

Circular Waste Valorization: Humic Acid Adsorption onto ZnS Nanoparticle-Loaded Biomass and Conversion into Nutrient-Rich Alginate Beads

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Supplemental file

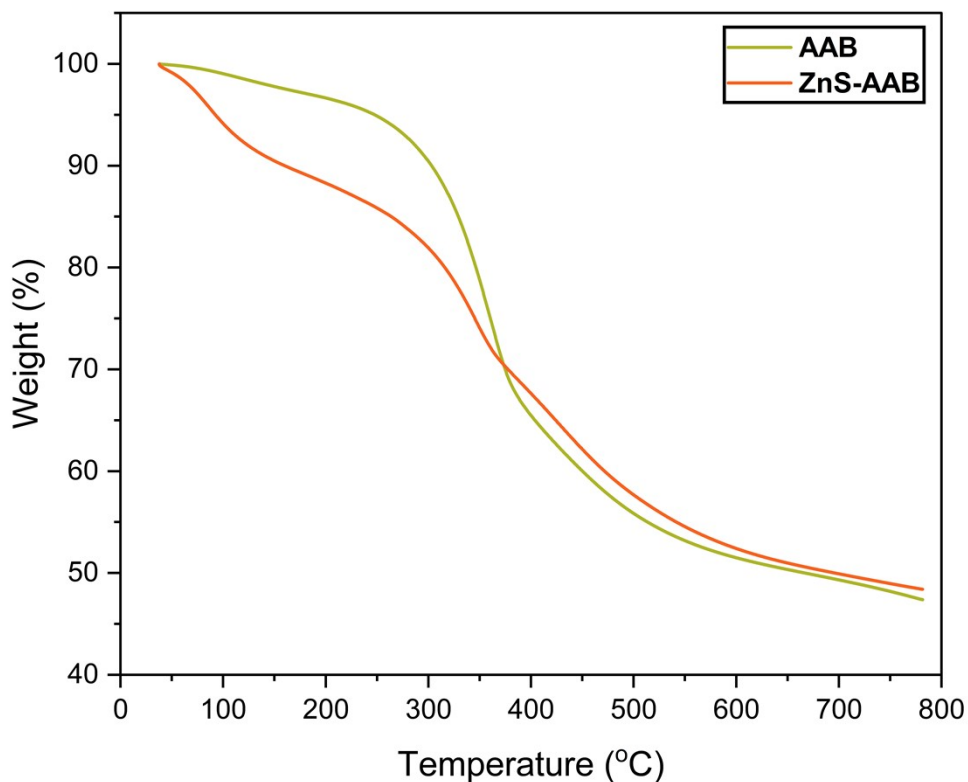
Figures

From the TGA Graph:

Biomass residue $R_b = 47.4\%$

ZnS–biomass residue $R_c = 48.4\%$

$$\text{ZnS wt\%} = \frac{R_b - R_c}{100 - R_b} \times 100$$



$$= \frac{48.4 - 47.4}{100 - 47.4} \times 100 = \frac{1.0}{52.6} \times 100 = 1.9\%$$

