Efficient Preparation and Characterization of LDH/GCN based 3D Foam for Sustainable Continuous Column Removal of $U^{6+}$and Cd^{2+} from Water: Mechanistic Insights and Application Feasibility

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1. Synthesis of LDH/g-C_3N_4

To synthesize g-C_3N_4, 10 grams of melamine were placed in an alumina crucible and heated in a furnace with a controlled heating rate of 5°C per minute. The temperature was maintained at 550°C for 2 hours. Once the process was complete, the material was allowed to naturally cool to room temperature (approximately 20°C). The resulting pale-yellow powder was then washed with water to eliminate any surface residues. After drying, the powder was finely ground using an agate mortar and pestle to obtain g-C_3N_4.

For the preparation of LDH/g-C_3N_4, a hydrothermal method was used with a Mg:Fe molar ratio of 1:2. In this process, 1 gram of g-C_3N_4 was ultrasonically dispersed in a solution consisting of 100 mL methanol and water (1:1 ratio by volume) for 30 minutes to achieve a uniform suspension. A salt solution containing $MgCl_2 \cdot 7H_2O$ and $FeCl_3 \cdot 6H_2O$ (with the same Mg:Fe ratio of 1:2) was then added to the suspension under continuous stirring to maintain the desired proportion of GCN to MgFe LDH. The pH of the solution was adjusted to 10 using 2 M NaOH. The mixture was kept at 60°C for 12 hours, after which the precipitate was washed several times with deionized water and dried at 60°C for another 12 hours.

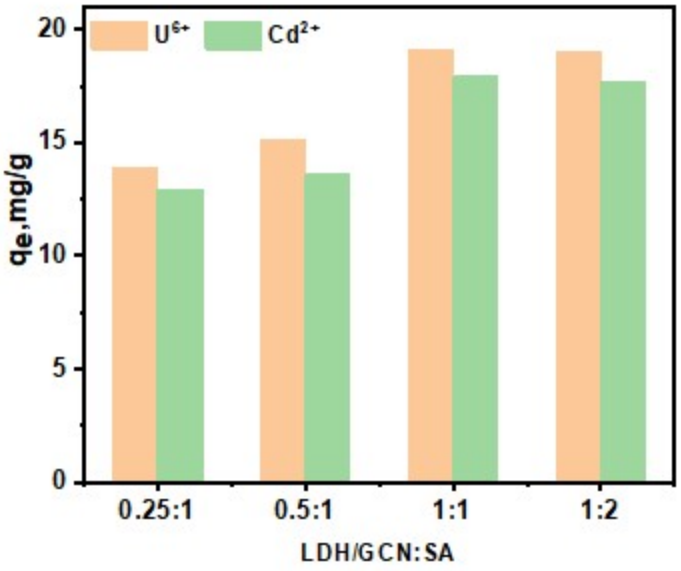

Fig.S1. U^{6+} and Cd^{2+} removal on different weight ratio of LDH/GCN:SA foam.

2. Instruments for characterization of LDH/g-C_3N_4 foam

To investigate the surface functionalization of the LDH/g-C_3N_4 foam, various analytical techniques were employed. ATR-FTIR (Attenuated Total Reflectance Fourier Transform Infrared) spectroscopy was conducted using a Shimadzu QATR™-S spectrometer equipped with a diamond crystal. This method was used to analyze the functional groups present on the surface. The microstructural properties of the carbon felt were examined with an energy-dispersive X-ray spectrometer (SEM-EDS), specifically the 7100F model from Jeol Korea, S-4300, and EDX-350 from Hitachi, Japan. The surface area of the adsorbent, determined by nitrogen adsorption, was measured using BET analysis with the Micrometrics ASAP2425 model from the USA. To gain insights into the crystallinity changes on the LDH/g-C_3N_4 foam surface, X-ray diffraction (XRD) was performed using the Rigaku D/Max–2500 X-ray diffractometer from Japan. The Cu Kα X-ray radiation was operated at 40 kV and 40 mA, with the samples being scanned at a rate of 4° min^{-1}

over a 2θ range of 10° to 60°. Additionally, X-ray photoelectron spectroscopy (XPS) was utilized to analyze the C/O ratio and elemental composition. This was carried out using a Spectrum GX & ESCALAB–210 instrument from Spain, with a monochromatic Al K Alpha X-ray source (1486.6 eV) powered by a 20 kV Ulvac PHI Quantera-II spectrometer at Chungbuk National University, South Korea. For the analysis of U^{6+} and Cd^{2+} species, ICP-OES was utilized with an Optima 2100 DV from PerkinElmer, USA, equipped with an autosampler. Graphs and data visualizations were created using Origin2018 software.

