CuO@Pyridine Composite for Efficient Removal of Malachite Green and Cd(II) from Water: Adsorption Performance and Mechanistic Insights

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Supplementary data

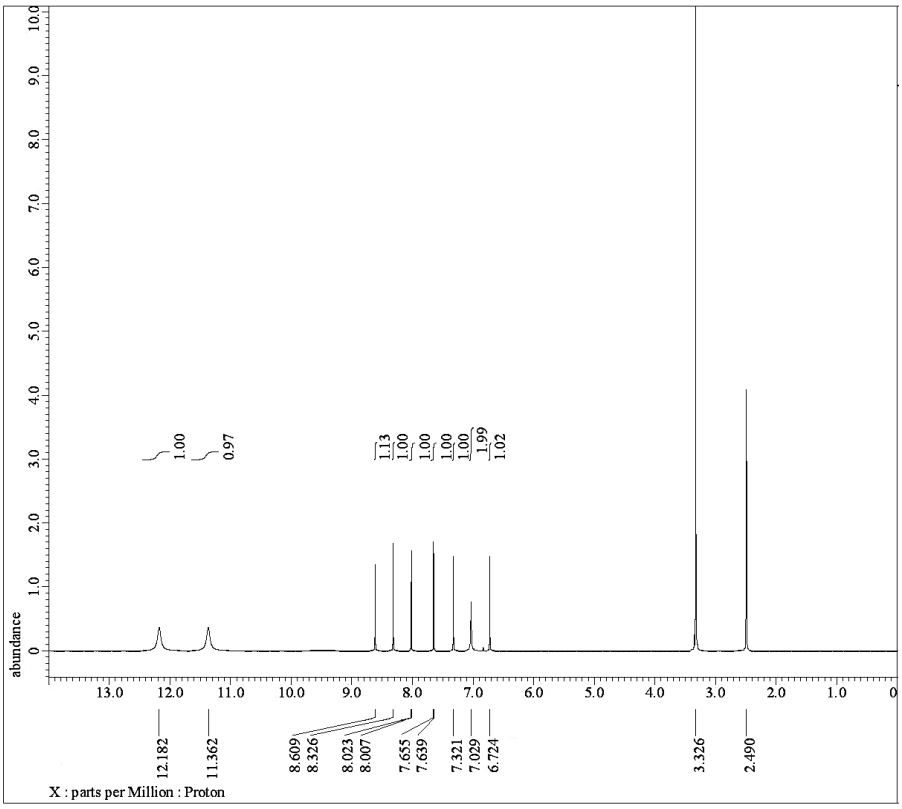


Figure S1. ^{1}H NMR spectrum of Sorbent **Pyridine PC**.

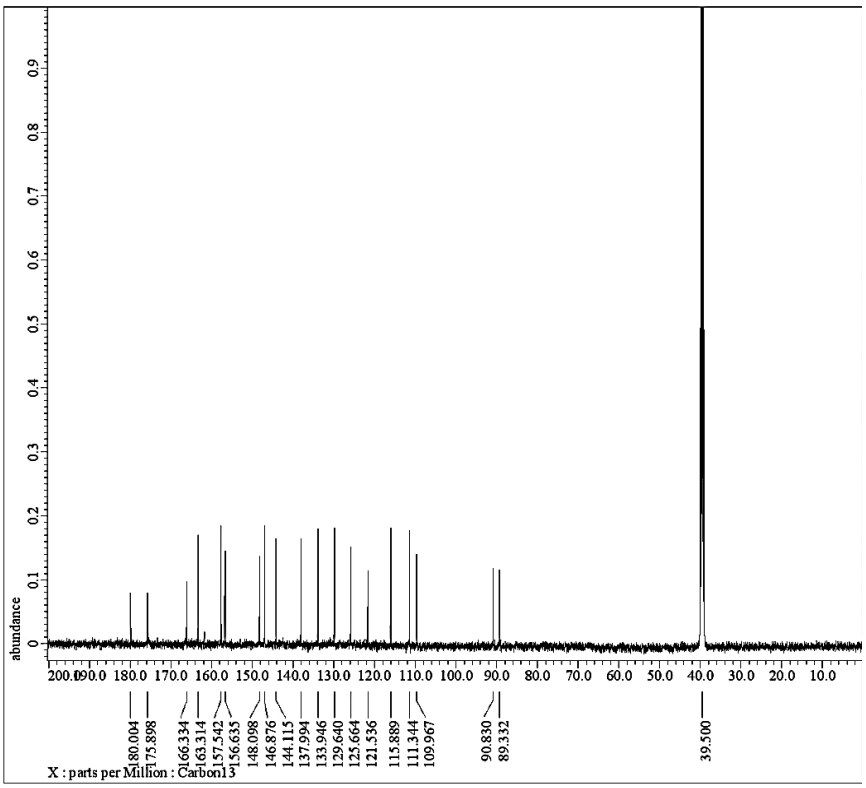


Figure S2. ^{13}C NMR spectrum of Sorbent **Pyridine PC**.

