
Supplementary Material

Adsorption of Cadmium and Lead Capacity and Environmental Stability of Magnesium-Modified High-Sulfur Hydrochar: Greenly Utilizing Chicken Feather

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Table S1. The element content of chicken feathers (%)

Elemental context	C	H	N	S
Chicken feather	39.88	6.04	12.07	4.02

Table S2. Nutrient content and basic physicochemical properties of soil tested

Index	Unit	Context
pH	/	6.34 ± 0.15
Total nitrogen		1.69 ± 0.01
Total phosphorus		0.66 ± 0.10
Total potassium	g·kg ⁻¹	20.61 ± 0.05
Soil organic matter		33.34 ± 0.04
Alkali-hydrolyzable nitrogen		153.00 ± 1.04
Available phosphorus	mg·kg ⁻¹	13.23 ± 0.17
Readily available potassium		68.60 ± 0.26
Cation exchange capacity		14.20 ± 0.06
Exchangeable calcium		2483.04 ± 1.96
Exchangeable magnesium	cmol·kg ⁻¹	324.395 ± 2.04

Table S3. Fertilizer application method for the bok choy potting test

	Base fertilizer	First topdressing	Second topdressing	Third topdressing
Fertilizer proportion	40%	15%	30%	15%
Fertilizer time	Before transplanting 7 d	After transplanting 7 d	After transplanting 14 d	After transplanting 21 d

Table S4. Sulfur content of biochar and hydrochar in different studies

Sulfur context (%)	Pyrolysis process	Reaction temperature (°C)	Raw material	Reference
0.88	Slow pyrolysis	450	Chicken feather	[22]
0.96	Slow pyrolysis	450	Chicken feather	[22]
0.32	Slow pyrolysis	450	Chicken feather	[23]
~0.37	Slow pyrolysis	400	Sewage	[68]
0.02	Slow pyrolysis	450	Corn straw	[69]
1.88	Hydrothermal carbonization	150	Chicken feather	[26]
0.38	Hydrothermal carbonization	200	Rice Straw	[40]
0.31	Hydrothermal carbonization	200	Swine Manure	[40]
3.336	Hydrothermal carbonization	180	Chicken feather	This work
3.683	Hydrothermal carbonization	180	Chicken feather	This work

Table S5. Carbon stability and carbon loss rate of hydrochar determined by H₂O₂ oxidation (%)

	WF	MWF
Carbon stability	58.16 ± 0.8a	59.42 ± 0.3a
Carbon loss rate	41.84 ± 0.8a	40.58 ± 0.3a

Different lowercase letters indicate significant differences between processes ($p < 0.05$).

Table S6. Properties and nutrient composition of different organic water-soluble fertilizers

	WF	MWF	WFNPK	MWFNPK
pH (1: 200)	8.219 ± 0.074	7.422 ± 0.065	6.360 ± 0.091	5.627 ± 0.038
Organic matter (g·L ⁻¹)	49.68 ± 0.04	53.84 ± 0.61	49.68 ± 0.04	53.84 ± 0.61
TN (g·L ⁻¹)	9.84 ± 0.42	7.37 ± 0.21	82.48	82.48
TP (g·L ⁻¹)	0.04 ± 0.00	0.12 ± 0.00	13.57	13.57
TK (g·L ⁻¹)	0.02 ± 0.00	0.02 ± 0.00	44.22	44.22
Mg (g·L ⁻¹)	0.01 ± 0.00	22.69 ± 0.07	0.01 ± 0.00	22.69 ± 0.07

Table S7 Effects of different fertilization treatments on yield indexes of bok choy

