Supplementary Information

Co-catalysis of trace dissolved Fe(III) with biochar in hydrogen peroxide activation for enhanced oxidation of pollutants

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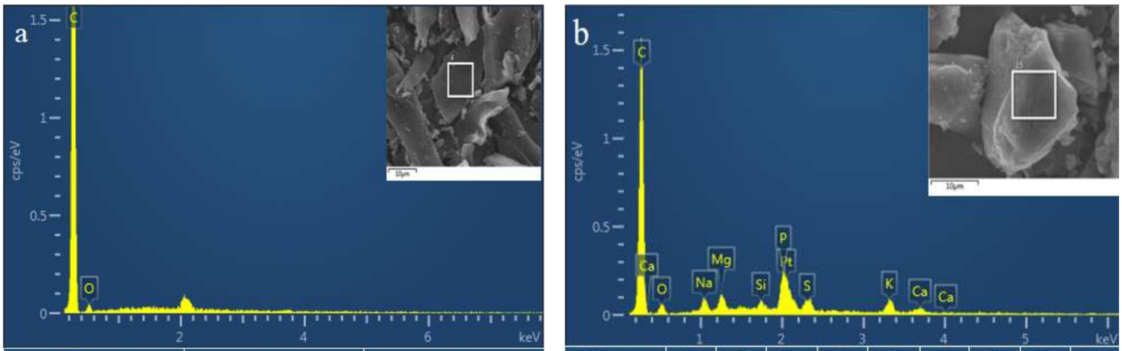
Table S1. The compositions and properties of two biochar samples

Sample	LB[1]	WB
SA_{BET} (m^2/g)	6.66	409
pH	9.11 ± 0.03	8.03 ± 0.06
Ash (%)	23.4 ± 0.1	0.89 ± 0.03
Elemental compositions (%)		
C	66.0 ± 0.3	93.9 ± 0.4
H	1.53 ± 0.1	1.46 ± 0.1
O	4.31 ± 0.4	3.83 ± 0.2
N	3.36 ± 0.1	0

Table S2. The experimental conditions corresponding to the results shown in different figures

Run	Biochar dosage (g/L)	Iron species dosage (mg/L)	H_2O_2 dosage	pH_0	Figure
1	LB 3.0	/	/	3.0	Fig. 1(a)
2	LB 3.0	/	5.0	3.0	Fig. 1(a) (c) (d); Fig. 2; Fig. 3(a) (b); Fig. 4
3	/	/	5.0	3.0	Fig. 1(a) (b) (c)
4	/	Fe(III) 0.30	5.0	3.0	Fig. 1(a) (b) (c) (d); Fig. 2; Fig. 4; Fig. 6(c)
5	LB 3.0	Fe(III) 0.30	5.0	3.0	Fig. 1(a) (c) (d); Fig. 2; Fig. 3(a) (b) (c); Fig. 4; Fig. 6(a) (b) (c) (d)
6	WB 3.0	/	/	3.0	Fig. 1(b)
7	WB 3.0	/	5.0	3.0	Fig. 1(b) (c) (d); Fig. 2
8	WB 3.0	Fe(III) 0.30	5.0	3.0	Fig. 1(a) (c) (d); Fig. 2; Fig. 4
9	LB 3.0	Fe(III) 0.10	5.0	3.0	Fig. 3(a) (b)
10	LB 3.0	Fe(III) 0.60	5.0	3.0	Fig. 3(a) (b)
11	LB 3.0	Fe(III) 1.00	5.0	3.0	Fig. 3(a) (b)
12	LB 3.0	Fe(II) 0.30	5.0	3.0	Fig. 3(c)