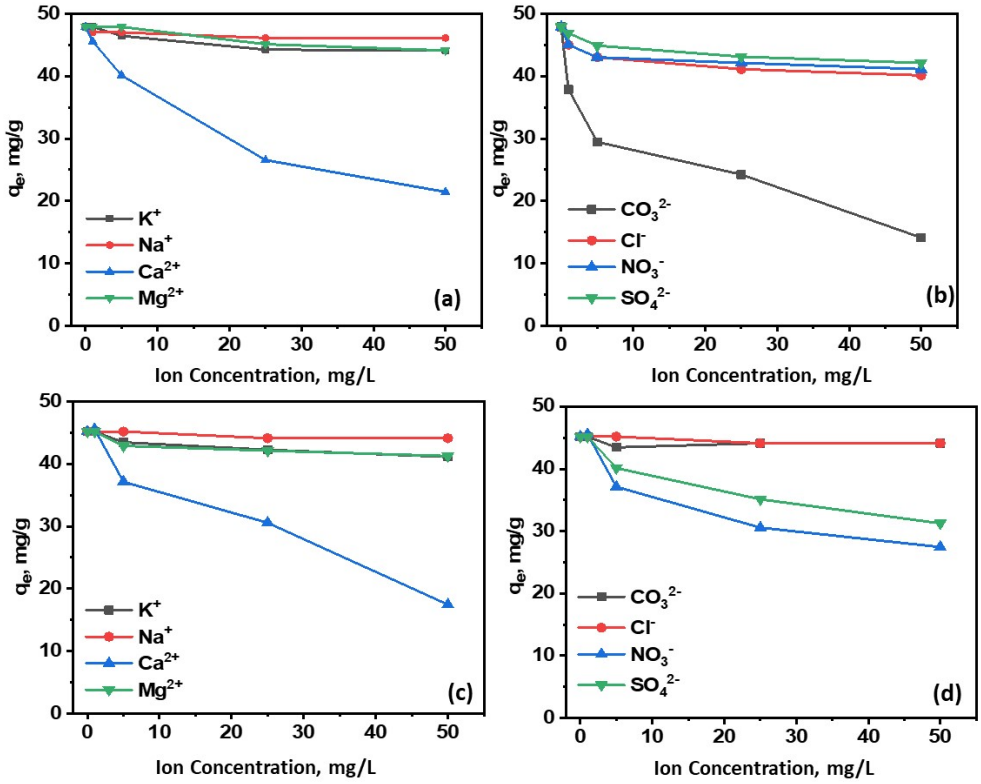

Fig. S2. (a & b) Effect of cation and anion ions effect on U^{6+} and (c & d) Effect of cation and anion ions on Cd^{2+} on LDH/g-C_3N_4 foam.