Treatment	CK	NPK	WF	WFNPK	MWFNPK
Ground fresh weight (g)	27.71 ± 1.75a	33.39 ± 2.36b	32.29 ± 2.85ab	35.33 ± 2.07bc	39.04 ± 2.86c
Ground dry weight (g)	1.45 ± 0.20a	1.63 ± 0.22ab	1.71 ± 0.28ab	1.77 ± 0.21ab	2.09 ± 0.10b
Leaf length (cm)	19.88 ± 2.78a	20.91 ± 2.24ab	20.21 ± 1.48ab	21.79 ± 2.33bc	22.70 ± 1.21c
Leaf width (cm)	8.18 ± 1.01a	8.76 ± 1.06ab	8.70 ± 0.94ab	8.46 ± 1.11ab	9.27 ± 1.32b
Leaf number	6.11 ± 0.57a	6.44 ± 0.68ab	6.89 ± 0.57bc	7.00 ± 0.94c	6.78 ± 0.79bc
Plant height (cm)	21.2 ± 3.04a	21.90 ± 2.41a	21.51 ± 1.38a	22.60 ± 2.24ab	23.60 ± 1.45b
Root length (cm)	6.40 ± 0.36a	6.58 ± 1.38a	7.00 ± 0.80a	7.37 ± 0.45a	7.33 ± 1.86a

Different lowercase letters indicate significant differences between processes ($p < 0.05$)