13	/	Fe(II) 0.30	5.0	3.0	Fig. 3(c)
14	WB 1.0	/	5.0	3.0	Fig. 3(d)
15	/	Fe_2O_3 1.0	5.0	3.0	Fig. 3(d)
16	WB 1.0	Fe_2O_3 1.0	5.0	3.0	Fig. 3(d)
17	/	Fe_3O_4 1.0	5.0	3.0	Fig. 3(d)
18	WB 1.0	Fe_3O_4 1.0	5.0	3.0	Fig. 3(d)
19	LB 3.0	Fe(III) 0.30	5.0	2.0	Fig. 6(a)
20	LB 3.0	Fe(III) 0.30	5.0	2.5	Fig. 6(a)
21	LB 3.0	Fe(III) 0.30	5.0	3.5	Fig. 6(a)
22	LB 3.0	Fe(III) 0.30	5.0	4.0	Fig. 6(a)
23	LB 3.0	Fe(III) 0.30	/	3.0	Fig. 6(b)
24	LB 3.0	Fe(III) 0.30	1.0	3.0	Fig. 6(b)
25	LB 3.0	Fe(III) 0.30	3.0	3.0	Fig. 6(b)
26	LB 3.0	Fe(III) 0.30	7.0	3.0	Fig. 6(b)
27	LB 3.0	Fe(III) 0.30	9.0	3.0	Fig. 6(b)
28	LB 1.0	Fe(III) 0.30	5.0	3.0	Fig. 6(c)
29	LB 2.0	Fe(III) 0.30	5.0	3.0	Fig. 6(c)
30	LB 4.0	Fe(III) 0.30	5.0	3.0	Fig. 6(c)
31	LB 5.0	Fe(III) 0.30	5.0	3.0	Fig. 6(c)



Element	C	O
Atomic100%	94.32	5.68

Element	C	O	Na	Mg	Si	P	S	K	Ca
Atomic100%	86.90	7.56	0.91	0.77	0.32	1.63	0.63	0.92	0.37

Fig. S1. SEM-EDS information of (a) WB and (b) LB samples. The data were obtained in a scanning electron microscope (SEM) (JSM-6360LV, JEOL, Japan) equipped with an energy dispersive X-ray spectrometer (EDS) (X-act, Oxford, UK).

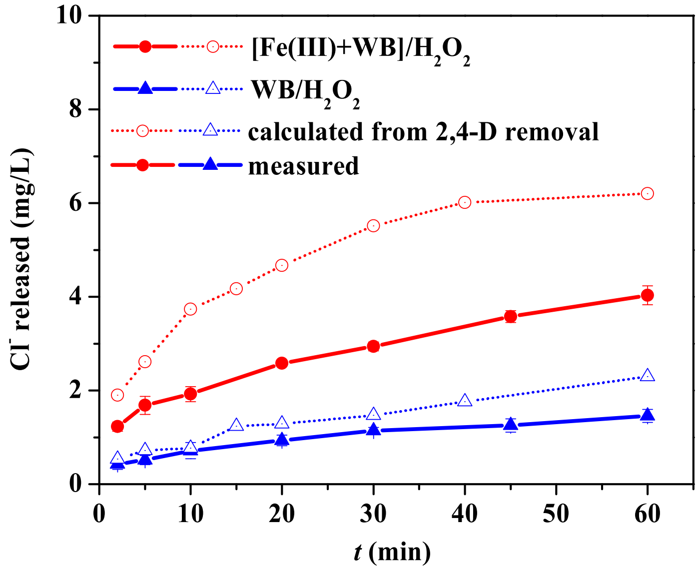


Fig. S2. Change of chloride concentration during the oxidation of 2,4-D in [Fe(III)+WB]/H_2O_2 and WB/H_2O_2. The solid lines represent that measured using ionic chromatograph following a method reported previously [2]. The dot lines represent that theoretically calculated from the removal of 2,4-D. Dosage: Fe(III) =0.30 mg/L, WB = 3.0 g/L, and H_2O_2 = 5.0 mmol/L; and pH_0 = 3.0.

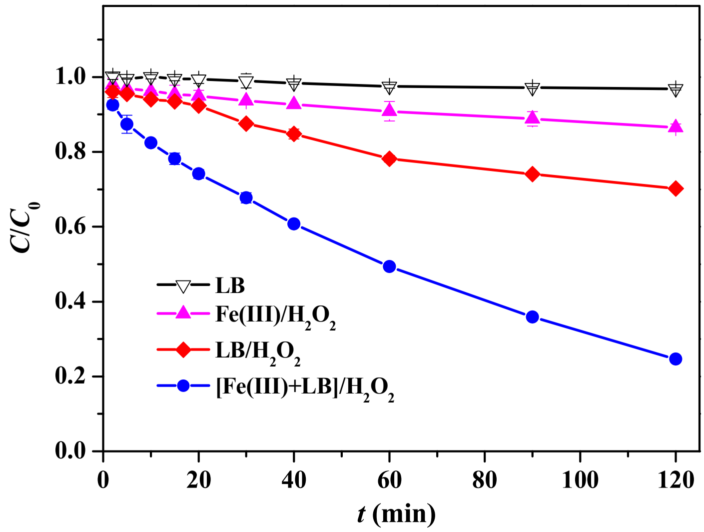


Fig. S3. Removal of sulfamethazine (SMZ) (C_0 = 20 mg/L) in the systems using different combination of trace Fe(III) (0.30 mg/L), biochar (LB) (3.0 g/L) and/or H_2O_2 (5.0 mmol/L), and pH_0 = 3.0.

