel metal ion from aqueous solution using cement kiln dust, Journal of Water Process Engineering, 33 (2020) 101033.

[8] X.-H. Qi, K.-Z. Du, M.-L. Feng, J.-R. Li, C.-F. Du, B. Zhang, X.-Y. Huang, A two-dimensionally microporous thiostannate with superior Cs+ and Sr2+ ion-exchange property, Journal of Materials Chemistry A, 3 (2015) 5665-5673.

[9] M.J. Manos, M.G. Kanatzidis, Highly Efficient and Rapid Cs+ Uptake by the Layered Metal Sulfide K2xMnxSn3−xS6 (KMS-1), Journal of the American Chemical Society, 131 (2009) 6599-6607.

[10] J.L. Mertz, Z.H. Fard, C.D. Malliakas, M.J. Manos, M.G. Kanatzidis, Selective Removal of Cs+, Sr2+, and Ni2+ by K2xMgxSn3–xS6 (x = 0.5–1) (KMS-2) Relevant to Nuclear Waste Remediation, Chemistry of Materials, 25 (2013) 2116-2127.

[11] D. Sarma, C.D. Malliakas, K.S. Subrahmanyam, S.M. Islam, M.G. Kanatzidis, K2xSn4−xS8−x (x = 0.65–1): a new metal sulfide for rapid and selective removal of Cs+, Sr2+ and UO22+ ions, Chemical Science, 7 (2016) 1121-1132.

[12] A. Nilchi, R. Saberi, M. Moradi, H. Azizpour, R. Zarghami, Adsorption of cesium on copper hexacyanoferrate PAN composite ion exchanger from aqueous solution, Chemical Engineering Journal, 172 (2011) 572-580.