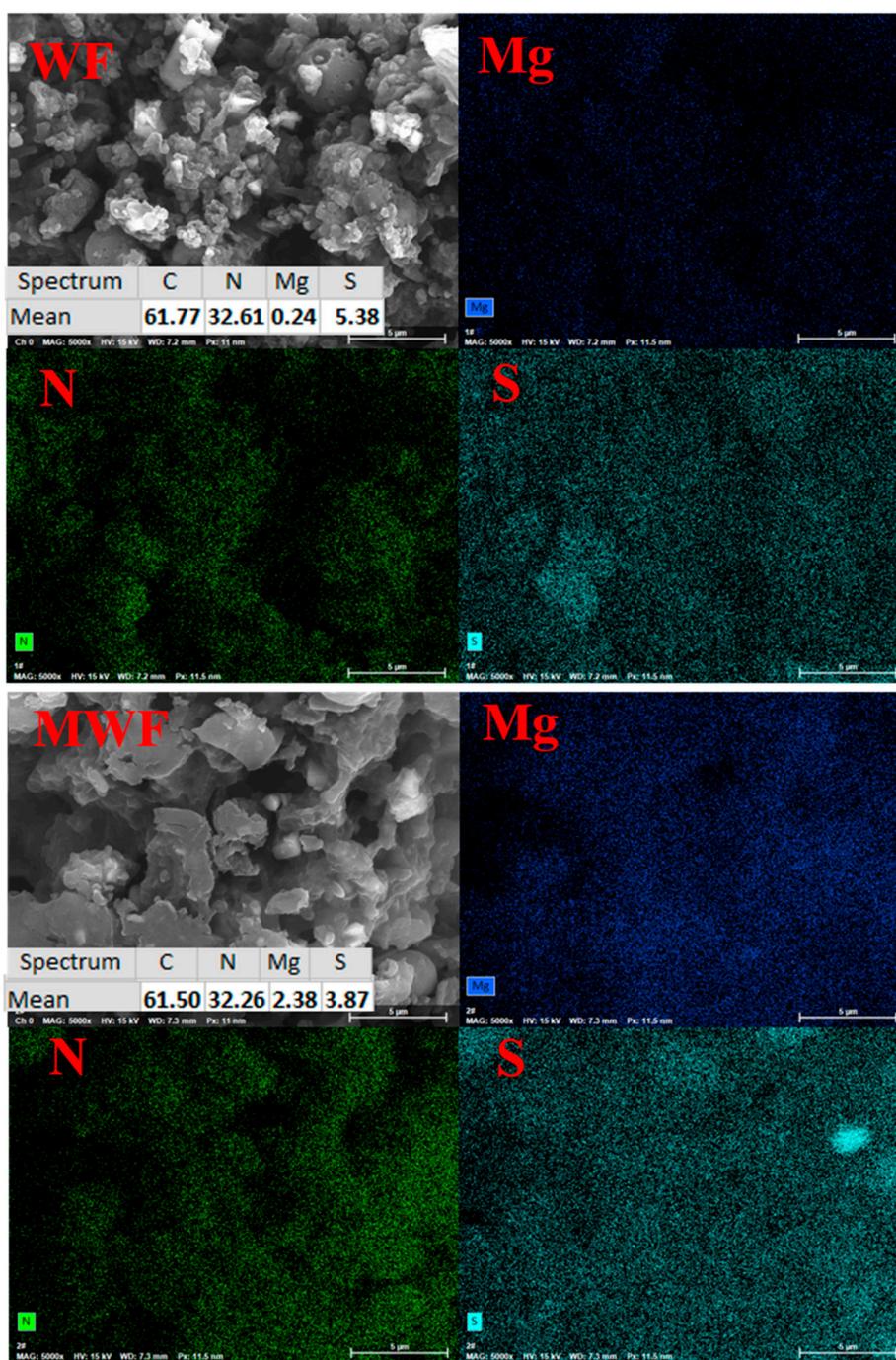


Figure S1. SEM-EDS images of hydrochar WF and MWF

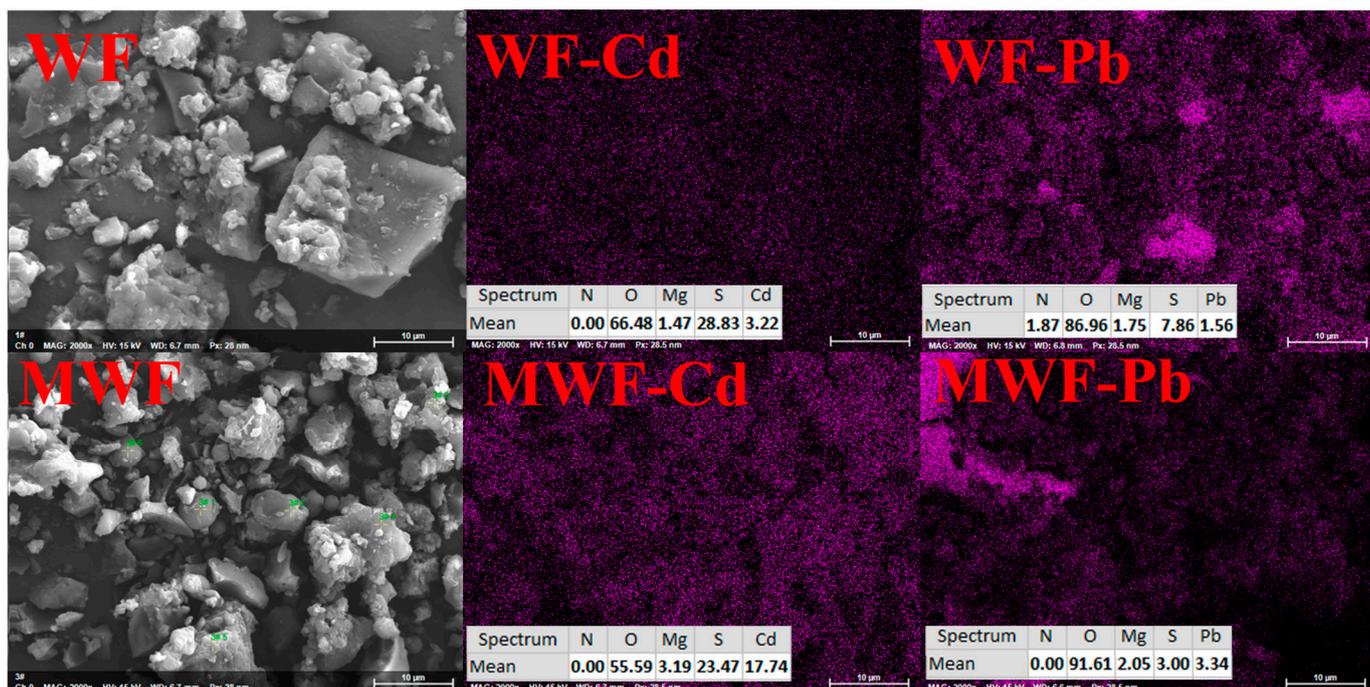


Figure S2. SEM-EDS images of Cd²⁺ and Pb²⁺ adsorbed by hydrochar WF and MWF

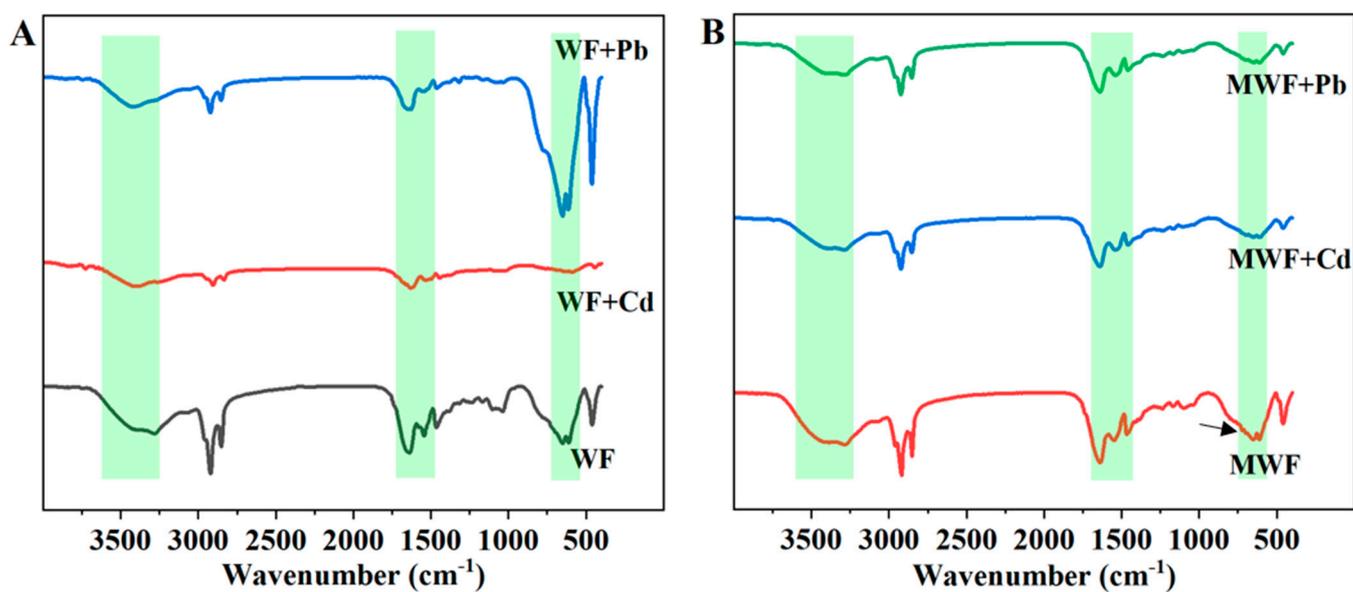


Figure S3. FTIR spectra before and after adsorption of Cd²⁺ and Pb²⁺ by hydrochar WF (A) and MWF (B)