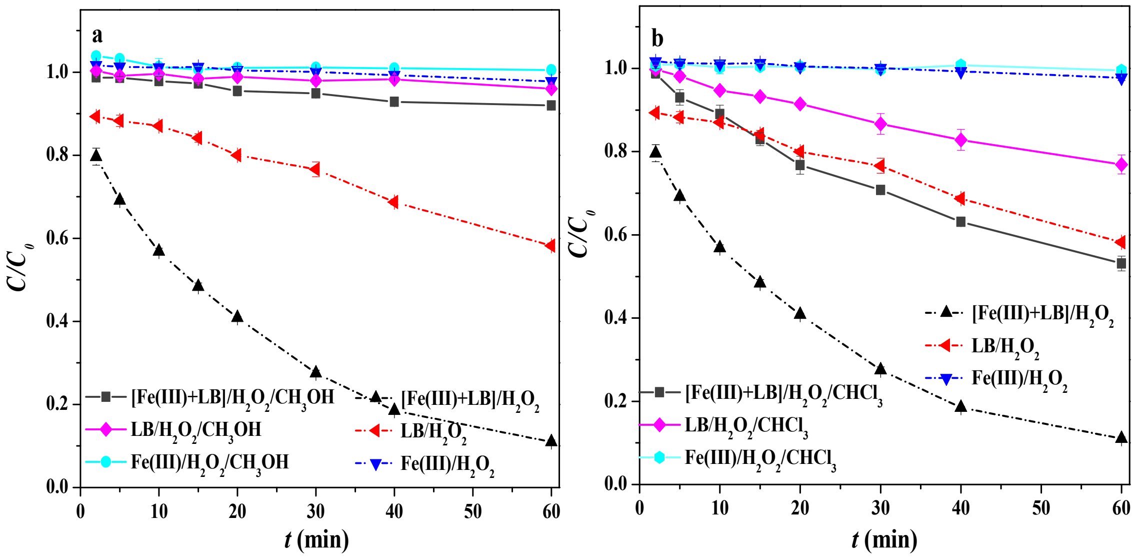


Fig. S4. Removal of 2,4-D (C_0 = 20 mg/L) in different oxidation systems with the presence of scavengers: (a) methanol = 50 mmol/L, and (b) chloroform = 50 mmol/L. The solid lines represent the reaction systems with addition of scavengers (CH_3OH or $CHCl_3$). The dash lines represent the systems without scavenger. Dosage: Fe(III) =0.30 mg/L, LB = 3.0 g/L, and H_2O_2 = 5.0 mmol/L; and pH_0 = 3.0.

