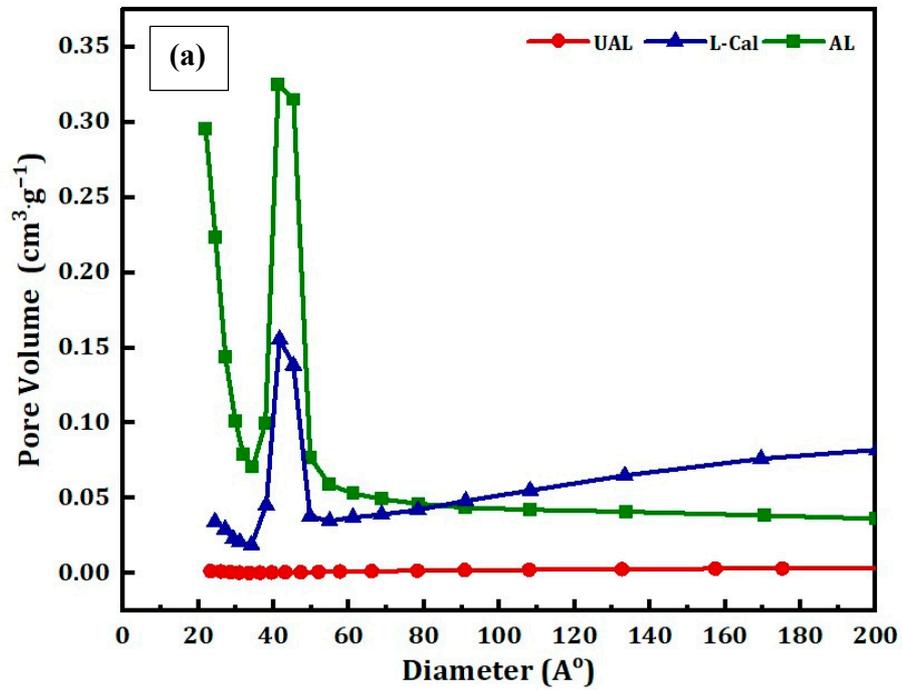


Figure S1: Experimental determination of pHPzc.



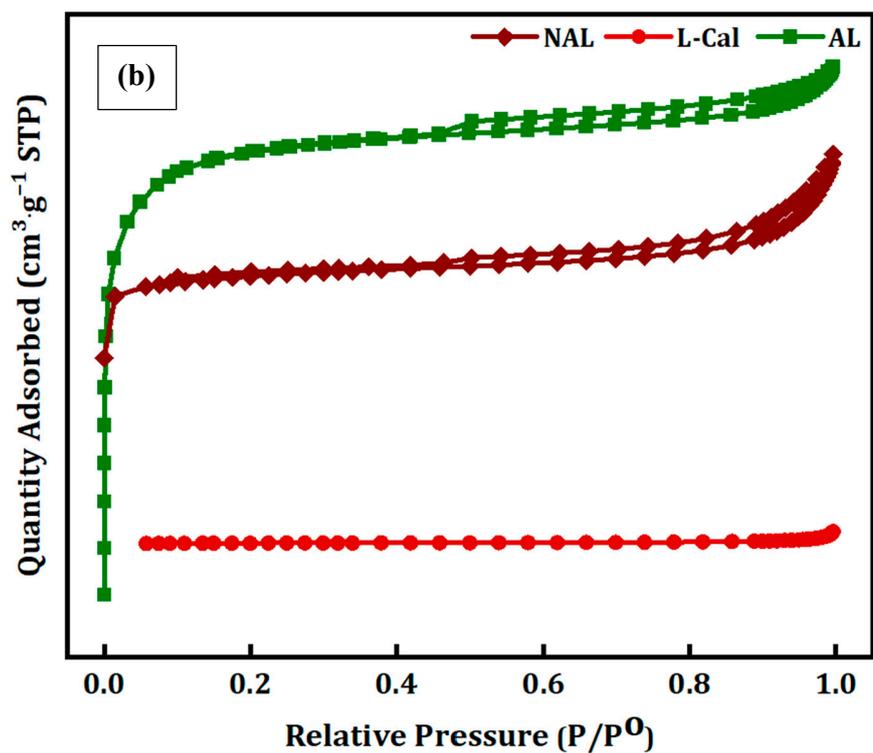


Figure S2: (a) Pore size distribution of the synthesized samples and (b) Nitrogen physisorption isotherms.