Fig.S1 TGA analysis of ZnS loading onto the acid activated biomass

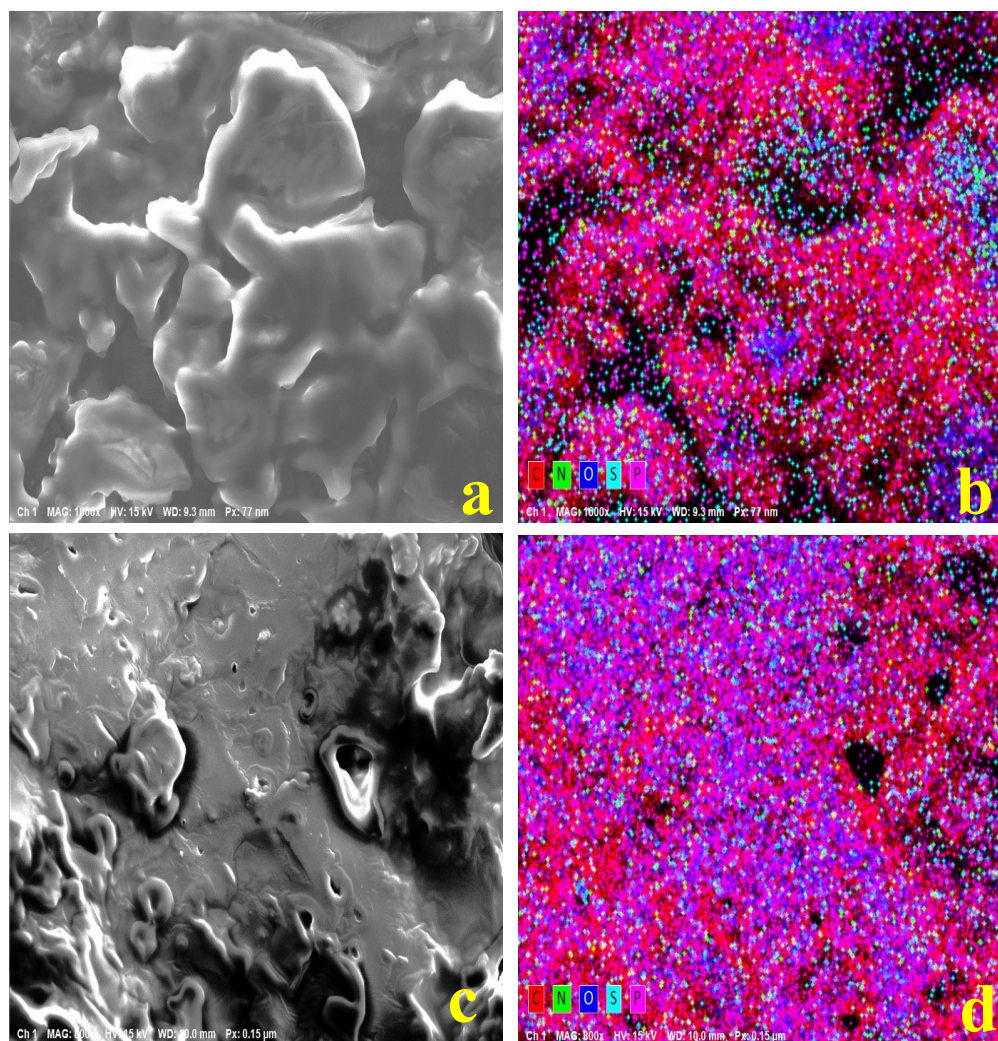


Fig. S2 EDX with elemental