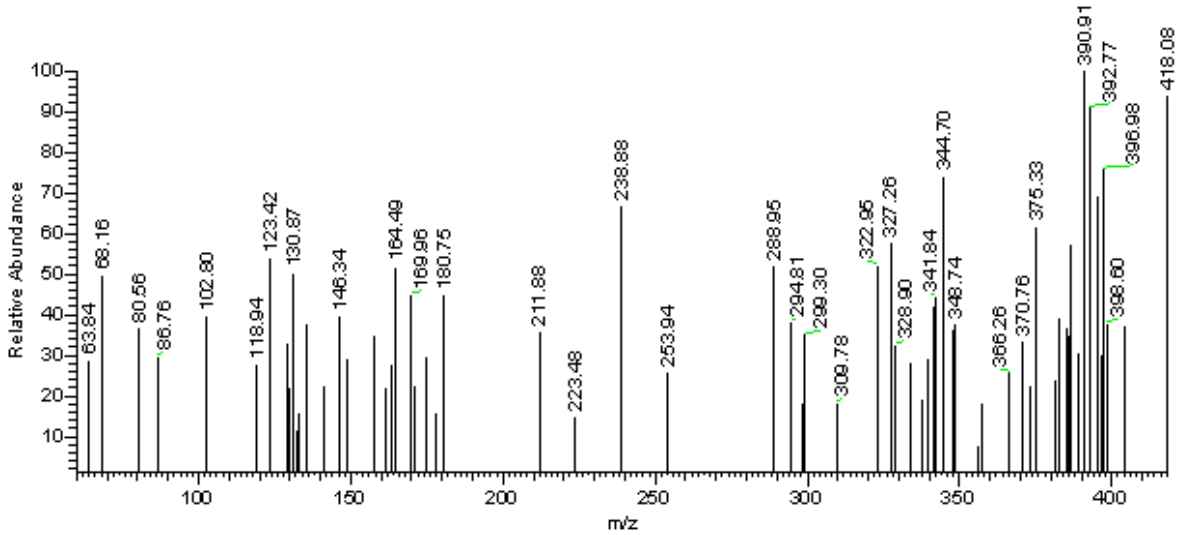


Figure S3. Mass spectrum of Sorbent **Pyridine PC**.