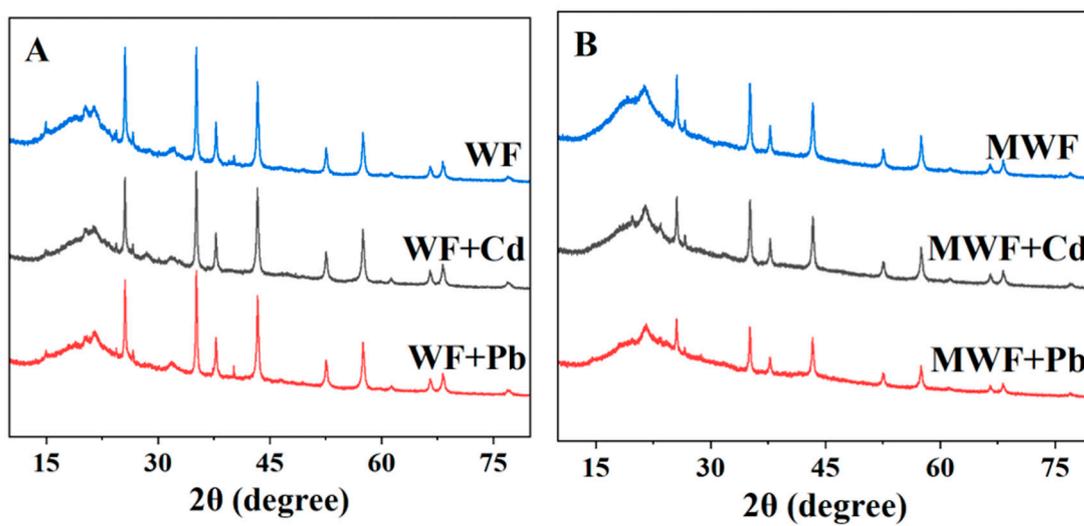


Figure S4. XRD patterns of hydrochar WF (A) and MWF (B) before and after adsorption of Cd²⁺ and Pb²⁺

