Supporting Information

for

Sustainable Synthesis of Porous Carbon with Molecular Sieve-like Properties from Waste Biomass-Derived Heavy Oil via Dual Green Activation Strategy for Enhanced Aqueous Environmental Remediation

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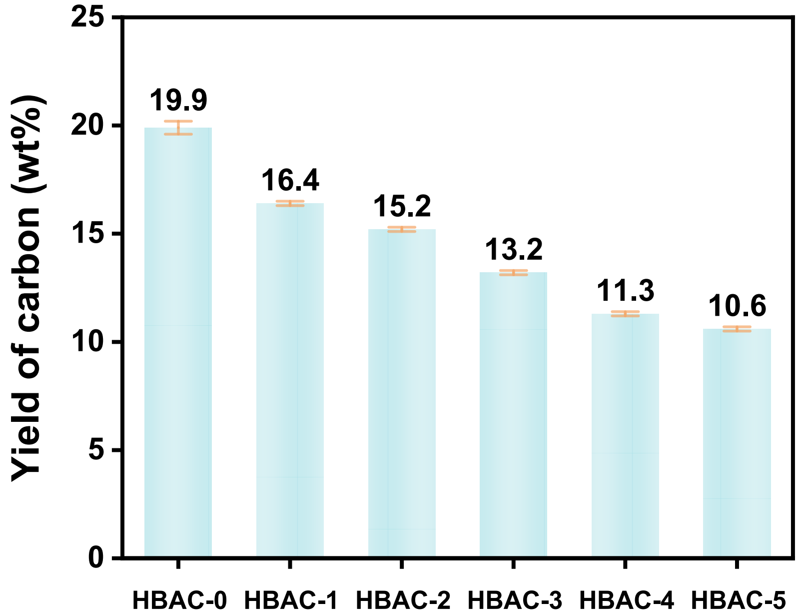

Figure S1. Yield of carbon adsorbents prepared by binary activation of HBO.

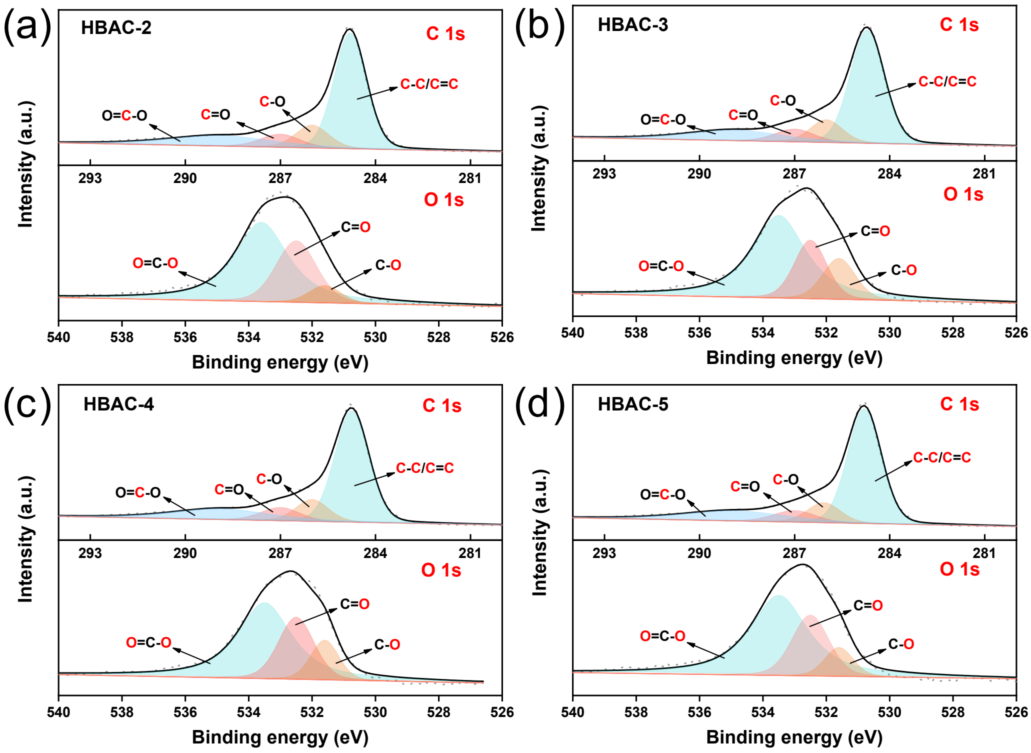

Figure S2. The fitting curves of XPS fine spectra of C 1s and O 1s of HBAC-2 (a), HBAC-3 (b), HBAC-4 (c), and HBAC-5 (d).