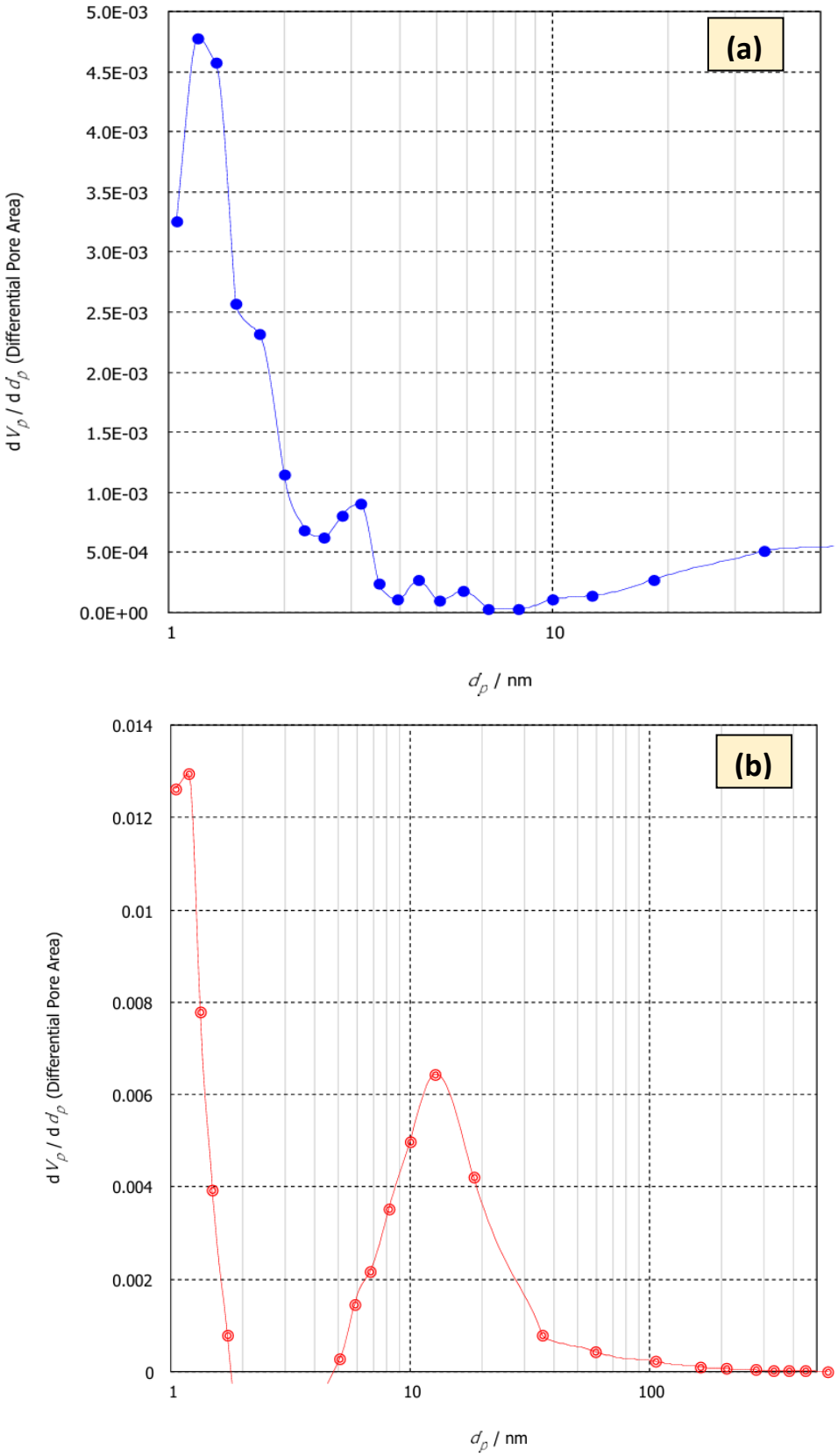


Figure S4. Pore size distribution curves of (**a**) **Pyridine-PC** and (**b**) **CuO@Pyridine-PC** derived from nitrogen adsorption–desorption analysis.

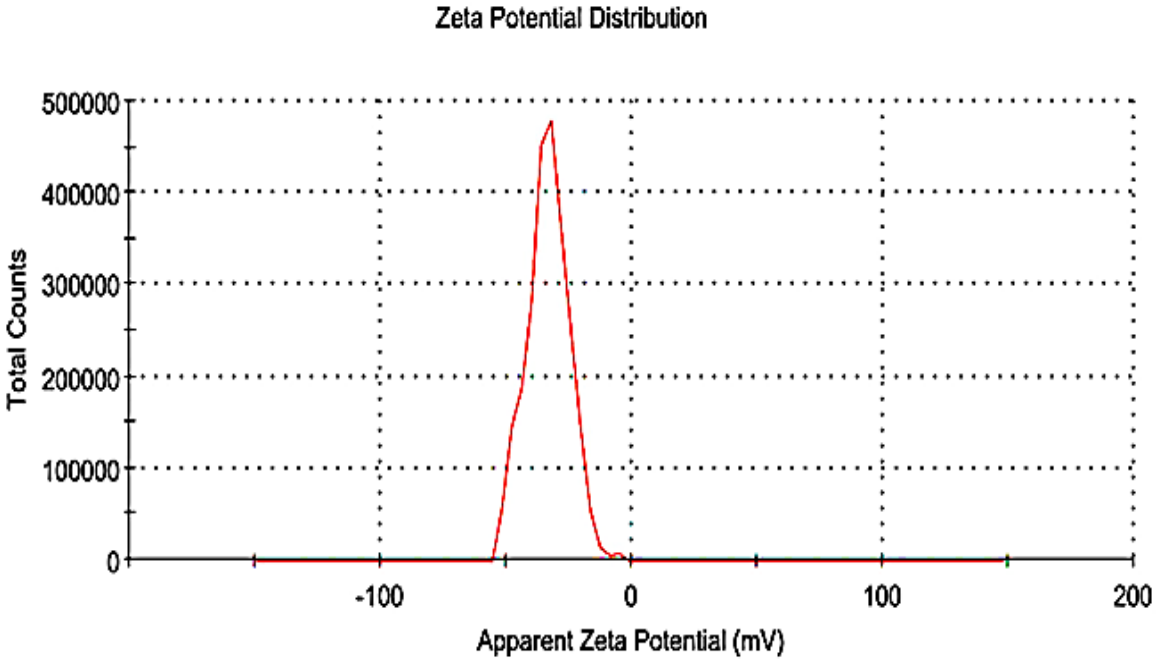


Figure S5. Zeta potential profile of **CuO@Pyridine PC** composite.