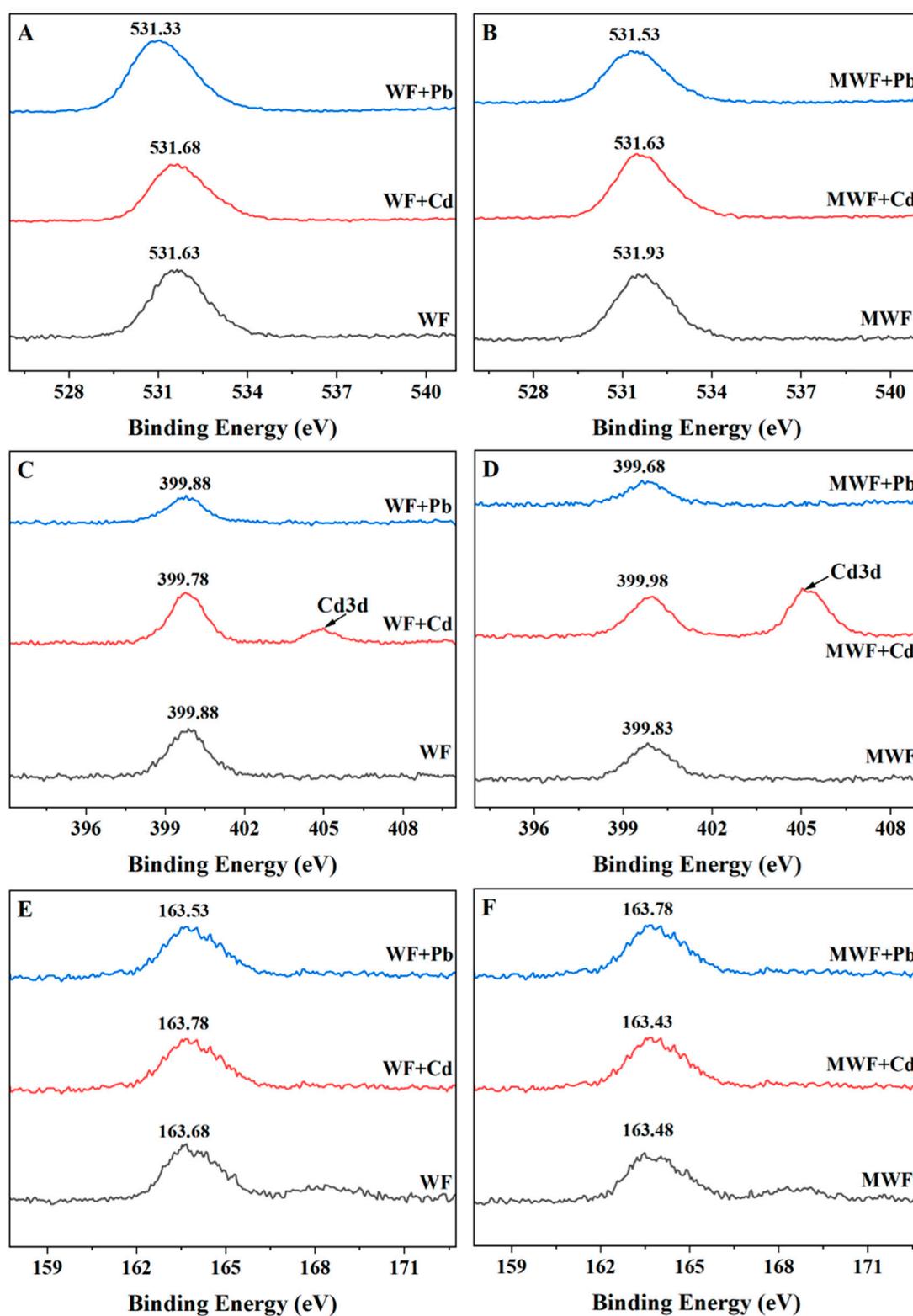


Figure S5. The XPS spectra of O1s (A, B), N1s (C, D) and S2p (E, F) of hydrochar WF and MWF before and after adsorption of Cd²⁺ and Pb²⁺