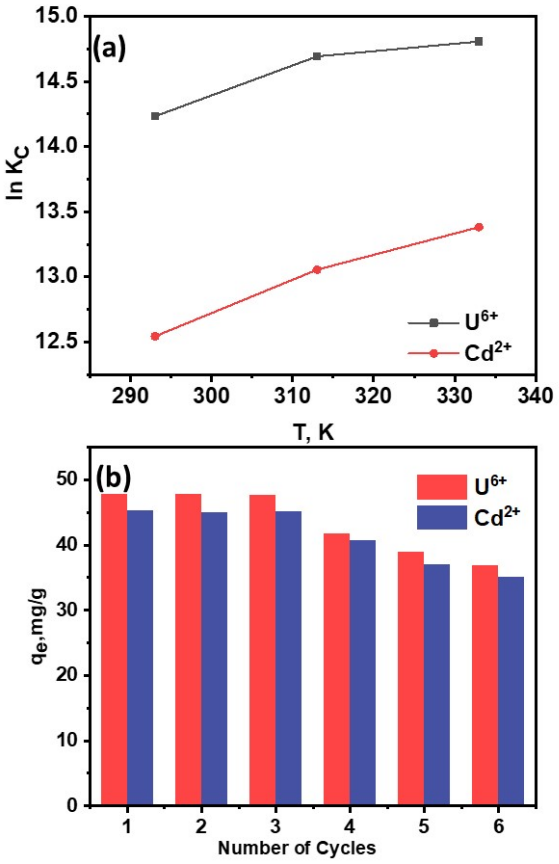

Fig. S3. (a) Plot of lnKc vs. T for the estimation of the thermodynamic and (b) desorption of U^{6+} and Cd^{2+} on the LDH/g-C_3N_4 foam.