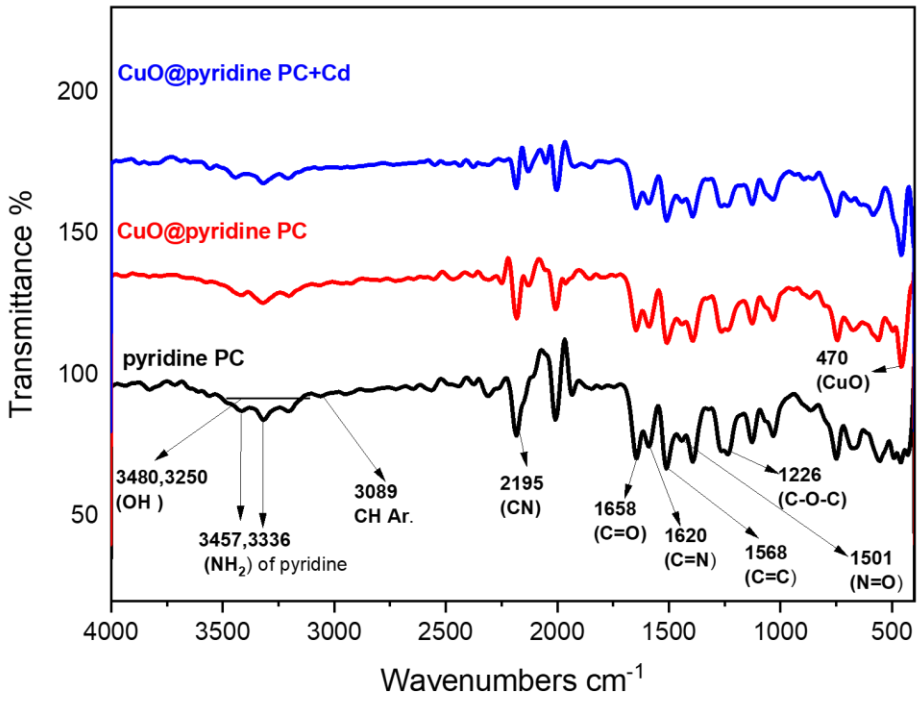
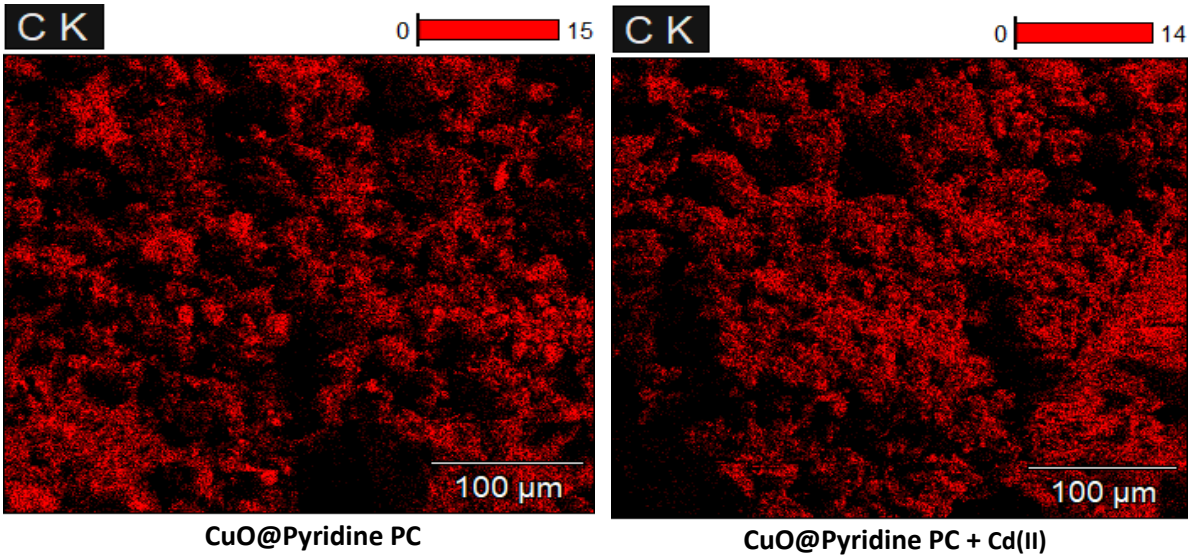


Figure S6. Comparative FT-IR spectra of Pyridine PC and CuO@Pyridine PC before and after five adsorption–desorption cycles.