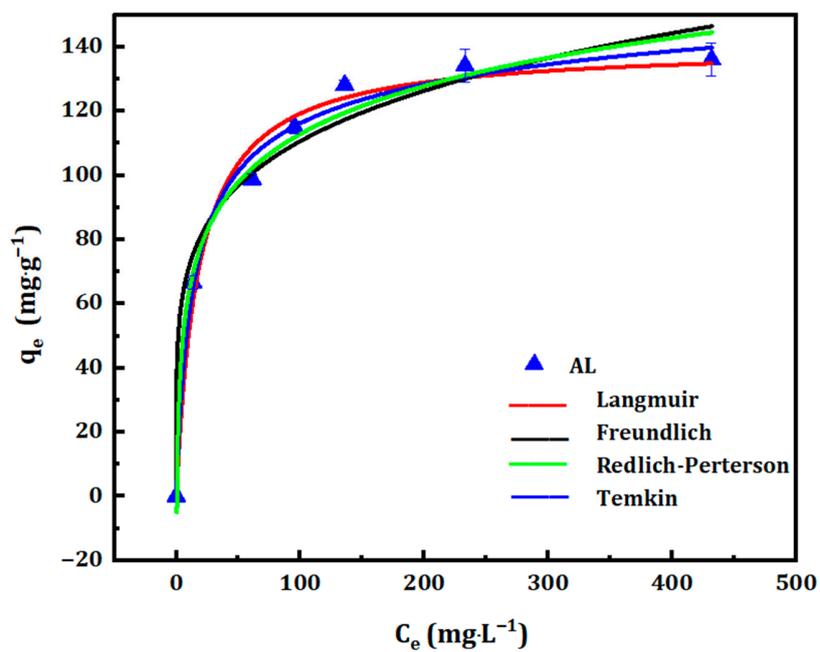


Figure S3: Nonlinear fitting of adsorption isotherm models.

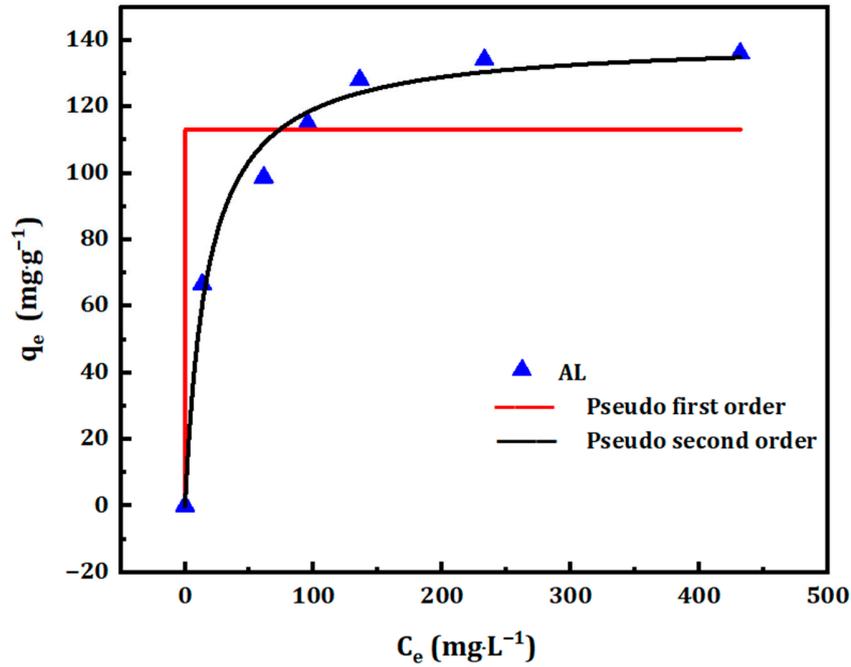


Figure S4: Nonlinear fitting of adsorption kinetic models.