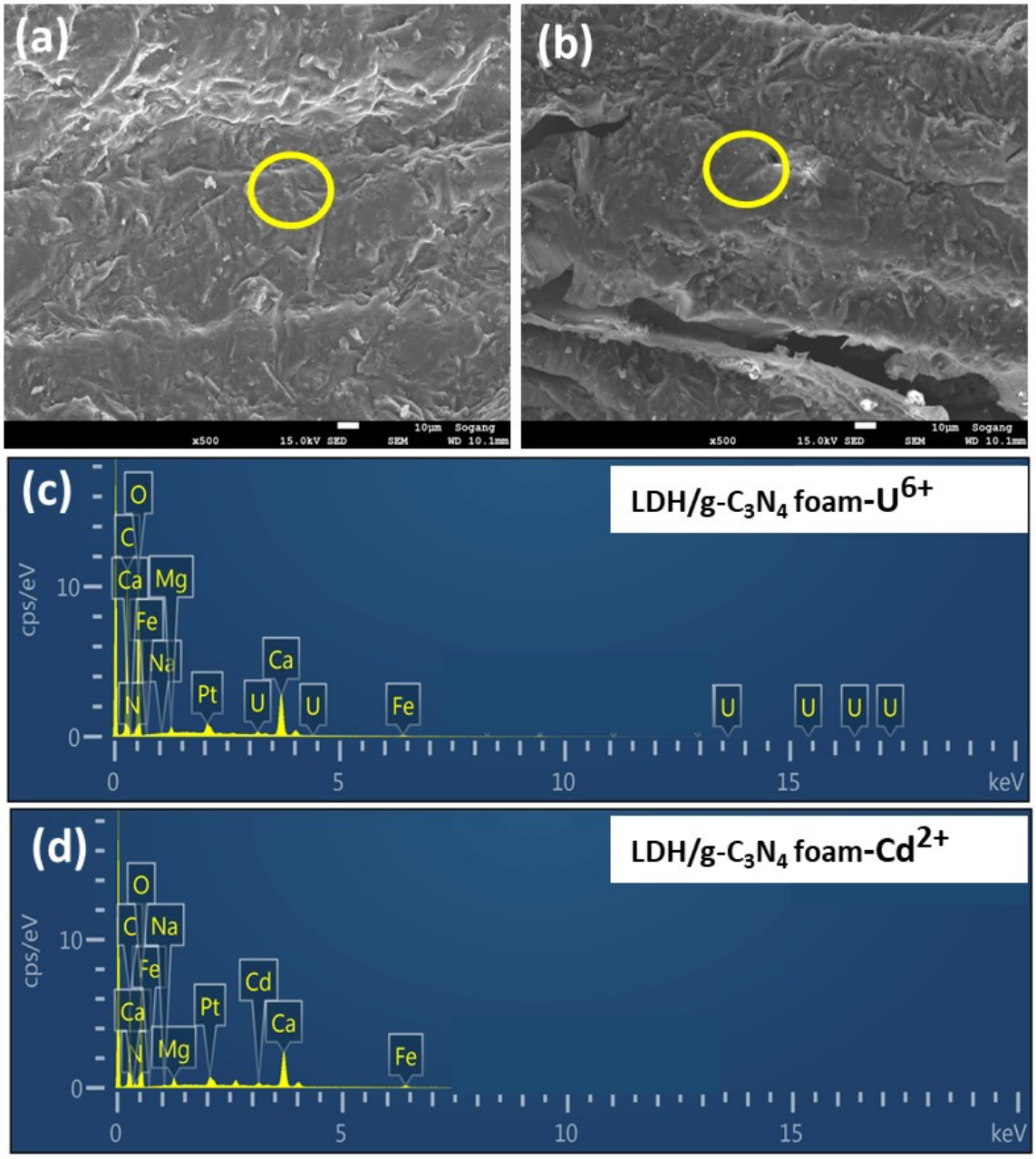

Fig. S4. (a) After adsorption SEM image (a& b), element analysis (c& d) of U^{6+} and Cd^{2+} on the LDH/g-C_3N_4 foam.

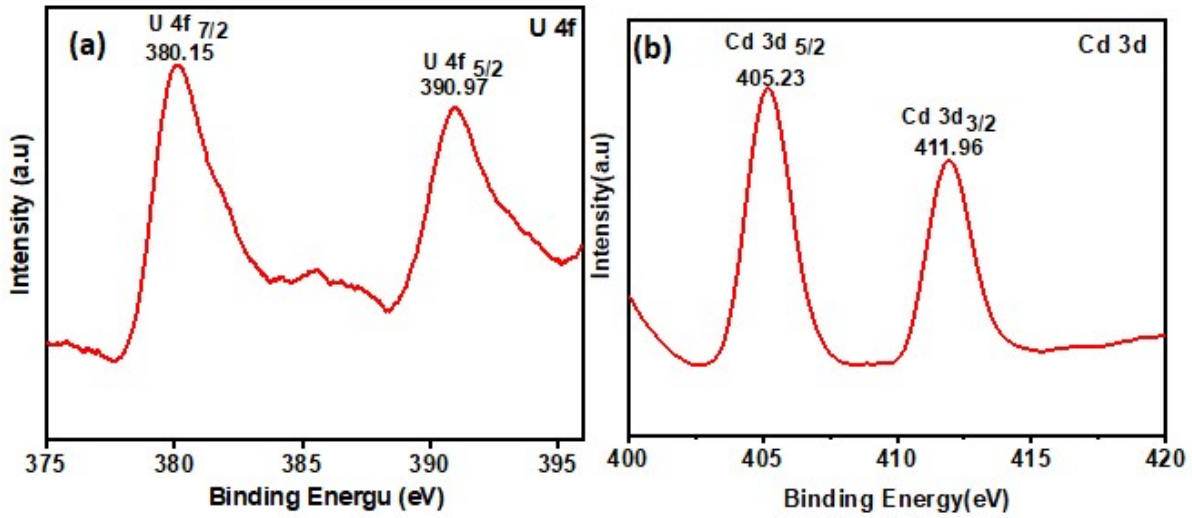

Fig. S5. (a) U^{6+} after adsorption of XPS (a) and (b) Cd^{2+} after adsorption of XPS.