mapping of (a) and (b) pristine biomass, (c) and (d) AAB

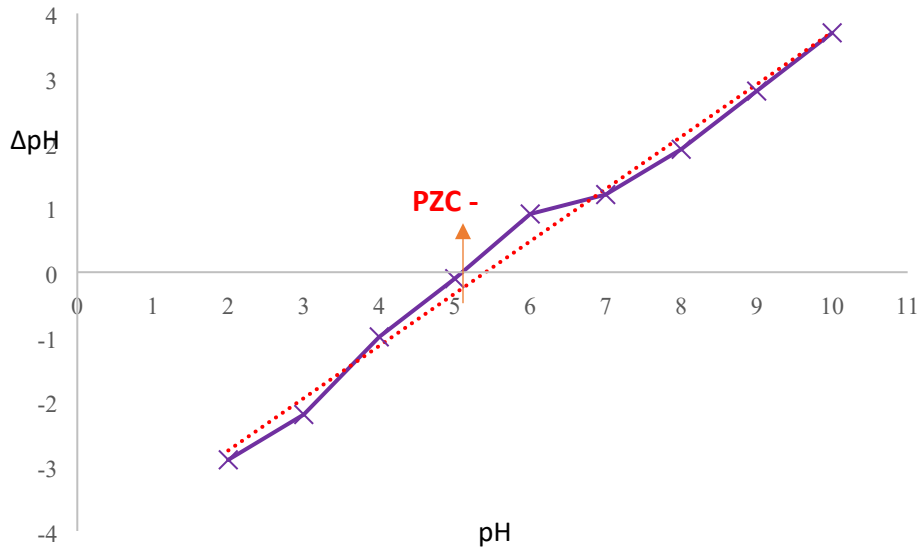
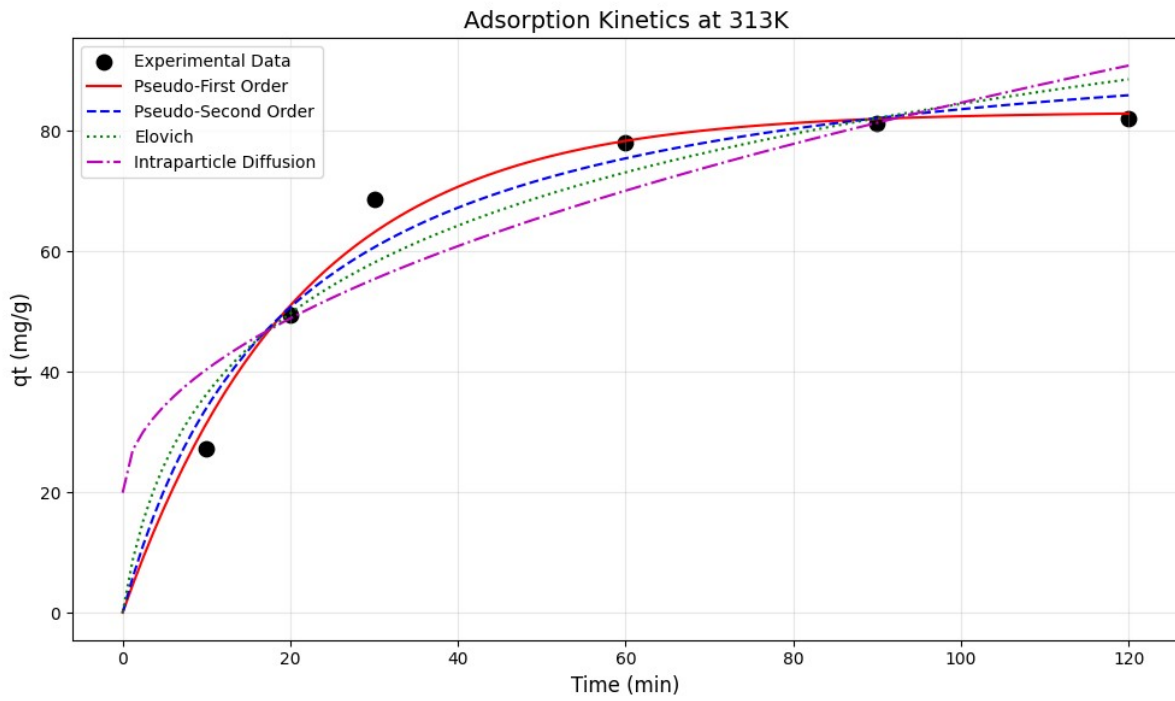


