

## Supporting Information

### **Production, characterization and environmental remediation of emerging phosphorus-rich biochar/hydrochar: A comprehensive review**

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Table S1 Available information on production and environmental application of P-rich CHAR

Preparation condition	Feedstock	Modifying agents	Application fields	Reference
Pyrolysis, anaerobism, 550°C for 2h	corn stalk, bamboo, wood, and rice husk	$K_3PO_4$	Cd and Cu contaminated paddy field soil remediation	1
Pyrolysis, anaerobism, 500°C for 2h	rape straw	$KH_2PO_4$ / $Ca(H_2PO_4)_2$	Pb, Cd, and Cu contaminated silt soil remediation	2
Pyrolysis, anaerobism 500°C for 2 h	Pine tree sawdust and switchgrass	triple superphosphate and bone meal	Pb, Cu, and Cd contaminated soil remediation	3
Pyrolysis, anaerobism, 600°C for 3 h	Date palm leaves	$KH_2PO_4$	Cd, Cu, Pb, and Zn contaminated soil remediation	4
Pyrolysis anaerobism 500°C for 4 h	Wheat straw	$KH_2PO_4$	Stabilization of Cr, Cu, Pb, and Zn during anaerobic digestion of swine manure	5
Pyrolysis, anaerobism, 650°C for 2 h	Pig carcass-derived biochar	The total P concentration of dead pig bodies was greater than 80 g/kg	Cd and Pb contaminated paddy soil remediation	6
Pyrolysis, anaerobism, 700°C for 2 h	Bamboo	$KH_2PO_4$ modification and crosslink Mg-Al double-hydroxide composite	uranium contaminated soil remediation	7
Pyrolysis impregnation	pristine biochar	red P	Cd and Pb contaminated soil remediation	8

Pyrolysis anaerobism 500°C for 2 h	Rape straw	$\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ and $\text{KH}_2\text{PO}_4$	Pb, Cd, and Cu contaminated soil remediation	9
Pyrolysis anaerobism 480°C for 2 h	Maize straw and cow dung	$\text{KH}_2\text{PO}_4$	Pb, Cd contaminated soil remediation	10
Pyrolysis anaerobism 550°C for 2 h	camphorwood chips, bamboo offcut, cornstalk and rice husk	$\text{K}_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$	Cu(II), Cd(II), As(V) contaminated soil remediation	11
Pyrolysis, anaerobism 500°C and 2 h	Rape straw	$\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ , $\text{KH}_2\text{PO}_4$ ,	$\text{Pb}^{2+}$ adsorption in water	12
Pyrolysis, anaerobism 350°C, 550°C, 740°C and 2 h	Bamboo	$\text{Na}_2\text{HPO}_4$	$\text{Cd}^{2+}$ adsorption in water	13
Hydrochar, anaerobism 230°C for 2h	Fresh banana peels	$\text{H}_3\text{PO}_4$	$\text{Pb}^{2+}$ adsorption in water	14
Hydrochar, anaerobism 230°C for 2 h	Fresh and dehydrated banana peels	$\text{H}_3\text{PO}_4$	$\text{Pb}^{2+}$ adsorption in water	15
Pyrolysis, anaerobism 200°C, 350°C, 500°C and 650°C for 2 h	Pine sawdust	$\text{H}_3\text{PO}_4$	$\text{Cu}^{2+}$ and $\text{Cd}^{2+}$ adsorption in water	16
Pyrolysis, anaerobism 450°C for 1 h	Chicken feather	$\text{H}_3\text{PO}_4$	$\text{Cd}^{2+}$ and $\text{Pb}^{2+}$ adsorption in water	17
Hydrochar, in air atmosphere, 250°C for 2 h	Pomelo peel	$\text{H}_3\text{PO}_4$	$\text{Ag}^+$ and $\text{Pb}^{2+}$ adsorption in water	18

