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*Supplementary Material for*

# Coupling of *kenaf* biochar and magnetic $BiFeO_3$ onto cross-linked chitosan for enhancing separation performance and Cr(VI) ions removal efficiency

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Table S1 Experimental design matrix of the $2^{5-1}$ FFD for Cr(VI) adsorption onto CKB. (A: pH, B: temperature, C: initial concentration of Cr(VI), D: NaCl, E: $KH_2PO_4$)

| Run number | Values of independent variables* | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| 1 | 2 | 50 | 90 | 0.1 | 0.01 |
| 2 | 2 | 10 | 90 | 0.1 | 0.1 |
| 3 | 6 | 50 | 90 | 0.01 | 0.01 |
| 4 | 6 | 50 | 90 | 0.1 | 0.1 |
| 5 | 6 | 10 | 90 | 0.01 | 0.1 |
| 6 | 2 | 10 | 90 | 0.01 | 0.01 |
| 7 | 2 | 50 | 90 | 0.01 | 0.1 |
| 8 | 6 | 10 | 90 | 0.1 | 0.01 |
| 9 | 2 | 10 | 10 | 0.01 | 0.1 |
| 10 | 6 | 10 | 10 | 0.01 | 0.01 |
| 11 | 6 | 50 | 10 | 0.01 | 0.1 |
| 12 | 2 | 50 | 10 | 0.1 | 0.1 |
| 13 | 2 | 50 | 10 | 0.01 | 0.01 |
| 14 | 6 | 10 | 10 | 0.1 | 0.1 |
| 15 | 2 | 10 | 10 | 0.1 | 0.01 |
| 16 | 6 | 50 | 10 | 0.1 | 0.01 |

The regeneration ability of an adsorbent is considered as a significant factor to assess its cost-effectiveness [1] [2]. In order to investigate the regenerability and reusability of CKB, the adsorption-desorption cycle experiments were performed on CKB. At first, 12 mg/g of Cr(Ⅵ) was loaded onto CKB by contacting 0.2 g CKB with 50 mg/L of Cr(Ⅵ) solution (50 mL) at pH 2.0 in a thermostatic shaker at 150 rpm under 30 ℃. Then for desorption, Cr(Ⅵ)-loaded CKB was separated from solutions using a magnet and then washed by ultrapure water for three times. Next, Cr(Ⅵ)-loaded CKB was contacted with 50 mL of 0.5 M NaOH in a thermostatic shaker at 150 rpm under 30 ℃. After washing CKB by ultrapure water for three times, the adsorbent was reused in the next adsorption cycle. Three consecutive adsorption-desorption cycles were examined.

As shown in the first two cycles in Fig. S1, the adsorption capacity of CKB was 12 mg/g. In the third cycle the adsorption capacity of CKB was slightly reduced to 9 mg/g. Therefore, CKB can be successfully reused for two adsorption-desorption cycles without loss of its original adsorption capacity.

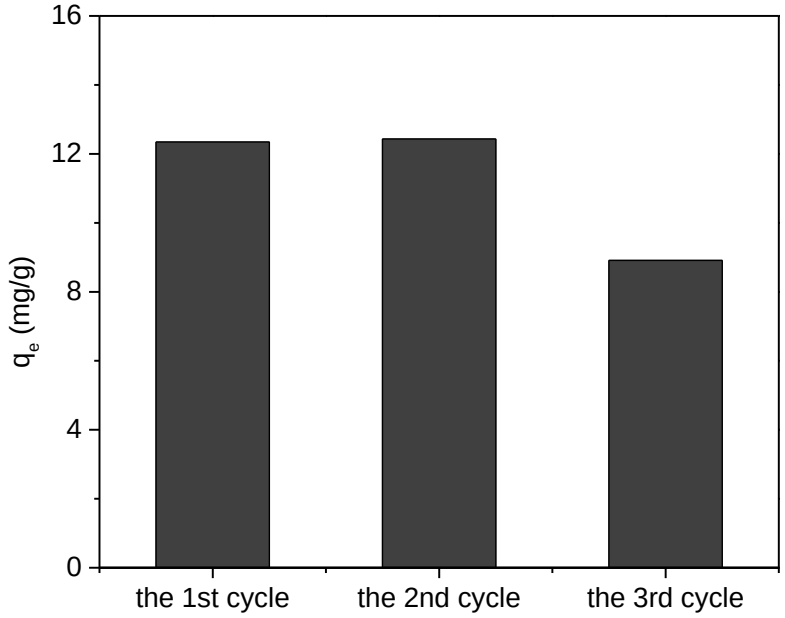


Figure S1. Reuse experiment of CKB for three cycles: $C_{0Cr(VI)}$ = 50mg/L, $W$ = 0.2 g, $T$ = 30 °C, $t$ = 4 h, pH = 2.