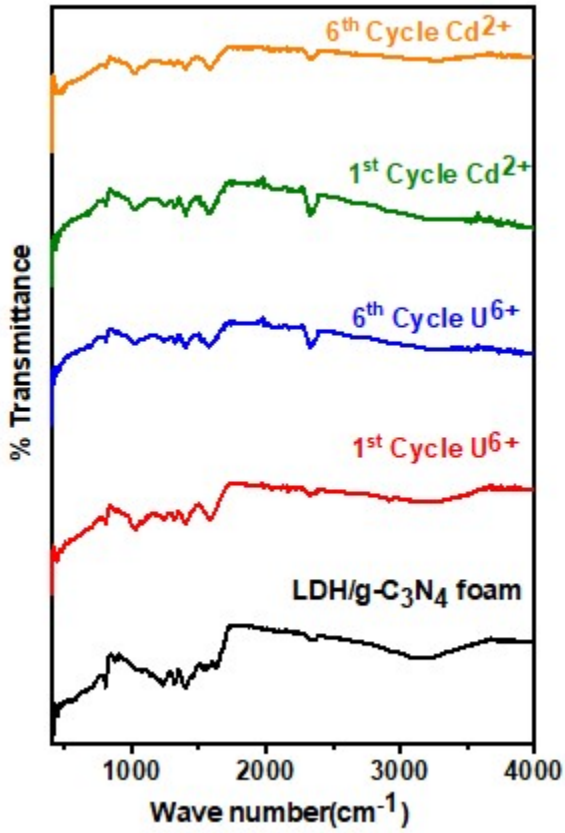

Fig. S6. FT-IR spectrum of recyclability of LDH/GCN foam.

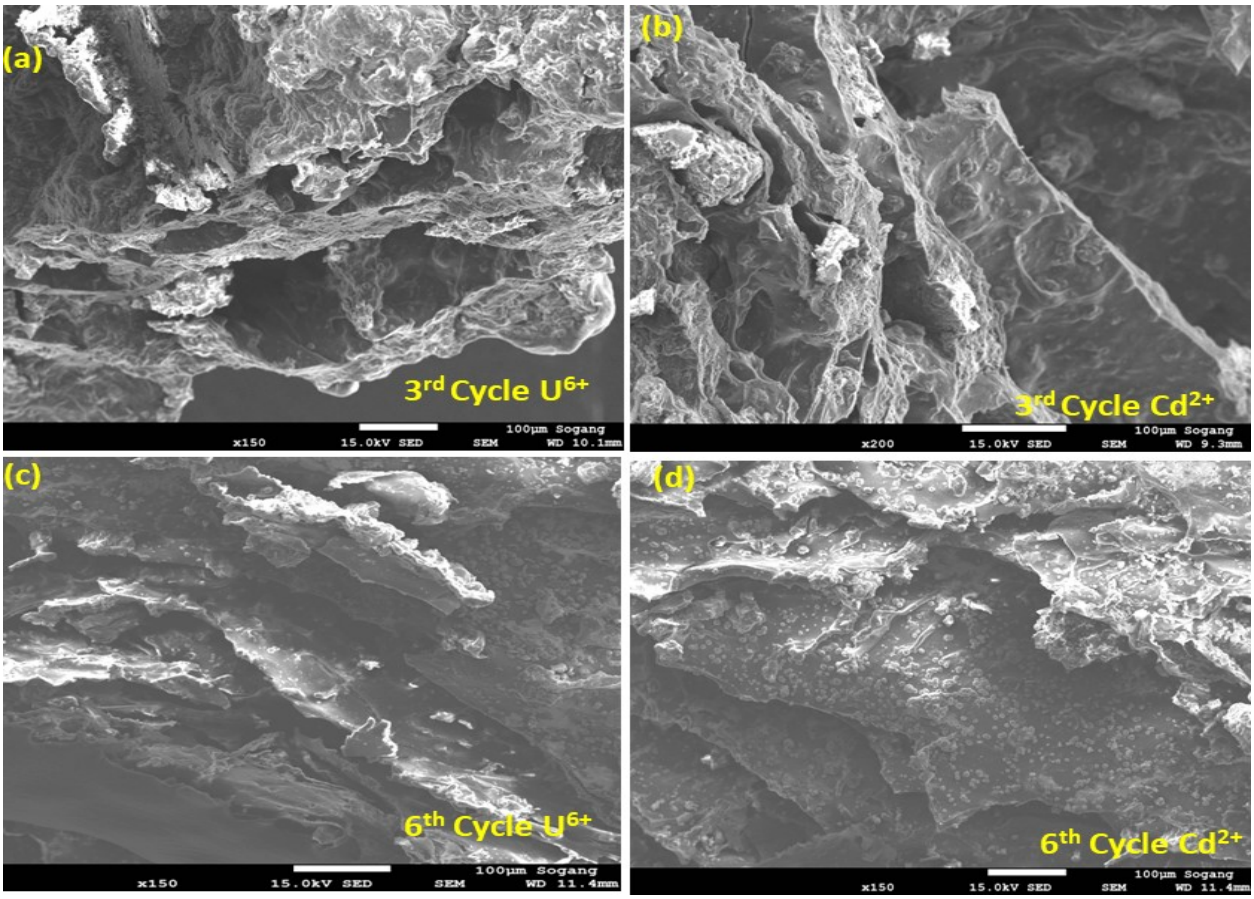

Fig. S7. SEM image of recyclability of LDH/GCN foam.