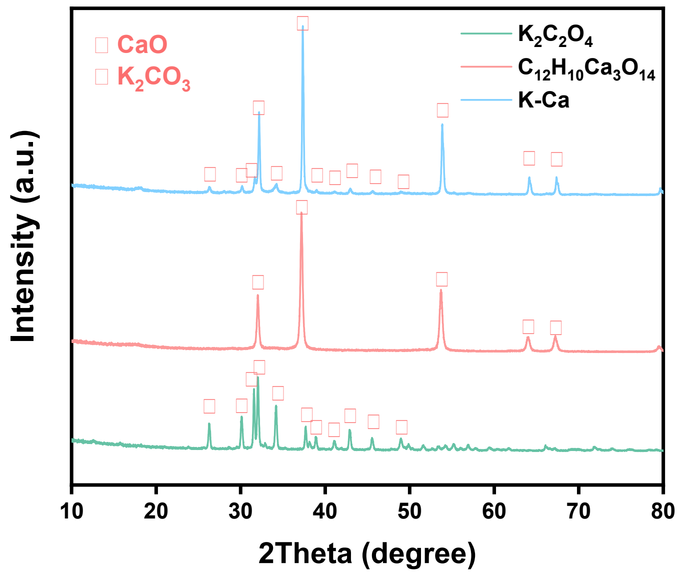

Figure S3. XRD patterns of the samples.

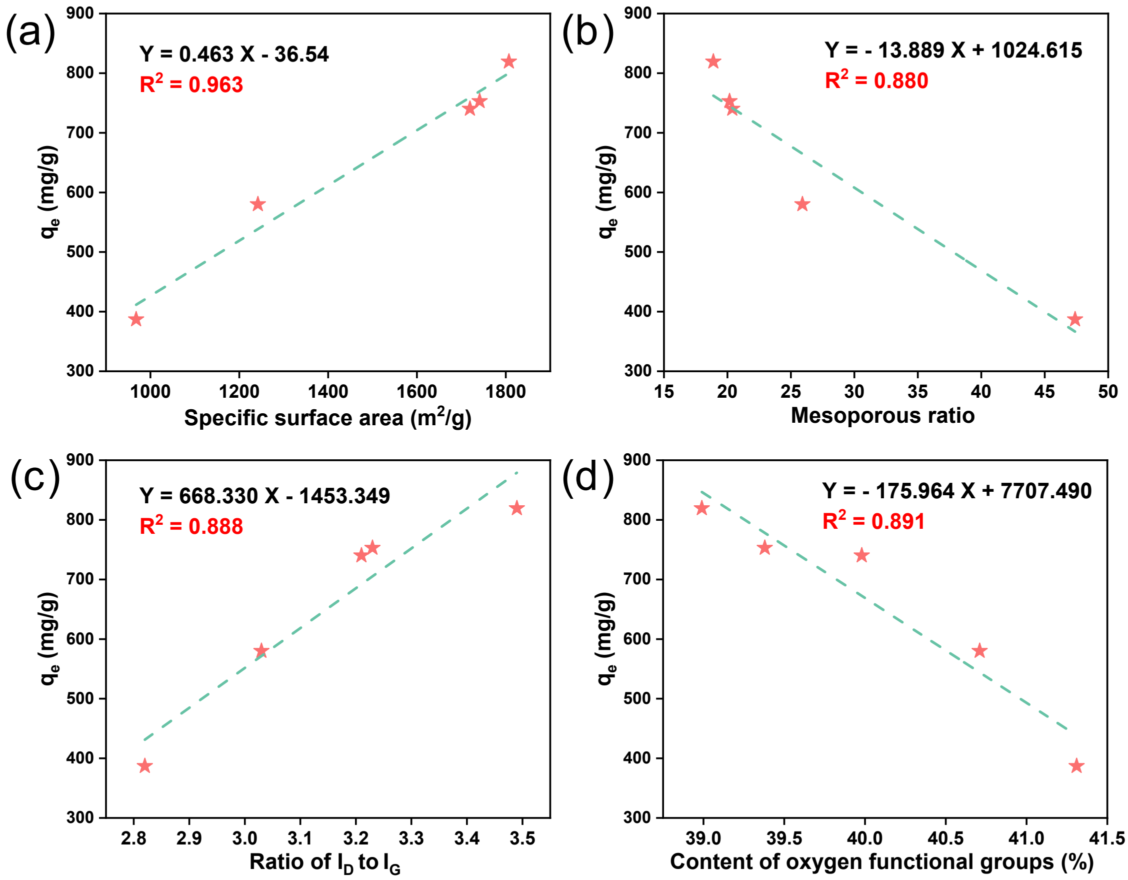

Figure S4. Linear correlation between adsorption capacity and specific surface area (a), ratio of mesoporous (b), ratio of I_D to I_G (c), and oxygen functional groups content (d) of the HBACs.