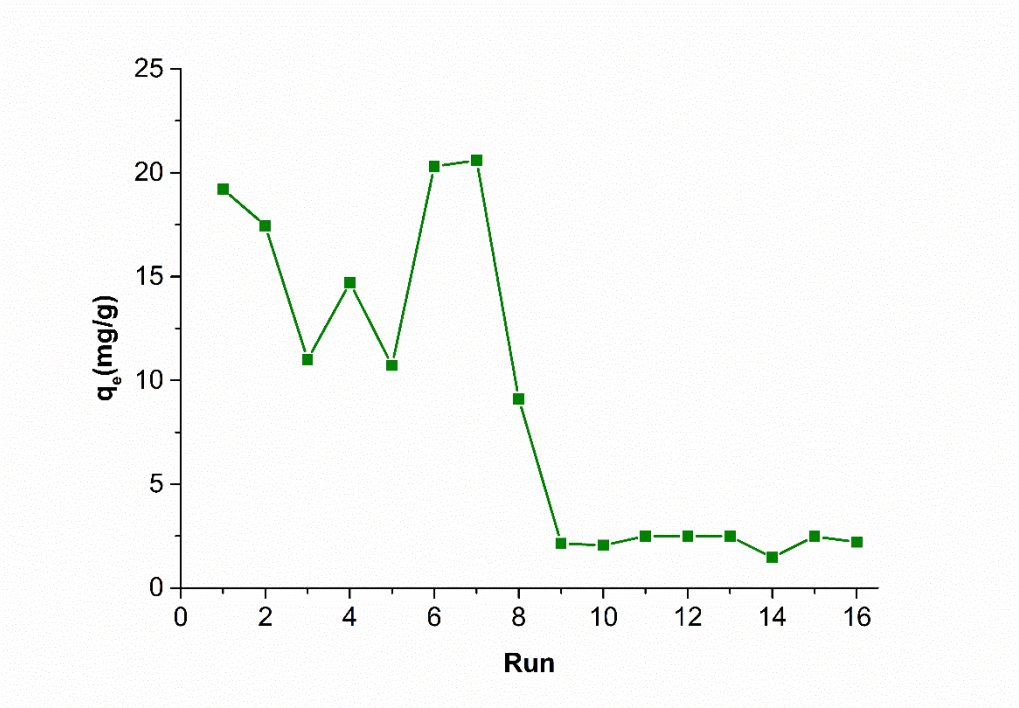


Figure S2 Cr(VI) removal onto CKB under various experimental conditions designed by $2^{5-1}$ FFD