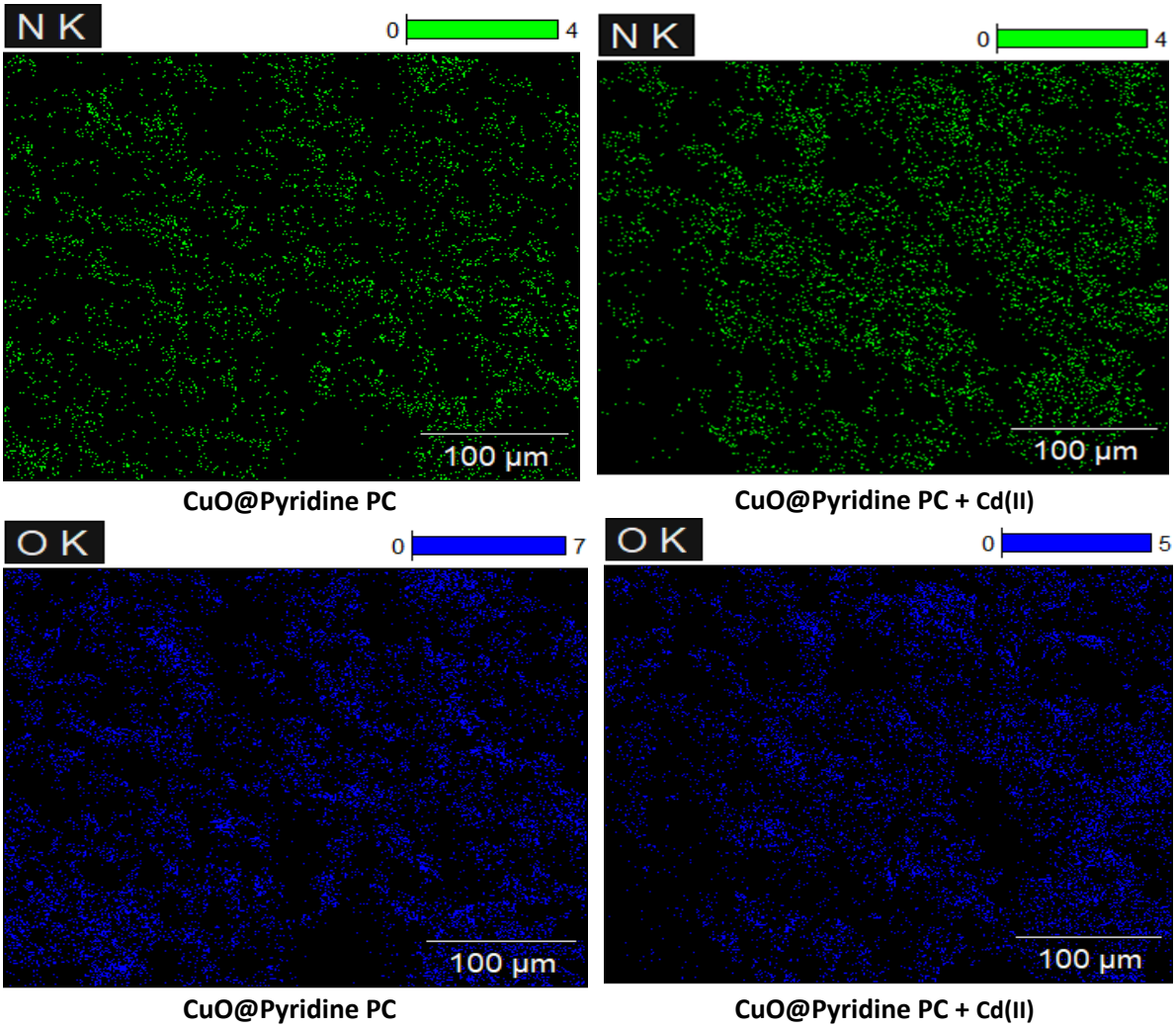


Figure S7. EDX elemental mapping of C, N, and O in **CuO@Pyridine PC** Before and after adsorption of Cd(II). Scale bar: 100 µm.