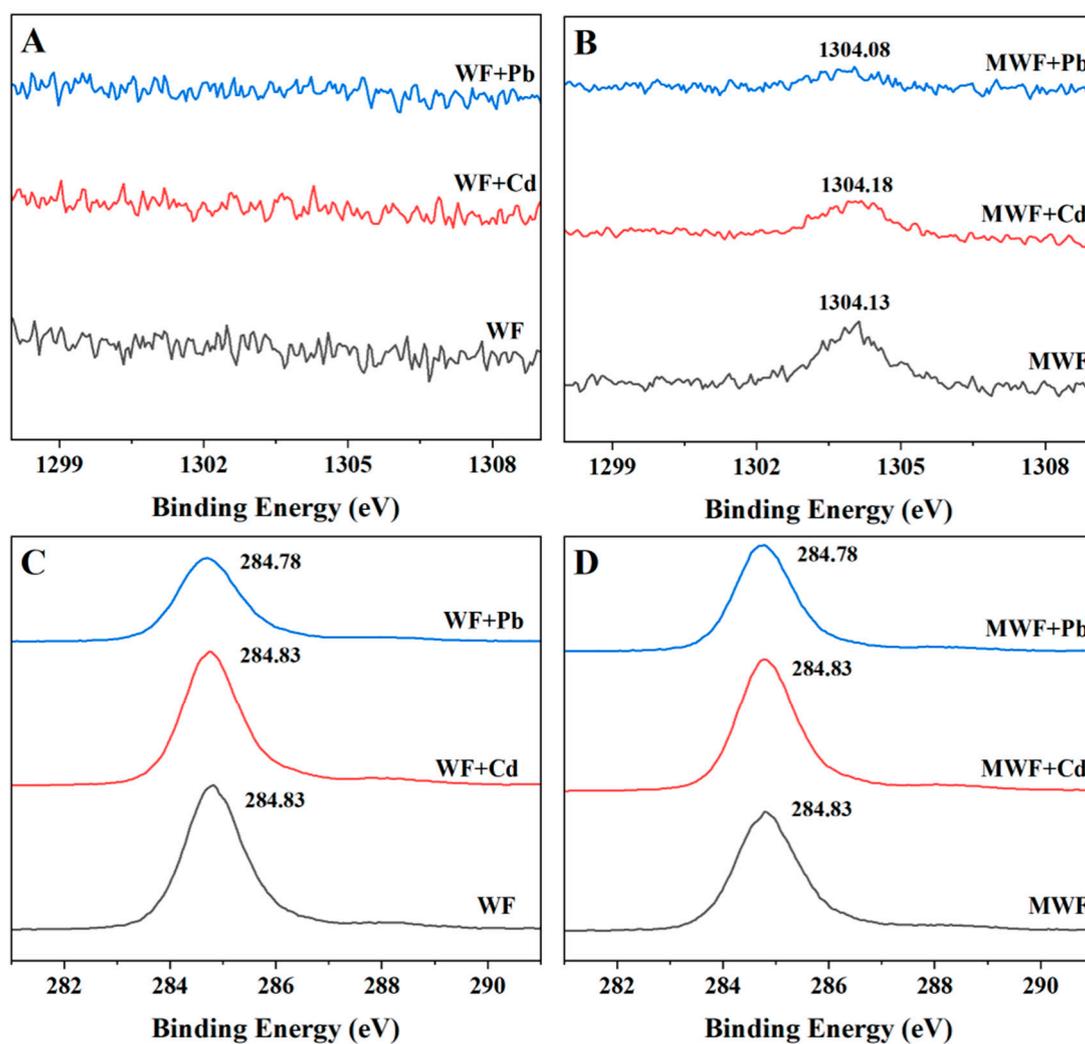


Figure S6. The XPS spectra of Mg1s (A, B) and C1s (C, D) of hydrochar WF and MWF before and after adsorption of Cd^{2+} and Pb^{2+}