Table S1: Langmuir, Freundlich, Redlich-Peterson and Temkin Isotherm Constants for the AL

| CM Samples | Langmuir Constants | | | Freundlich Constants | | |
|------------|---|--|-------|----------------------|---|-------|
| | Q_{\max} ($\text{mg}\cdot\text{g}^{-1}$) | K_L ($\text{L}\cdot\text{mg}^{-1}$) | R^2 | $1/n$ | K_F ($\text{mg}^{1-1/n}\cdot\text{L}^{1/n}\cdot\text{g}^{-1}$) | R^2 |
| AL | 140.36 | 0.056 | 0.987 | 0.19 | 45.82 | 0.976 |
| | Redlich-Peterson Constants | | | Temkin Constants | | |
| | B | A | R^2 | B | A | R^2 |
| AL | 0.93 | 0.12 | 0.992 | 21.613 | 1.852 | 0.987 |

Table S2: Pseudo-first-order and Pseudo-second-order Constants for the AL

| Kinetics Model | $q_{\text{theo.}}$ | K | R^2 |
|---------------------|--------------------|--------|-------|
| Pseudo-first-order | 113.1 | 21.7 | 0.755 |
| Pseudo-second-order | 140.36 | 0.0004 | 0.987 |

Table S3: Comparison of Various Adsorbent-Based Hydrochars Prepared by the HTC Process for their Lead (II) Removal

| Adsorbent | pH | Adsorbent dosage (g·L ⁻¹) | Concentrations used (mg·L ⁻¹) | Equilibrium time (hr) | q_{\max} (mg g ⁻¹) | Advantages | Limitations | Reference |
|------------------------------|-----|---------------------------------------|---|-----------------------|----------------------------------|--|--|-----------|
| Canola straw | 6.3 | 0.4 | 0, 50, 75, 100, 150, 200 | 3 | 24.4 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ > 80% of lead(II) adsorption occurred in the first 3 h ▪ Production temperature is low (180 °C) ▪ The yield is relatively high (60.5%) | <ul style="list-style-type: none"> ▪ Low surface area (4.4 m² g⁻¹) ▪ Low adsorption capacity | [22] |
| Wheat straw | 5.4 | 0.4 | 0, 50, 75, 100, 150, 200 | 3 | 9.94 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ > 80% of lead(II) adsorption occurred in the first 3 h ▪ Production temperature is low (180 °C) ▪ High yield (69.5%) | <ul style="list-style-type: none"> ▪ Low surface area (4.5 m² g⁻¹) ▪ Not suitable for lead removal due to low adsorption capacity | [22] |
| Sawdust of white spruce | 3.3 | 0.4 | 0, 50, 75, 100, 150, 200 | 3 | 7.69 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ > 80% of lead(II) adsorption occurred in the first 3 h ▪ Production temperature is relatively low (240 °C) ▪ The yield is relatively high (54.5%) | <ul style="list-style-type: none"> ▪ Low surface area (30.6 m² g⁻¹) ▪ Not suitable for lead removal due to low adsorption capacity | [22] |
| Manure pellet | 5.5 | 0.4 | 0, 50, 75, 100, 150, 200 | 3 | 23.8 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ > 80% of lead(II) adsorption occurred in the first 3 h ▪ Production temperature is low (180 °C) ▪ High yield (67.5%) | <ul style="list-style-type: none"> ▪ Low surface area (11.7 m² g⁻¹) ▪ Low adsorption capacity | [22] |
| <i>Crocus sativus</i> petals | 5 | 0.5 | 50,75,100, 125, 150, 175, 200 | 11.5 | 89.5 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ High surface area (862.4 m² g⁻¹) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Low yield (21%) ▪ High activation temperature (800 °C) | [23] |
| Paulownia leaves | 5 | 1 | 0, 30, 50, 70, 100, 150, 200, 300, 400, 500 | 25 | 174.8 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (220 °C) ▪ Good adsorption capacity | | [16] |
| Grape pomace | 5 | 0.5 | 40–180 | 3 | 137 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (220 °C) | | [24] |

| | | | | | | | | |
|---------------------------|-----|------|---------------------------------|----|-------|---|--|------|
| | | | | | | <ul style="list-style-type: none"> ▪ Good adsorption capacity | | |
| <i>Laminaria japonica</i> | | 1 | 10–200 | 6 | 108 | <ul style="list-style-type: none"> ▪ Production temperature is relatively low (200 °C) ▪ Short residence time (45 min) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Low yield (< 27%) ▪ Low surface area (2.23 m² g⁻¹) | [58] |
| Sawdust | 5 | | 10–200 | 1 | 92.8 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (260 °C) ▪ Good adsorption capacity | | [59] |
| Lincomycin residue | 5-6 | 1.33 | 10, 50, 100, 150, 200 | 4 | 57.4 | <ul style="list-style-type: none"> ▪ Production temperature is relatively low (210 °C) ▪ Short residence time (60 min) ▪ Acceptable adsorption capacity | <ul style="list-style-type: none"> ▪ Medium yield (45%) | [60] |
| Soybean | 4 | 1.33 | 10–200 | 3 | 104 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (210 °C) ▪ High yield (90%) ▪ Good adsorption capacity | | [61] |
| Chitosan | 4 | 1.33 | 10–200 | 3 | 86.2 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (210 °C) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Medium yield (41%) | [61] |
| Oil-tea camellia shells | 3–6 | 0.4 | 10–480 | 5 | 476 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ High adsorption capacity | <ul style="list-style-type: none"> ▪ Two steps of the heating process (600 °C for 1 h and 120 °C for 6 h) | [62] |
| <i>Camellia sinensis</i> | 5 | 1 | 100 | 6 | 143.9 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (240 °C) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Medium yield (51%) | [63] |
| <i>Camellia sinensis</i> | 5 | 1 | 0, 150, 300, 450, 600, 750, 900 | 24 | 198.7 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (240 °C) ▪ Short residence time (2 h) ▪ High adsorption capacity | <ul style="list-style-type: none"> ▪ Low yield (35%) ▪ Low surface area (18.7 m² g⁻¹) | [64] |