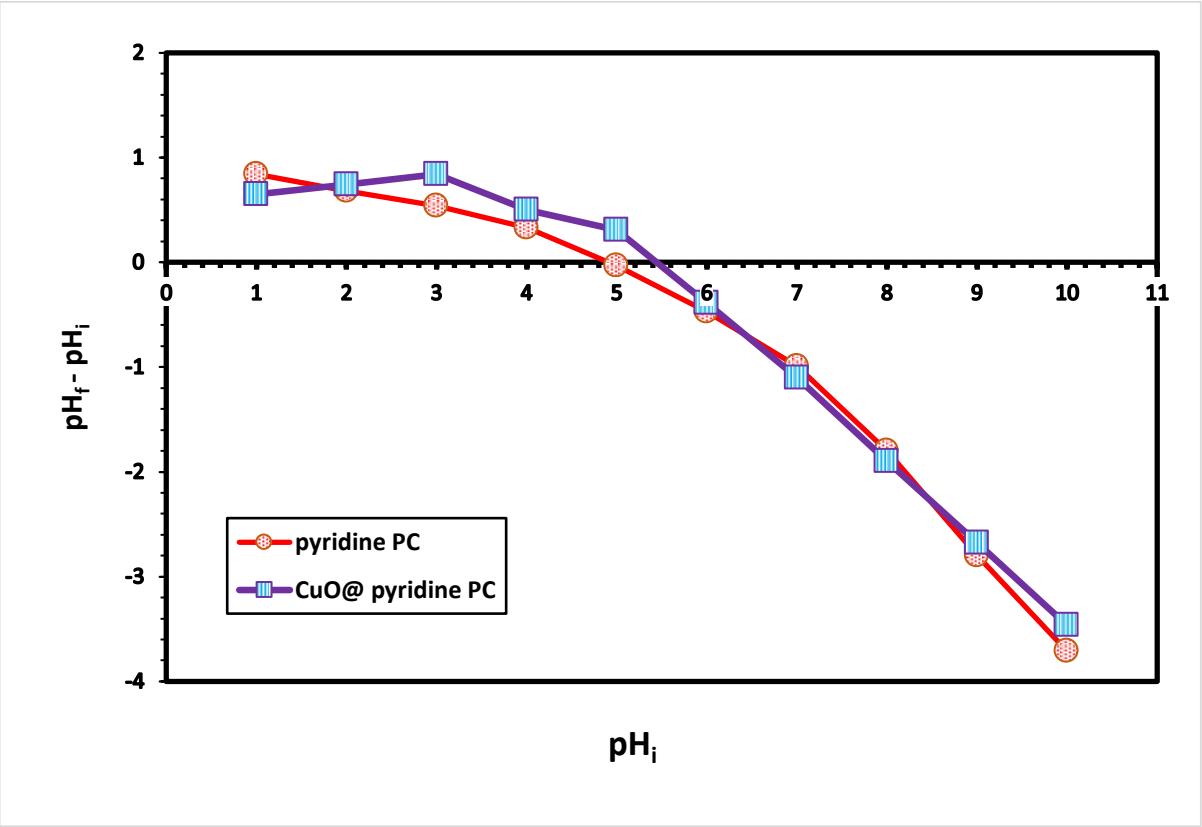


Figure S8. Determination of pH_{PZC} for by **Pyridine PC** and **CuO@Pyridine PC** composite. (SD: 2 g L−1; Background salt: NaCl (0.1 M); agitation time: 24 h; agitation speed: 200 rpm; T: 25 °C).