Hydrochar, in air atmosphere, 120°C for 2h	Cauliflower leaves	H <sub>3</sub> PO <sub>4</sub>	Cu <sup>2+</sup> and Pb <sup>2+</sup> adsorption in water	19
Pyrolysis, anaerobism 600°C for 1 h	Coffee residue	H <sub>3</sub> PO <sub>4</sub>	Pb <sup>2+</sup> and Cd <sup>2+</sup> adsorption in water	20
Pyrolysis, anaerobism 350°C, 500°C, 600°C for 2 h	Pine tree sawdust	H <sub>3</sub> PO <sub>4</sub>	Pb <sup>2+</sup> adsorption in water	21
Pyrolysis, anaerobism 350°C for 1 h	Taraxacum mongolicum Hand-Mazz	KH <sub>2</sub> PO <sub>4</sub>	As <sup>3+</sup> adsorption in water	22
Pyrolysis, Oxygen limiting 200°C, 350°C for 4 h	air-dried dairy manure	—	Pb <sup>2+</sup> adsorption in water	23
Hydrochar, anaerobism 450°C for 2 h	water hyacinth	H <sub>3</sub> PO <sub>4</sub>	Pb <sup>2+</sup> adsorption in water	24
Hydrochar, anaerobism 240°C for 2 h	corn straw	H <sub>3</sub> PO <sub>4</sub>	Pb <sup>2+</sup> adsorption in water	25
Pyrolysis anaerobism 550°C for 2 h	bamboo cutoff	Na <sub>2</sub> HPO <sub>4</sub>	Cd <sup>2+</sup> adsorption in water	26
Pyrolysis anaerobism 400°C for 2 h	reed straw	Potassium dihydrogen phosphate; hydroxyapatite	Pb <sup>2+</sup> adsorption in water	27
Pyrolysis anaerobism 500°C for 2 h	Rape straw	Ca(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> ·H <sub>2</sub> O and KH <sub>2</sub> PO <sub>4</sub>	Pb <sup>2+</sup> adsorption in water	28
Pyrolysis anaerobism 650°C for 4 h	Pine sawdust	H <sub>3</sub> PO <sub>4</sub>	Cu <sup>2+</sup> and Cd <sup>2+</sup> adsorption in water	29
Pyrolysis anaerobism 500°C for 2 h	Apple tree branches	KH <sub>2</sub> PO <sub>4</sub> , K <sub>2</sub> HPO <sub>4</sub> ·3H <sub>2</sub> O, and K <sub>3</sub> PO <sub>4</sub> ·3H <sub>2</sub> O	Cd <sup>2+</sup> adsorption in water	30

Pyrolysis anaerobism 550°C, 650°C, 750°C for 2 h	bamboo	K <sub>3</sub> PO <sub>4</sub>	Cd <sup>2+</sup> adsorption in water	31
Hydrochar, anaerobism 400°C for 1 h	cow manure	—	Pb <sup>2+</sup> and Cd <sup>2+</sup> adsorption in water	32
Pyrolysis anaerobism 500°C for 1 h	eucalyptus wood	H <sub>3</sub> PO <sub>4</sub>	Cr <sup>6+</sup> adsorption in water	33
Pyrolysis, anaerobism 550°C, for 1 h	rice straw	Ca(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub>	Carbon retention	34
Pyrolysis, anaerobism 500°C for 2 h	cellulose, xylan and lignin solid powders	Ca(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub>	Carbon retention	35
Hydrochar, anaerobism 200°C, 260°C for 2 h	Microalgae	cultured in wastewater	P slow-release	36
Pyrolysis, anaerobism 550°C, for 2 h	cotton straw and bentonite	Mg <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> solution	P slow-release	37
Pyrolysis anaerobism 600°C for 2 h, 3 h, 4 h	fermentation waste	—	P slow-release	38
Hydrochar, anaerobism 220°C, 240°C, 260°C for 2 h	wetland plant	—	P slow-release	39
Pyrolysis anaerobism 450°C for 2 h	sugarcane straw	H <sub>3</sub> PO <sub>4</sub>	P slow-release	40
Pyrolysis anaerobism 600°C for 5 h	Sewage sludge	—	P slow-release	41

Note: “—” means “without modifying agent”.

Table S2 Basic physiochemical properties of P-rich hydrochar derived from different raw biomass

Sample	Element content					References
	C(%)	H(%)	O(%)	O/C	H/C	
Banana peels	59.71	7.29	24.37	0.408	0.122	14
H <sub>3</sub> PO <sub>4</sub> modified banana peels hydrochar	63.11	6.37	21.12	0.334	0.100	
Cauliflower leaves	59.17	7.02	23.57	0.398	0.188	42
H <sub>3</sub> PO <sub>4</sub> modified cauliflower leaves hydrochar	67.13	5.37	13.47	0.201	0.074	
cow manure	44.37	4.58	23.25	0.524	0.126	43
K <sub>3</sub> PO <sub>4</sub> modified cow manure hydrochar	46.33	4.62	17.35	0.374	0.099	
verticillata	—	—	—	—	—	39
verticillata hydrochar	62.28	5.99	10.34	0.166	0.096	
spicatum	—	—	—	—	—	
spicatum hydrochar	52.66	4.81	13.09	0.248	0.091	
indica	—	—	—	—	—	44
Indica hydrochar	59.09	5.42	16.93	0.286	0.092	
Corn straw	46.53	5.85	39.55	0.85	0.127	44
phosphate rack-modified corn straw hydrochar	67.37	4.72	18.39	0.27	0.055	

Note: The raw biomass was calculated after removing the moisture. “—” means not reported.

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