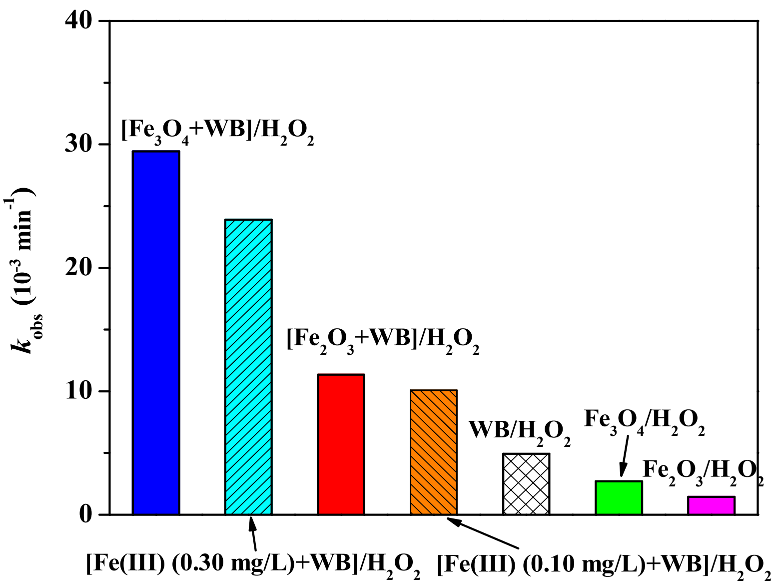


Fig. S5. The k_{obs} values for 2,4-D (20 mg/L) degradation in different oxidation systems. Dosage: WB = 1.0 g/L, H_2O_2 = 5.0 mmol/L, and iron minerals (Fe_3O_4 or Fe_2O_3) =1.0 g/L; and pH_0 = 3.0.

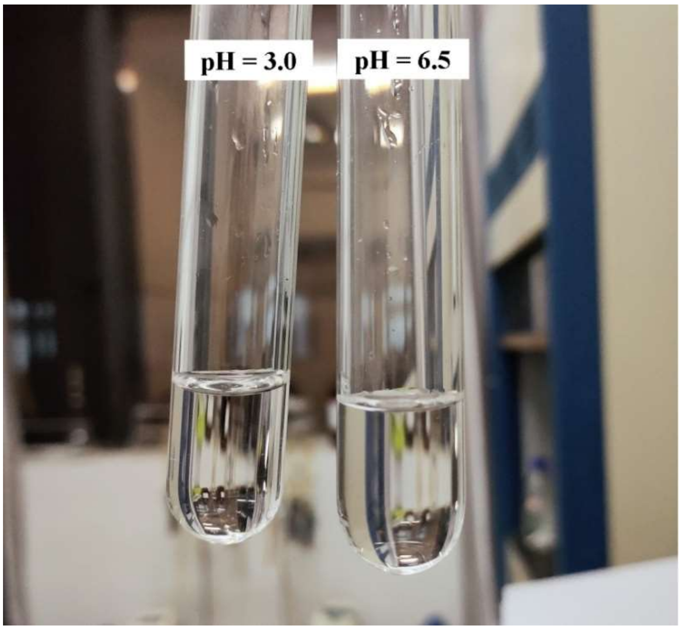


Fig. S6. Photos of the clear solution after reaction in [Fe(III)+LB]/H_2O_2, left: initial pH of 3.0, and right: pH adjusted to 6.5. Dosage: Fe(III) =0.30 mg/L, LB = 3.0 g/L, and H_2O_2 = 5.0 mmol/L; and pH_0 = 3.0.

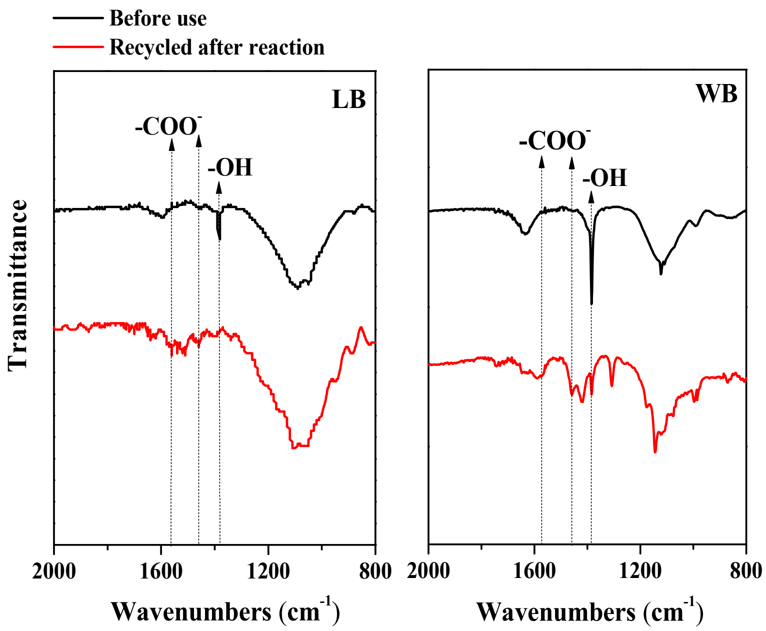


Fig. S7. FTIR spectra of the LB and WB samples before use, and recycled after reaction from the co-catalytic systems.