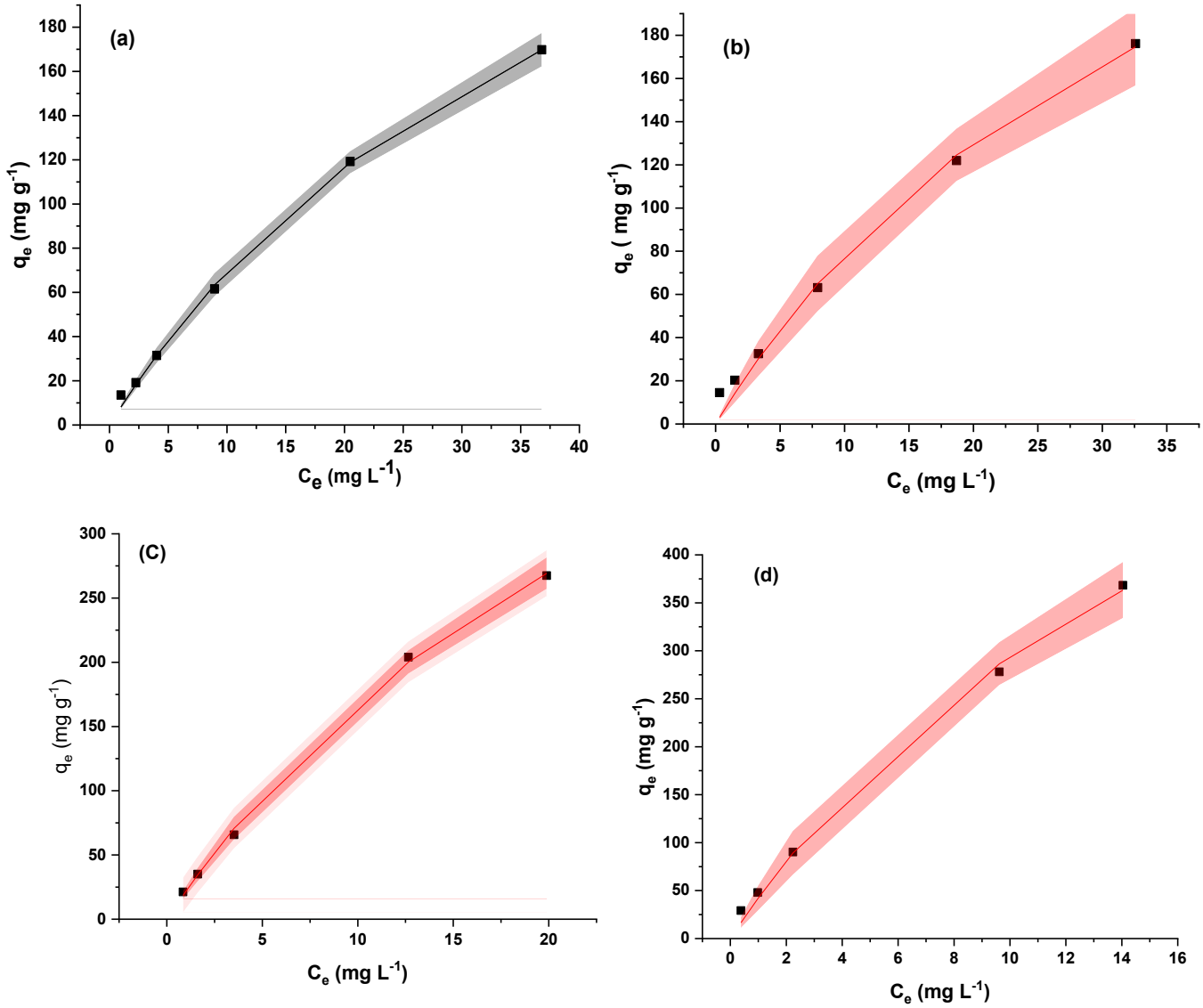


Figure S9. Nonlinear Langmuir isotherm fitting for MG and Cd(II) adsorption **Pyridine PC** and **CuO@Pyridine PC**. (**a**) Pyridine PC–MG, (**b**) CuO@Pyridine PC–MG, (**c**) Pyridine PC–Cd(II), (**d**) CuO@Pyridine PC–Cd(II).

