**Supplementary Information**

**A facile approach to develop industrial waste encapsulated cryogenic alginate beads to sequester toxic bivalent heavy metals**

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**Figure S1.** EDX plots of pristine **(a)**, Pb(II) saturated **(b)**, and Cd(II) saturated **(c)** SMFCAB.

Inset: Elemental analysis data.

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| **Adsorbent** |  **Experimental conditions** | **qm****(mg/g)** | **t** **(min)** | **Reference** |
| Surfactant modified chitosan beads | *Co*:50 mg/L; pH: 5 ; T: 301K; *m*: 0.675g/L | Pb(II)/100 | 480 | (Pal and Pal, 2017) |
| Chelating polyacrylonitrile beads | *Co*: 9-10.5 mg/L;pH:7 T: 303K; *m*: 5g/L | Pb(II)/145Cd(II)/156 | 600 | (Bhunia et al., 2018)  |
| Chitosan-alginate beads | *Co*: 20 – 300 mg/L; pH: 4.5; T: 298K; *m*: 0.2g/L | Pb(II)/60.3 | 100 | (Nagh et al., 2010) |
| Chitosan@Fe3O4 nanocomposite beads | *Co*: 70 mg/L; pH: 6; T: 298K  | Pb(II)/63.3 | 120 | (Tran et al., 2010)  |
| Porous attapulgite/polymer beads | *Co*:100 – 500 mg/L; pH: 5.2 ; T: 293K; *m*: 0.250g | Cd(II)/32.7 | 360 |  (Feng et al., 2017)  |
| Magnetic poly(vinyl alcohol)/modified gum taracanth/graphene oxide hydrogel beads | *Co*: 20 – 200 mg/L; pH: 6 ; T: 298K; *m*: 0.05g | Pb(II)/81.8 | 540 | (Sahraei et al., 2017)  |
| SMFCAB | *Co*: 25 to 300 mg/L; T: 298K; *m*: 0.01g; pH: 5.5 for Pb(II) and 7.2 for Cd(II) |  Pb(II)/200 Cd(II)/178.6 | Pb(II)/90 Cd(II)/120 | This study |

**Table S1.** Comparison of the maximum monolayer adsorption capacities (*qm*) and equilibration time (t) for Pb(II)/Cd(II) adsorption on beads

**Text S1. Isotherm models**

Langmuir isotherm model assumes formation of monomolecular layer over adsorbent surface without interaction between the adsorbed molecules. Langmuir isotherm model in linearized form is expressed as (Langmuir, 1918):
where *qm* (mg/g) and *KL* (L/mg) are the constants for maximum monolayer adsorption capacity and a constant related to the heat of adsorption, respectively.

The essential feature of Langmuir isotherm can be expressed by separation factor (*RL*), a dimensionless constant, can be represented as:

The magnitude of *RL* reflects the nature of adsorption. If *RL* > 1(unfavorable adsorption process), 0 < *RL* < 1 (favorable adsorption process), *RL* =1 (linear adsorption process), *RL* = 0 (irreversible adsorption process).

 Freundlich isotherm in non-linear form is expressed as (Freundlich, 1906):

where *KF* ((mg/g) (L/mg)(1/n)) and *n* are the Freundlich constants related to bonding energy and deviation in adsorption from linearity, respectively. If *n =*1 (linear adsorption process), *n* < 1 (chemical adsorption process), *n* > 1 (physical adsorption process).

**Text S2. Kinetic models**

The pseudo-first-order (Lagergren, 1898)and pseudo-second-order (Ho and McKay, 1998) kinetics models in linearized forms are expressed as:

where *qe* and *qt* are the adsorption capacities at equilibrium, and at time *t*, respectively, *K1* and *K2* are the pseudo-first-order and pseudo-second-order rate constants, respectively.

**Text S3.** **Thermodynamic parameters**

Thermodynamic parameters viz. standard Gibb’s free energy change (*ΔG°*), entropy change (*ΔS°*), and enthalpy change (*ΔH°*) were calculated as:

where *R* is the universal gas constant (8.314 J/mol-K), *T* is the absolute temperature (K), and *Kc* is a separation factor. *ΔS°* and *ΔH°* were calculated from the intercept and slope of the plot of *ln* *Kc* versus 1/*T*.