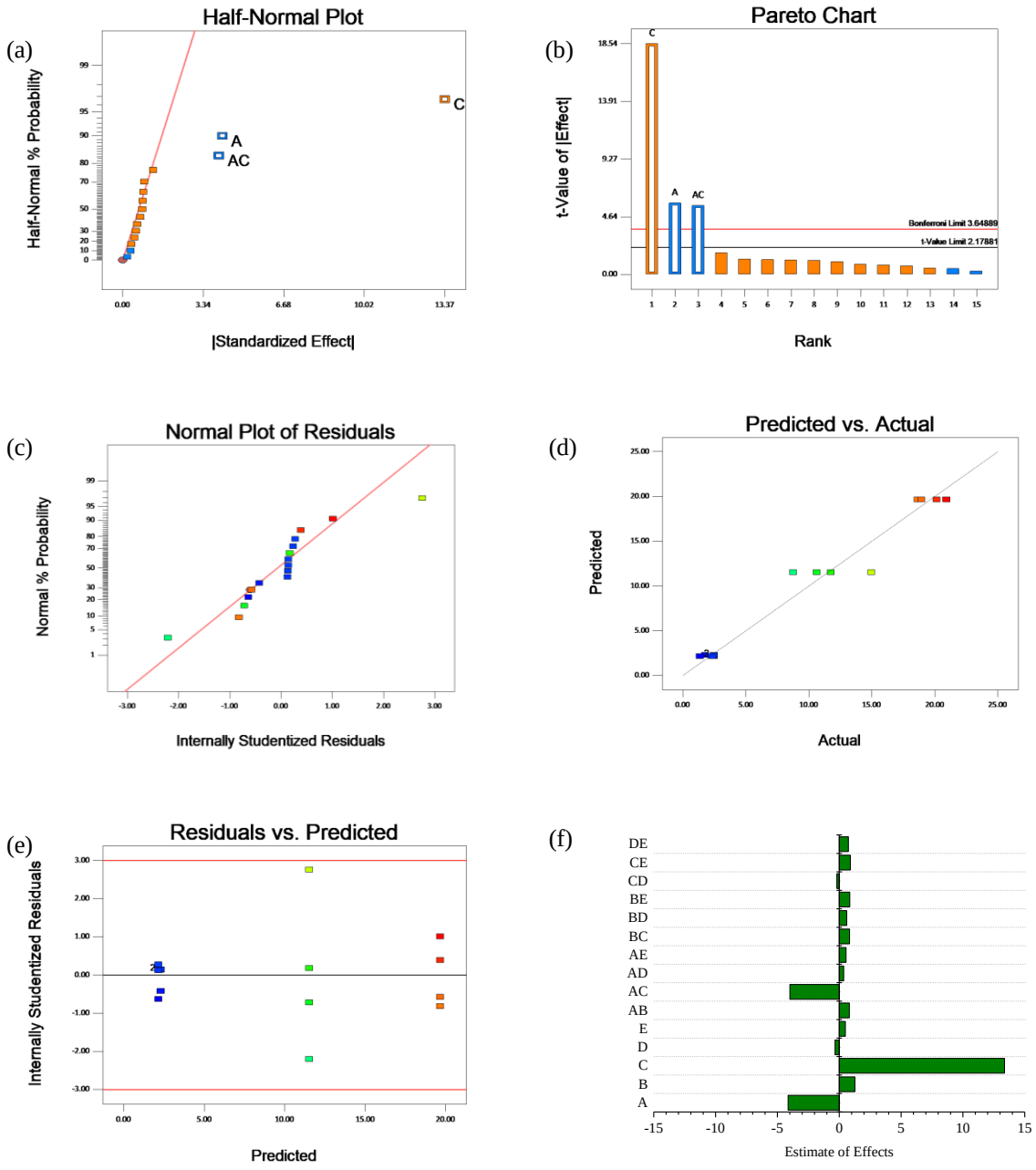


Figure S3 (a) Half-normal probability plot; (b) Pareto chart; (c) Normal plot of residuals; (d) Comparison of predicted and experimental adsorption capacities; (e) Plots of internally standardized residuals with predicted values; (f) Estimates of effects: Identification of main factors and interaction factors on Cr(VI) adsorption by CKB: (A) pH; (B) Temperature; (C) initial concentration of Cr(VI); (D) NaCl; (E) $KH_2PO_4$.