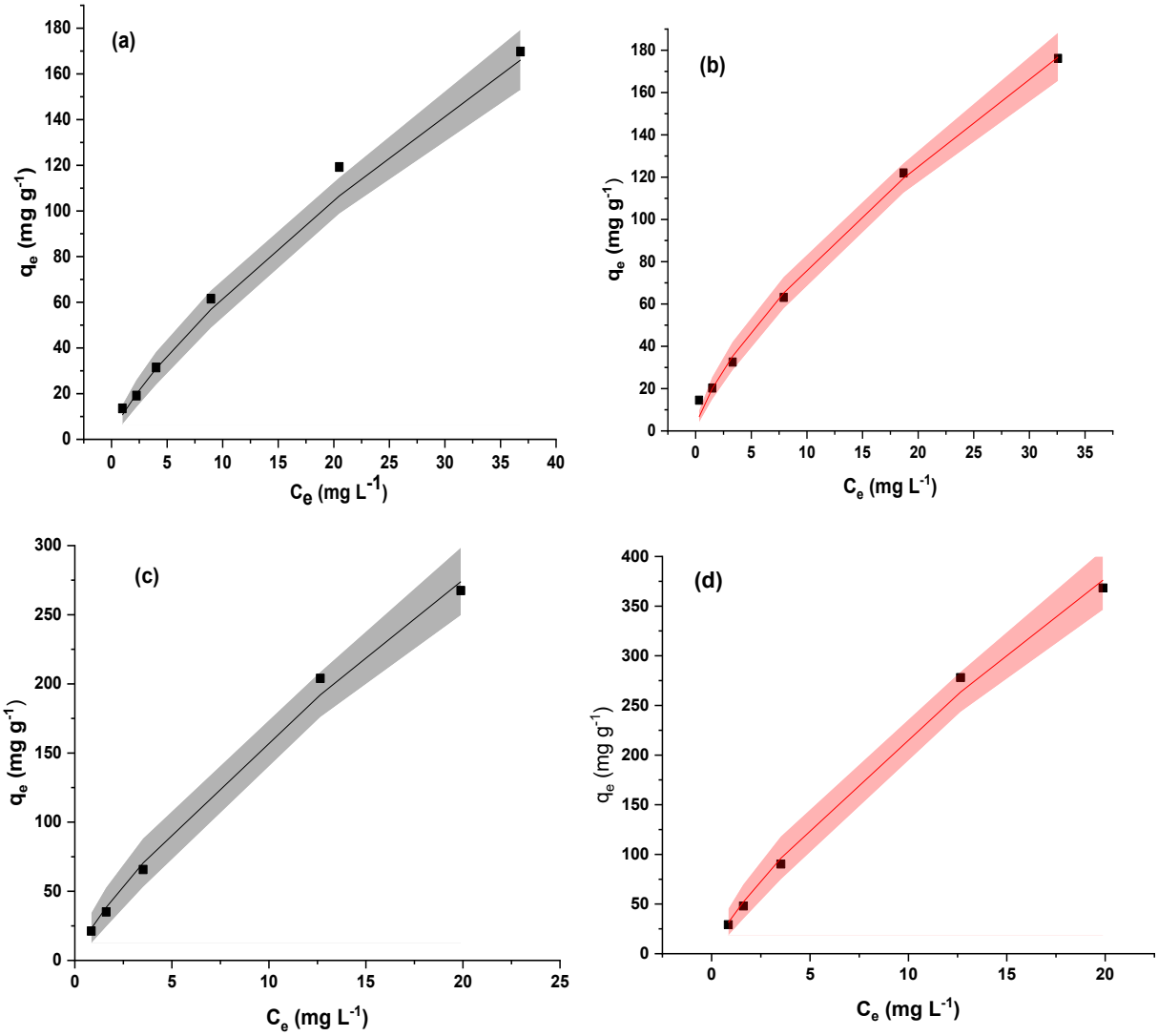


Figure S10. Nonlinear Freundlich isotherm fitting for MG and Cd(II) adsorption **Pyridine PC** and **CuO@Pyridine PC**. (**a**) Pyridine PC–MG, (**b**) CuO@Pyridine PC–, (**c**) Pyridine PC–Cd(II), (**d**) CuO@Pyridine PC–Cd(II).

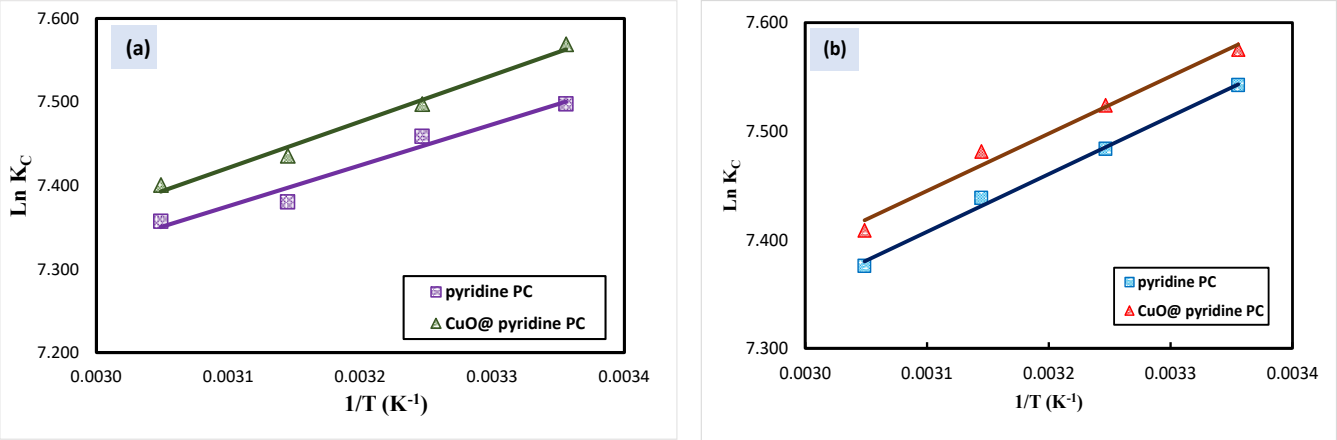


Figure S11. Van't Hoff plots for (**a**) MG dye and (**b**) Cd^{2+} adsorption on **Pyridine PC** and **CuO@Pyridine PC**.

Table S1. Kinetic, isotherm, and thermodynamics equations for MG dye and Cd(II) adsorption process.

Kinetics	**Equations**
Pseudo-first-order	$\log(q_e - q_t) = log\, q_e - \left(\frac{K_1}{2.303}\right)\mathrm{t}$
Pseudo-second-order	$\frac{t}{q_t} = \frac{1}{K_2\, q_e^2} + \frac{1}{q_e}\,\mathrm{t}$
Isotherms	**Equations**
Langmuir model	$\frac{\mathbf{C_e}}{\mathbf{q_e}} = \frac{\mathbf{C_e}}{\mathbf{q_{max}}} + \frac{\mathbf{1}}{\mathbf{q_{max}\, K_L}}$
Freundlich model	$\mathbf{\log(q_e) = \log K_f + \frac{1}{n} \log C_e}$
Temkin model	$q_e = \frac{RT}{b_T} ln\, K_T C_e$
Thermodynamics	**Equations**
$\boldsymbol{\ln K = \frac{-\Delta H^o}{RT} + \frac{\Delta S^o}{R}}$	
$\boldsymbol{\Delta G = \Delta H - T\Delta S}$	