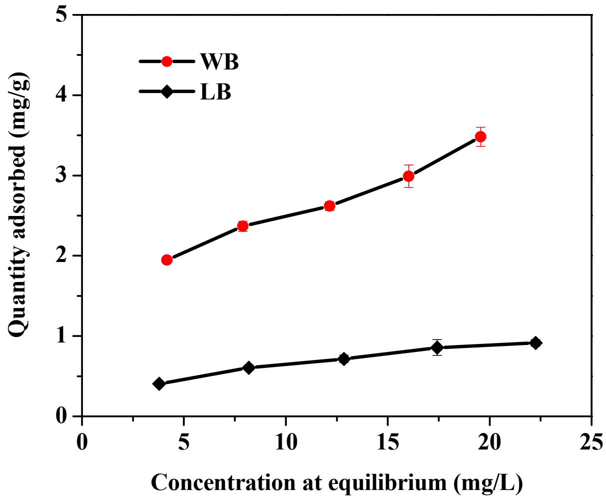


Fig. S8. Adsorption isotherms of 2,4-D by LB and WB sample (3.0 g/L), after equilibrium for 24 h at 25 °C and pH 3.0.

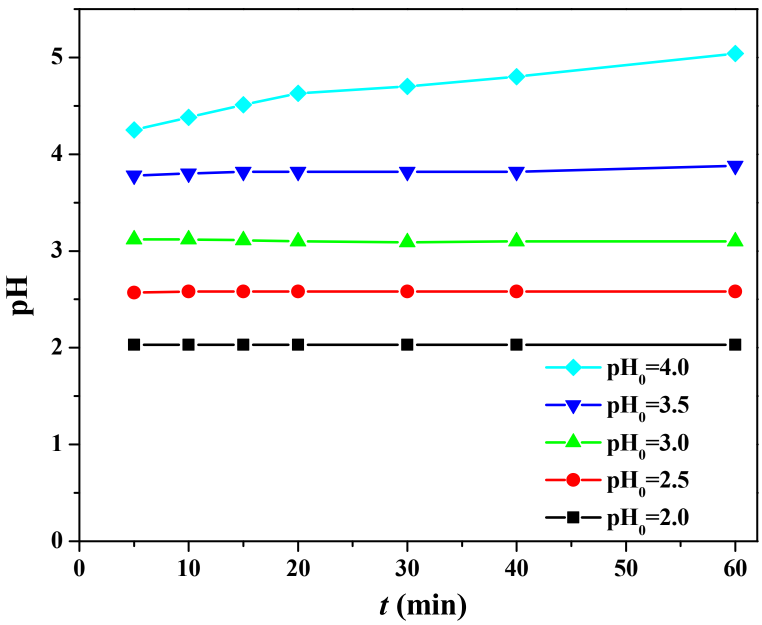


Fig. S9. Change of pH during the reaction in [Fe(III)+LB]/H_2O_2 using various pH_0. Experimental conditions: C_0 (2,4-D) = 20 mg/L, LB = 3.0 g/L, H_2O_2 = 5.0 mmol/L, and Fe(III) = 0.30 mg/L.

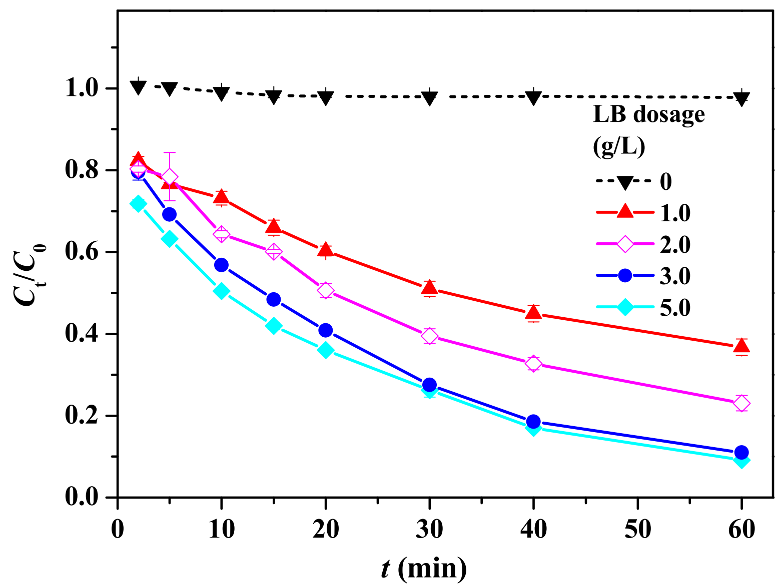


Fig. S10. Removal of 2,4-D (C_0 = 20 mg/L) by [Fe(III)+LB]/H_2O_2 with various LB dosage. Experimental conditions: Fe(III) = 0.30 mg/L, and H_2O_2 = 5.0 mmol/L; and pH_0 = 3.0.