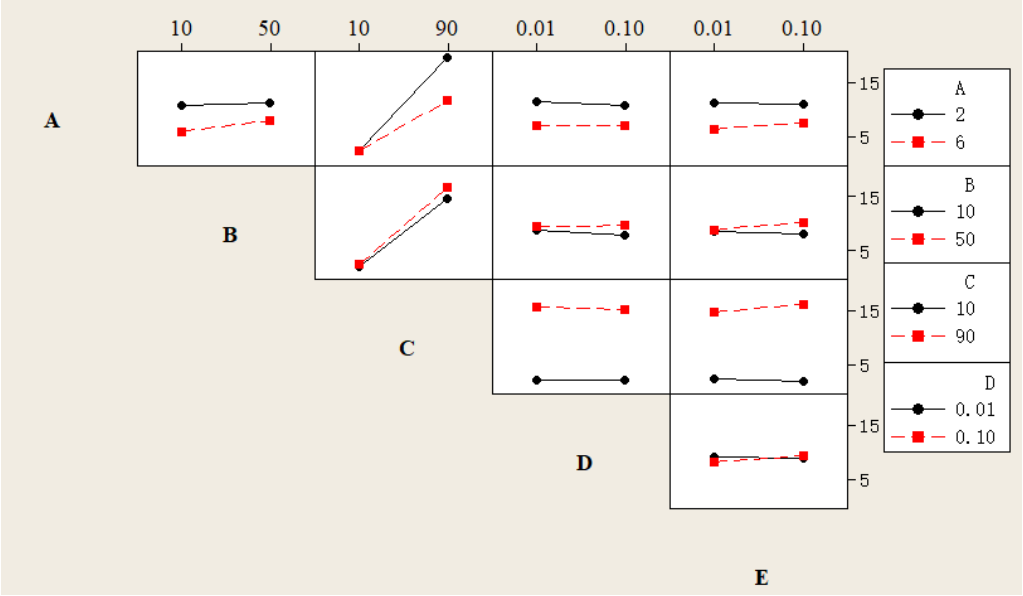


Figure S4 Interaction effects plot for Cr(VI) decontamination: (A) pH; (B) Temperature; (C) initial concentration of Cr(VI); (D) NaCl; (E) $KH_2PO_4$.

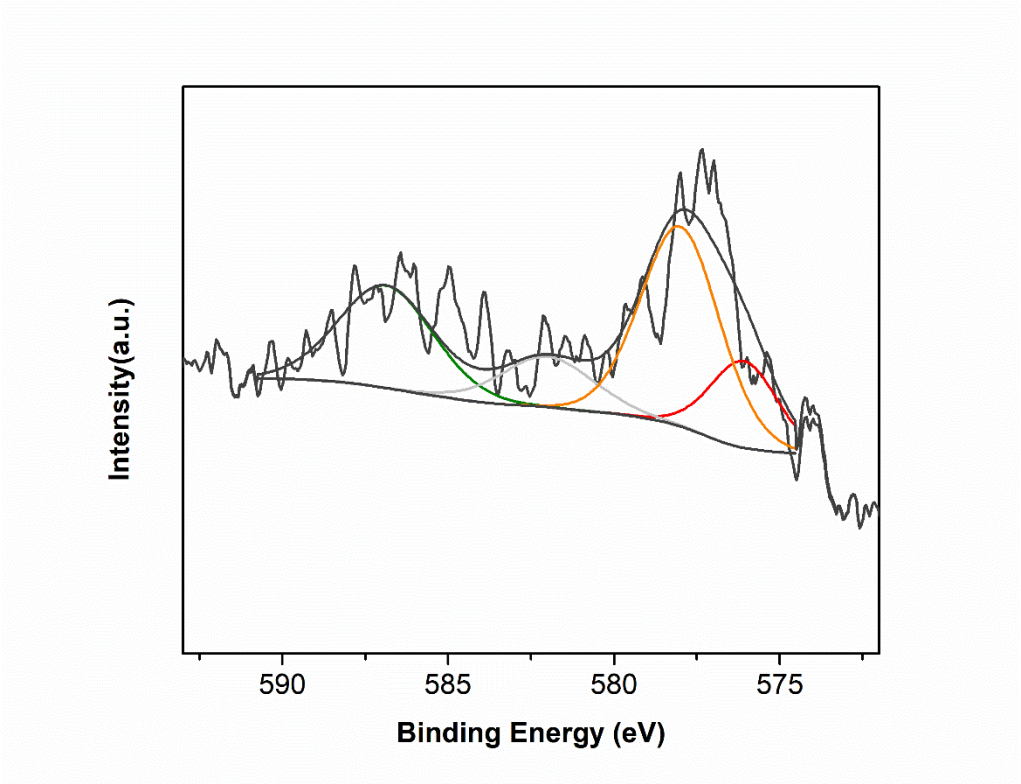


Figure. S5 Cr 2*p* XPS spectra of CKB after adsorption.

## References

1. Bhaumik, M.; Maity, A.; Srinivasu, V.V.; Onyango, M.S. Enhanced removal of Cr(VI) from aqueous solution using polypyrrole/$Fe_3O_4$ magnetic nanocomposite. *Journal of hazardous materials* **2011**, *190*, 381-390, doi:10.1016/j.jhazmat.2011.03.062.
2. Vilardi, G.; Ochando-Pulido, J.M.; Stoller, M.; Verdone, N.; Di Palma, L. Fenton oxidation and chromium recovery from tannery wastewater by means of iron-based coated biomass as heterogeneous catalyst in fixed-bed columns. *Chemical Engineering Journal* **2018**, *351*, 1-11, doi:10.1016/j.cej.2018.06.095.