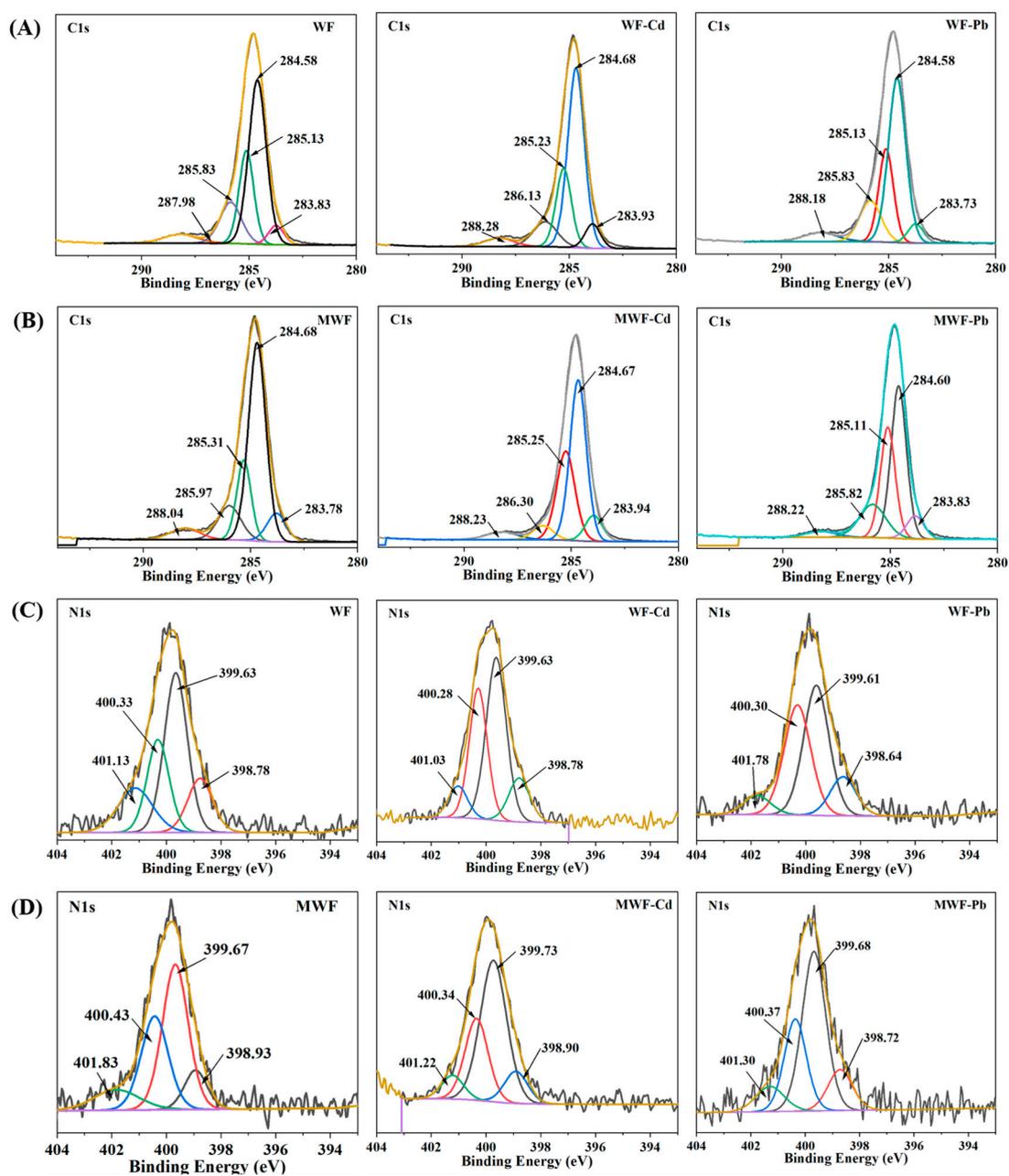


Figure S7. The C1s (A, B) and N1s (C, D) high-resolution XPS spectra of hydrochar WF (A, C) and MWF (B, D) before and after adsorption of Cd²⁺ and Pb²⁺

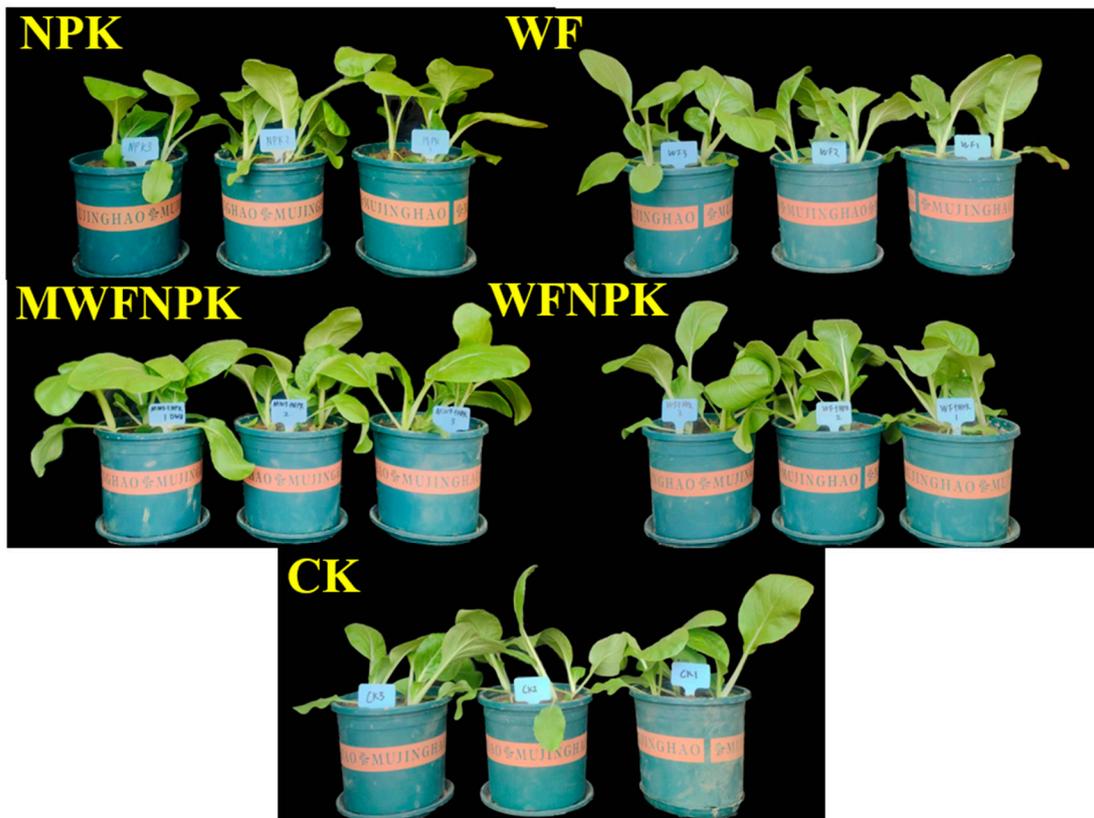


Figure S8. Growth of bok choy under different fertilization treatments