| | | | | | | | | |
|-------------------------------|-----|-----|---|------|-------|--|---|------|
| Fresh banana peels | 6 | 4 | 5–1000 | 5.5 | 241 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (230 °C) ▪ Short residence time (2 h) ▪ High adsorption capacity | <ul style="list-style-type: none"> ▪ Low yield (29%) ▪ Low surface area (31.5 m² g⁻¹) | [25] |
| Fresh banana peels | 6 | 1 | 30, 60, 90, 120, 150, 180, 200, 250, 300, 350, 400, 500, 600, 700 | 12 | 238 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (200 °C) ▪ Short residence time (2 h) ▪ High adsorption capacity | <ul style="list-style-type: none"> ▪ Low yield (26%) ▪ Low surface area (47.2 m² g⁻¹) | [26] |
| Sludge | 5–6 | 0.6 | 75, 100, 150 | 12.5 | 174 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (180 °C) ▪ Short residence time (2 h) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Low yield (26%) ▪ Long residence time (10 h) ▪ Low surface area (47.2 m² g⁻¹) | [65] |
| Sewage sludge | 4.3 | 0.5 | 0–100 | 12.5 | 62.4 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is low (120 °C) ▪ Acceptable adsorption capacity | | [66] |
| <i>Eupatorium adenophorum</i> | 6 | 2 | 50, 100, 200, 300, 400, 500, 600, 800 | 2.5 | 165 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (220 °C) ▪ Short residence time (1 h) ▪ Good adsorption capacity | | [67] |
| Natural honey | 5 | 0.2 | 100–700 | 15 | 133.2 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (180 °C) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Two long steps of the heating process (180 °C for 24 h and 300 °C for 20 h) | [68] |
| Enteromorpha | 8.1 | 30 | 0.2, 0.5, 0.8, 1, 2, 3, 5, 8 | 0.18 | 0.098 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (250 °C) ▪ Short residence time (40 min) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Low surface area (29.7 m² g⁻¹) | [69] |
| Areca nut husks | 6 | 0.1 | 0, 25, 50, 100 | | 79.9 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (250 °C) | <ul style="list-style-type: none"> ▪ Long residence time (9 h) | [70] |

| | | | | | | | | |
|-----------------------------------|-----|-----|--------------------------|-----|------|---|--|-----------|
| | | | | | | <ul style="list-style-type: none"> ▪ Short residence time (40 min) ▪ Good yield (59%) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Very low surface area (0.98 m² g⁻¹) | |
| Longan fruit exocarp | 5.5 | 5 | 25, 50, 70, 90, 100, 150 | 6 | 22.7 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (300 °C) | <ul style="list-style-type: none"> ▪ Long residence time (24 h) ▪ Low yield (35.89%) ▪ Low surface area (10.76 m² g⁻¹) ▪ Low adsorption capacity | [71] |
| Date palm leaves | 5 | 1 | 500–800 | 0.5 | 74.5 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ Production temperature is relatively low (300 °C) ▪ High yield (73%) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Long residence time (7 h) | [72] |
| Palm date-activated leaflets (AL) | 6 | 0.5 | 50-500 | 1 | 136 | <ul style="list-style-type: none"> ▪ Abundantly available ▪ High surface area (808 m² g⁻¹) ▪ Production temperature is relatively low (230 °C) ▪ Good adsorption capacity | <ul style="list-style-type: none"> ▪ Long residence time (8 h) | This work |