Supplementary Material S2 Batch adsorption experiments:

S2.1 Isothermal kinetic testing:

Weigh 0.02g each of LMO, CLMO, and CaO-LMO and place them in 50mL conical flasks. Add 50 mL of phytic acid solution with pH values of 3, 7, and 10, using hydrochloric acid and sodium hydroxide, with concentrations ranging from 5 to 300 mg/L. Sample at intervals of 0 to 2,880 min. Shake at 25°C and 180 rpm on a shaker. Filter the supernatant through a 0.45 µm pore size membrane and measure the phosphorus concentration using the ammonium molybdate spectrophotometric method, repeating the experiment three times. Fit the experimental data to Langmuir (S2-1), Freundlich (S2-2), and Dubinin-Radushkevich (D-R) (S2-3) isothermal adsorption equations, and to pseudo-first-order (S2-6), pseudo-second-order (S2-7), and intraparticle diffusion models (S2-8) for kinetic analysis.

Langmuir Isothermal Adsorption Equation: $q_e = q_m \frac{K_L C_e}{1+K_L C_e}$ (S2-1)

Freundlich Isothermal Adsorption Equation: $q_e = K_F {C_e}^{\frac{1}{n}}$ (S2-2)

Where (K_L) (L/mg P) is the Langmuir adsorption equilibrium constant; (K_F) (mg $^{(1\text{-}n)}$) L^n/g) and n are the adsorption intensity parameter and dimensionless linear constant of Freundlich; q_e represents the equilibrium adsorption capacity (mg P/g); q_m is the maximum adsorption capacity (mg P/g); C_e is the equilibrium concentration of phosphate in the solution (mg P/L).

Dubinin-Radushkevich (D-R) Adsorption Equation: $ln\,(q_e) = ln\,(q_{\mathrm{DR}}) - K_{\mathrm{DR}}\varepsilon^2$ (S2-3)

Polanyi Potential (ε) Formula: $\varepsilon = \mathrm{RTln}(1+ 1/C_e)$ (S2-4)

Average Adsorption Free Energy Formula: $E = (2K_{\mathrm{DR}})^{-0.5}$ (S2-5)

Where q_e (mmol/g) is the equilibrium adsorption amount on the adsorbent; q_{DR} (mmol/g) and K_{DR} (mol^2/kJ^2) are the D-R isotherm constants related to adsorption capacity and average adsorption free energy; ε (kJ^2/mol^2) is the Polanyi potential, ε = RTln(1+1/C_e); C_e (mol/L) is the equilibrium concentration of the adsorbate in the solution; R is the universal constant 8.314×10^{-3} kJ/(mol K); K (K) is the absolute temperature.

Pseudo-First-Order Kinetic Equation: $q_t = q_e(1 - e^{-k_1 t})$ (S2-6)

Pseudo-Second-Order Kinetic Equation: $\frac{t}{q_t} = \frac{1}{k_2 {q_e}^2} + \frac{1}{q_e} t$ (S2-7)

Intraparticle Diffusion (Weber-Morris) Equation: $q_t = K_d t^{\frac{1}{2}} + I$ (S2-8)

Where q_t (mg P/g) is the adsorption amount of phosphorus at time t; q_e (mg P/g) is the adsorption amount of phosphorus at equilibrium; k_1 (/min) is the adsorption rate constant of the pseudo-first-order equation; k_2 (g/mg P/min) is the adsorption rate constant of the pseudo-second-order equation. K_d (mg/g ($h^{-1/2}$)) is the rate constant of the diffusion model, and I (mg/g) is the constant corresponding to the boundary layer thickness.

S2.2 Impact factor experimentation:

Weigh 0.02 g of the material into a conical flask and add 50 mL of a phytic acid solution with an initial concentration of 100 mg/L. Adjust the pH of the solution to 2−12 using hydrochloric acid and sodium hydroxide to investigate the effect of different pH levels on the adsorption performance of phytic acid. Addition of NaCl (Cl^-), Na_2SO_4 (SO_4^{2-}), $NaNO_3$ (NO_3^-), Na_2CO_3 (CO_3^{2-}), and NH_4Cl (NH_4^+) at varying concentration gradients, with the solution pH adjusted to 7 using HCl and NaOH and various concentration gradients (0, 5, 35, 70, 140, 210, 280, and 350 mg/L), we examine the impact of common coexisting ions in actual water bodies on the adsorption performance of the material for phosphate. The experimental details remain consistent with the previous setup, and the experiment is repeated three times.