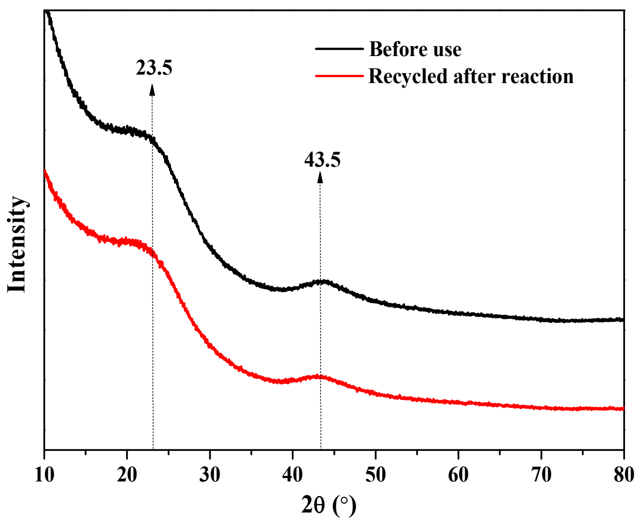


Fig. S11. XRD patterns of WB sample before use and recycled after reaction from the co-catalytic system.

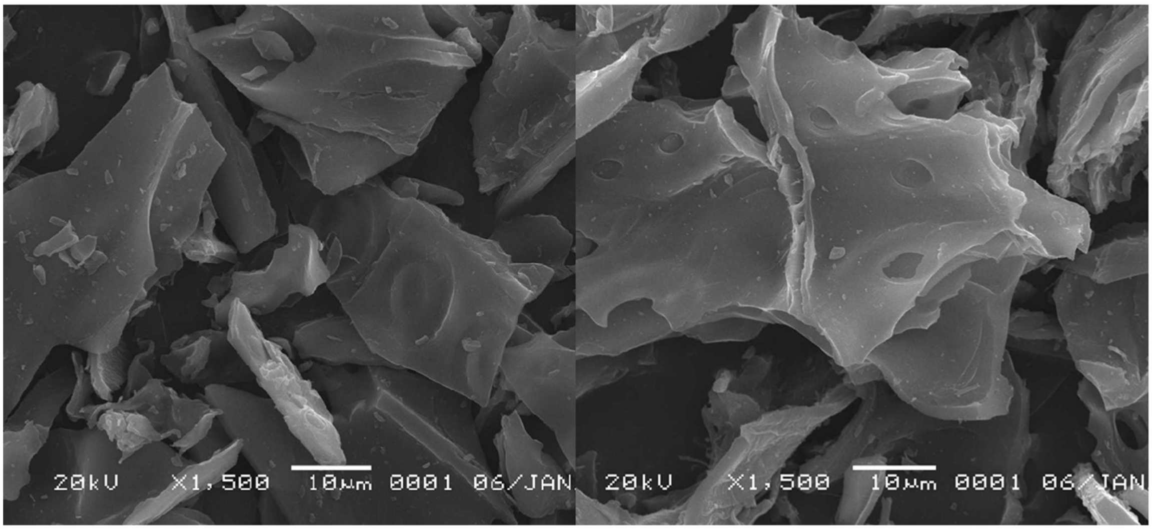


Fig. S12. SEM images of WB sample before use (left) and recycled after reaction (right).

References

[1] D. Feng, J. Lü, S. Guo and J. Li, Biochar enhanced the degradation of organic pollutants through a Fenton process using trace aqueous iron, J. Environ. Chem. Eng., 2021, 9, 104677, https://doi.org/10.1016/j.jece.2020.104677.

[2] X. Zhu, J. Li, B. Xie, D. Feng and Y. Li, Accelerating effects of biochar for pyrite-catalyzed Fenton-like oxidation of herbicide 2,4-D, Chem. Eng. J., 2020, 391, 123605, https://doi.org/10.1016/j.cej.2019.123605.