Fig. S3 Point Zero Charge of ZnS-AAB



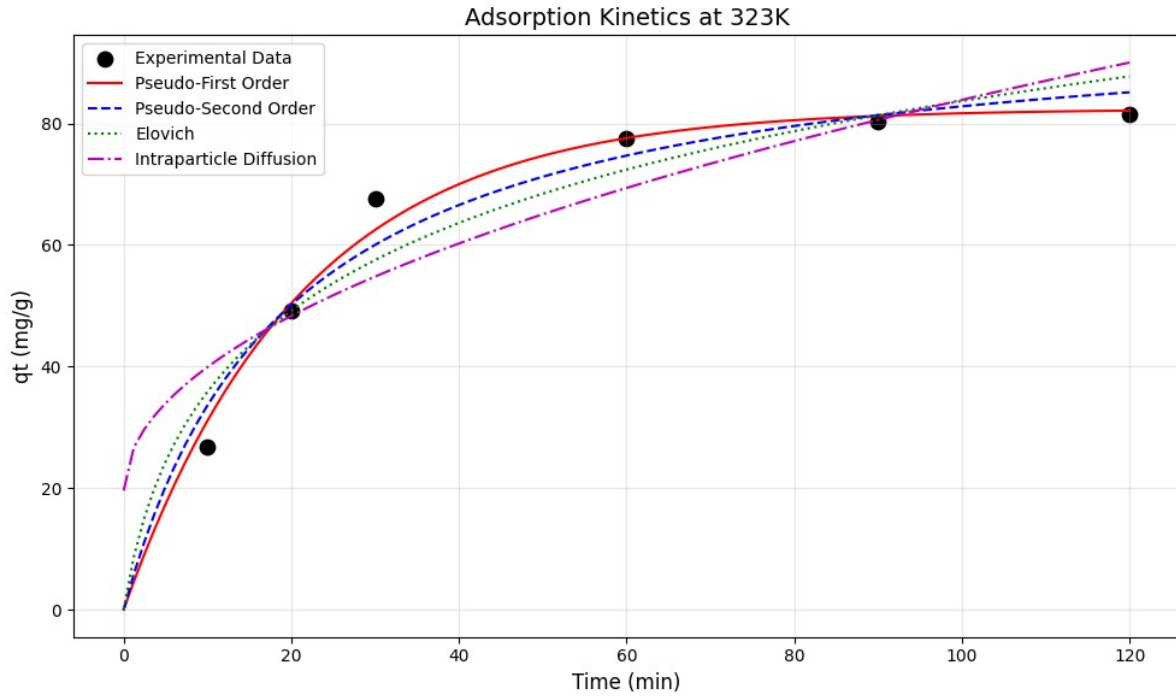


Fig.S4 Kinetic plots obtained for the removal of HA by ZnS-AAB at 313 and 323 K

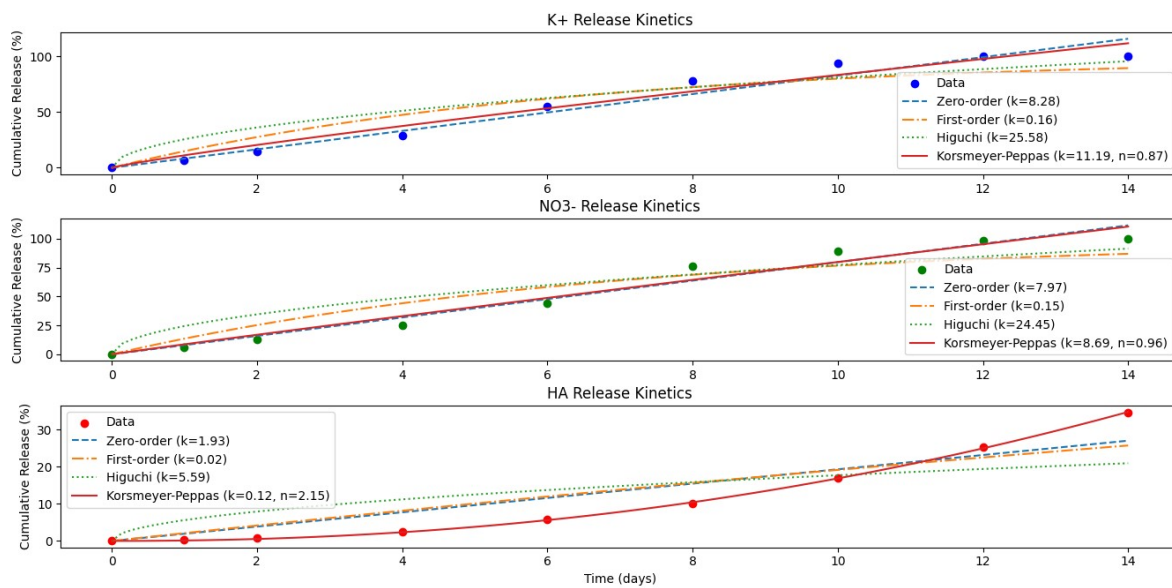


Fig. S5 Kinetic plots obtained for the nutrients release from HA loaded ZnS-AAB alginate composite beads

Table S1 Dimensionless separation factor (R_L) for various concentrations of HA

Initial Concentration	R_L Values
50	0.465116
100	0.30303
150	0.224719
200	0.178571
250	0.148148
300	0.126582

Table-S2 Kinetic constants obtained for the removal of HA by ZnS-AAB at 313K (Concentration 50 mg L⁻¹)

Model	Constants	Value	RMSE	AARE (%)
Pseudo first order	q_e (mg g ⁻¹)	82.8	3.45	4.38
	k_1 (min ⁻¹)	0.047		
	R^2	0.983		
Pseudo second order	q_e (mg g ⁻¹)	84.5	1.12	1.45
	k_2 (mg.g ⁻¹ min ⁻¹)	0.0013		
	R^2	0.997		
Elovich	α (mg. (g.min) ⁻¹)	2.52	2.45	3.12
	β (g mg ⁻¹)	0.085		
	R^2	0.991		
Intraparticle	k_{id} (mg. (g.min ^{0.5}) ⁻¹)	6.28	5.89	7.78
	C (mg g ⁻¹)	17.8		
	R^2	0.931		

Table-S3 Kinetic constants obtained for the removal of HA by ZnS-AAB at 323K
(Concentration 50 mg L⁻¹)

Model	Constants	Value	RMSE	AARE (%)
Pseudo first order	q_e (mg g ⁻¹)	82.1	3.67	4.72
	k_1 (min ⁻¹)	0.049		
	R^2	0.981		
Pseudo second order	q_e (mg g ⁻¹)	83.9	1.28	1.67
	k_2 (mg.g ⁻¹ min ⁻¹)	0.0014		
	R^2	0.996		
Elovich	α (mg. (g.min) ⁻¹)	2.61	2.67	3.45
	β (g mg ⁻¹)	0.082		
	R^2	0.989		
Intraparticle	k_{id} (mg. (g.min ^{0.5}) ⁻¹)	6.15	6.12	8.23
	C (mg g ⁻¹)	17.3		
	R^2	0.927		