Supplementary information

There are similar XRD patterns of various CS-GEL-HPMC material compositions, as shown in Fig. S1, the main peak at 2 θ between 20 ~ 25° corresponding to the amorphous carbon in the polymers. Reveal notable changes correlating with increasing HPMC content in samples CS0.5-GEL0.5, CS0.35-GEL0.35-HPMC0.3, and CS0.25-GEL0.25-HPMC0.5. Specifically, the primary peak (2 θ between 20 ~ 25°), indicative of the carbon chain structure, exhibits a slight shift towards higher degrees. This shift is attributed to the higher crystallinity of HPMC compared to the CS and GEL polymer matrix. Consequently, the incorporation of HPMC not only enhances the crystalline structure but also contributes to a more stable phase composition. This stability is particularly beneficial in the application of these membrane materials for the remediation of Cd^{2+} contaminated water and soil, suggesting a potential improvement in performance due to the structural integrity imparted by HPMC.

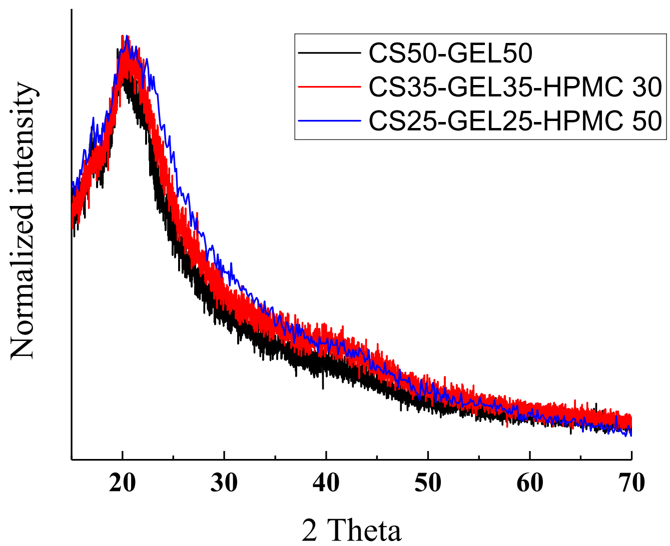

Figure S1. XRD of various CS-GEL-HPMC material compositions (CS0.5-GEL0.5, CS0.35-GEL0.35-HPMC0.3, and CS0.25-GEL0.25-HPMC0.5).

5 mL of 0.1 M HNO_3 was sufficient for the whole elution of the Cd^{2+} ions with a recovery of ~ 95%. As presented in Figure S2, in five consecutive adsorption-desorption cycles, no significant changes (less than 15%) in the adsorption capacity are observed, suggesting excellent reusability of this membrane material. Their recovery and reusability together highlight a sustainability of the new CS-GEL-HPMC membrane material, which leads to a lower cost in services.

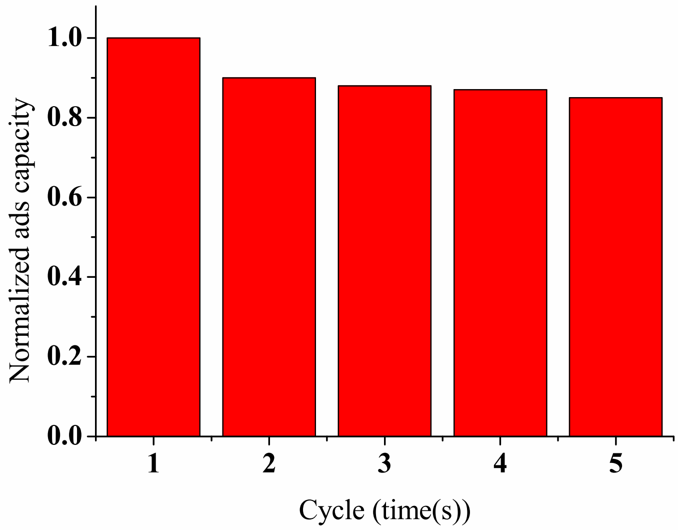

Figure S2. aqueous environmental adsorption efficiency of membrane materials after recovery with desorption treatments. [(0-1) normalized adsorption capacity by the value at the first cycle (initial experiment)]