Adsorption of phosphate from aqueous solution using hydrochar produced from agricultural wastes

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Figure S1: Column apparatus set-up

Breakthrough curve

Breakthrough curve is the representation of the pollutant-effluent concentration (Ct/C0) versus time in a fixed-bed column **(Figure S2)**. The solution of known adsorbate concentration is passed through the fixed-bed of adsorbent and the concentration of the effluent is monitored continuously at predetermined time interval until the inlet concentration is equal to the outlet concentration. Breakthrough is taken at the point when outlet P concentration reaches 5% of the influent concentration while saturation or exhaustion is the point where the outlet P concentration is nearly equal to the influent concentration [1]. The breakthrough curve and the shape obtained by plotting the experimental values are used to investigate the dynamic response of the column adsorption [2,3]. The longer the time taken to reach the break point and the exhaust

point better is the performance of the adsorbent [4]. In evaluating the performance of continuous fixed-bed column adsorption, parameters such as adsorbent dose and pollutant inlet concentration play an important role [4–6].
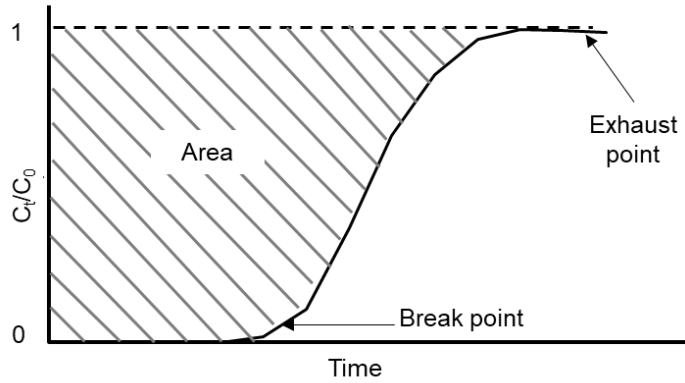

Figure S 2: Breakthrough Curve

The total mass of P retained in the column q_{total} (mg), at a given concentration for a constant flow rate (Q) can be calculated from the area under the breakthrough curve, using the Equation 1:

$$q_{total} = \frac{Q}{1000} \int_{t=0}^{t=total} C_{ad}\, dt \qquad (ES1)$$

The integral represents the area under the curve $C_{ad} = C_0 - C_t$ versus time from the start of the experiment up to the exhaust point. C0 (mg/L) is the initial concentration of P in the influent solution, C_t (mg/L) is the concentration of P in the effluent at time t (min). This area quantifies the total amount of P removed from the influent solution and retained by the adsorbent in the column [6,7].

The adsorption capacity q_e (mg P/g) is defined as the total amount of P adsorbed q_{total} (mg) per mass of the adsorbent m (g) and is calculated using Equation 2:

$$q_e = \frac{q_{total}}{m} \qquad (ES2)$$

Table S 1: Column study experimental design

Feedstock Mix DM:CS:ES	Adsorbent Dose (g)	Initial P Concentration (mg/L)
1:0:1	0.5	25
	0.5	50
	1	25
	1	50
2:0:1	0.5	25
	0.5	50
	1	25
	1	50
1:1:1	0.5	25
	0.5	50
	1	25
	1	50
2:1:1	0.5	25
	0.5	50
	1	25
	1	50

Table S 2: Physical properties of feedstocks and their mixes

Feedstock mix DM:CS:ES	Ash (%)	Moisture content (%)
DM only (1:0:0)	14.17	87.45
CS only (0:1:0)	6.06	10.82
ES only (0:0:1)	93.73	0.75
1:1:0	10.12	49.14
2:1:0	11.47	61.91
1:0:1	53.95	44.10
2:0:1	40.69	58.55
1:1:1	37.99	33.01
2:1:1	28.99	17.88

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