Table S1: Elements present in the groundwater (pH= 6) collected in year 2020 from the Nakdong mine area (Republic of Korea)

Contaminant	K^+	Ca^{2+}	Na^+	Mg^{2+}	Fe
Conc. (mg/L)	8.943	68.32	8.406	11.47	0.104
Contaminant	Cl^-	SO_4^{2-}	NO_3^-	HCO_3^-	PO_4^{3-}
Conc. (mg/L)	14.1	43.4	14.8	172	NA

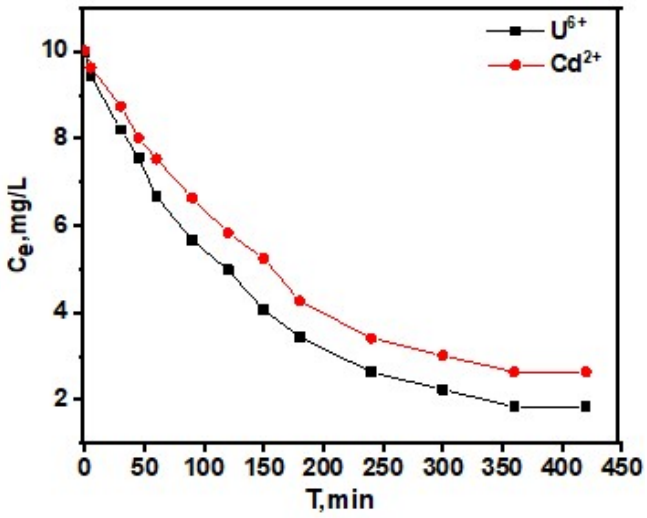

Fig. S8. U^{6+} and Cd^{2+} removal from ground water using LDH/GCN foam.

Table S2: Breakthrough adsorption capacities and model parameters for column adsorption of U^{6+} and Cd^{2+} in synthetic water, for LDH/ g-C_3N_4 foam (V:0.5ml/ min and C_0: 10 mg/L).

Bed Height, cm	Metal ion	**Thomas**		R^2	**Adams-Bohart**		R^2	**Yoon-Nelson**		R^2
		k_{Th} (L/ mg·h	**Q_{th} (mg/ g)**		**k_{ab} (L/ mg ·h)**	**Q_{ab} (mg/cm^3)**		**k_{YN} (h)**	**τ (h)**	
5	U^{6+}	0.065	38.95	0.966	0.019	4.81	0.8 01	0.189	574	0.956
	Cd^{2+}	0.055	21.60	0.950	0.025	3.81	0.875	0.274	393	0.950
10	U^{6+}	0.042	22.06	0.942	0.028	3.47	0.925	0.292	358	0.942
	Cd^{2+}	0.038	16.45	0.945	0.016	2.92	0.983	0.258	175	0.970

Table S3: Breakthrough adsorption capacities and model parameters for column adsorption of U^{6+} and Cd^{2+} in real water system, for LDH/ g-C_3N_4 foam (V:0.5ml/ min, bed heigh:10 cm and 10 mg/L).

Metal ion	**Thomas**		R^2	**Adams-Bohart**		R^2	**Yoon-Nelson**		R^2
	k_{Th} (L/ mg·h	**Q_{th} (mg/ g)**		**k_{ab} (L/ mg ·h)**	**Q_{ab} (mg/cm^3)**		**k_{YN} (h)**	**τ (h)**	
U^{6+}	0.032	12.56	0.971	0.011	2.24	0.812	0.201	246	0.956
Cd^{2+}	0.055	8.25	0.964	0.020	1.98	0.823	0.184	156	0.950