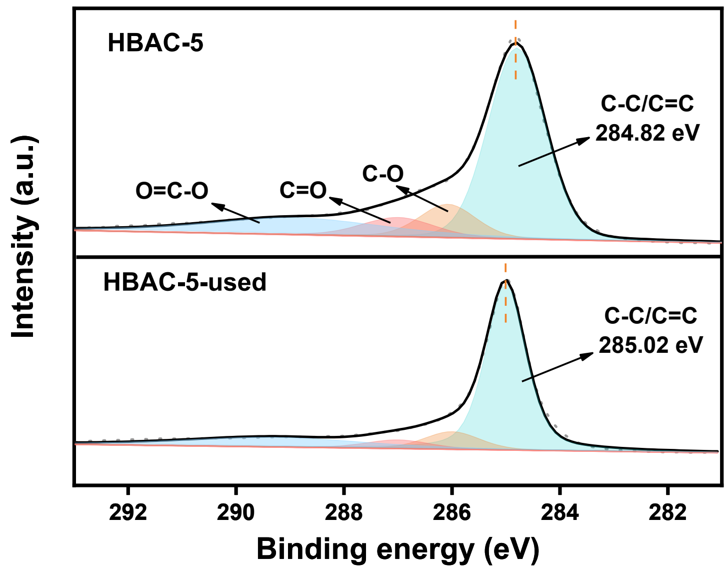

Figure S5. The fitting curves of XPS fine spectra of C 1s of HBAC-5 and HBAC-5-used.

Table S1. Adsorption results of CAC and the HBACs at different initial concentrations of MB.

Adsorbents	Initial concentration of MB (mg/L)						
	25	**50**	**100**	**200**	**400**	**600**	**800**
CAC	24.999	49.995	99.990	199.940	355.550	418.72	425.870
HBAC-0	24.999	49.995	99.980	199.930	332.080	341.85	346.880
HBAC-1	24.999	49.995	99.985	199.940	345.170	357.30	368.250
HBAC-2	24.999	49.995	99.990	199.940	399.840	498.65	545.390
HBAC-3	24.999	49.995	99.990	199.950	399.940	594.61	674.600
HBAC-4	24.999	49.995	99.990	199.950	399.950	596.08	676.270
HBAC-5	24.999	49.995	99.990	199.960	399.950	599.03	724.560

Experimental parameters: m_{AC} = 50 mg; V_{MB} = 50 mL; t = 1440 min; T = 298 K

Table S2. Adsorption results of CAC and HBACs at different adsorption times of MB.

Adsorbents	Adsorption time of MB (min)										
	0	**10**	**20**	**30**	**60**	**120**	**240**	**360**	**480**	**720**	**1440**
CAC	0	252.69	264.11	333.64	350.62	371.11	395.39	397.34	399.68	405.63	425.87
HBAC-0	0	188.86	199.53	221.30	248.78	262.55	310.16	322.88	326.60	340.96	356.65
HBAC-1	0	198.68	207.95	233.40	261.71	272.69	327.30	331.54	335.86	344.43	368.25
HBAC-2	0	324.55	360.60	405.11	421.86	491.10	497.78	504.88	510.35	526.34	545.39
HBAC-3	0	479.22	503.05	550.28	555.79	630.82	633.96	638.91	643.89	653.49	674.60
HBAC-4	0	490.15	511.10	563.01	568.25	633.01	639.77	645.60	652.06	657.30	676.27
HBAC-5	0	536.65	553.88	587.63	609.38	665.08	667.46	673.17	680.31	690.55	724.56

Experimental parameters: m_{AC} = 50 mg; V_{MB} = 50 mL; T = 298 K; c_0 = 1000 mg/g

Table S3. Comparison of MB adsorption performance of AC in different reports.

Entry	Feedstock	Activator	SSA (m^2/g)	TPV (cm^3/g)	Adsorption capacity (mg/g)	Adsorption Kinetics	Adsorption Isotherm	Ref.
S1	Pine	CO_2 & H_2O	906	0.46	160	PSO	Langmuir	[1]
S2	Citrus	NaOH	695	0.28	299	PSO	Freundlich	[2]
S3	Garden Waste	KOH	884	0.46	352	PSO	Freundlich	[3]
S4	Sugarcane bagasse	Physical ball milling	359	0.01	354	PSO	Langmuir	[4]
S5	Coconut husk	KOH & CO_2	1118	0.62	435	PSO	Langmuir	[5]
S6	Coconut husk	NaOH	1726	0.90	457	PSO	/	[6]
S7	Tile algae	KOH	744	0.45	480	PFO	Langmuir	[7]
S8	Walnut shell	KOH & CO_2	1654	1.60	540	PSO	Langmuir	[8]
S9	Date palm	H_3BO_4	/	/	666	PSO	Langmuir	[9]
S10	Kenaf	$K_2C_2O_4$	1258	0.68	330	/	/	[10]
S11	Bio-oil	$C_{12}H_{10}Ca_3O_{14}$	922	1.82	411	PSO	Langmuir	[11]
S12	Bio-oil	$K_2C_2O_4$	1147	0.70	357	PSO	Langmuir	This work
S13	Bio-oil	$C_{12}H_{10}Ca_3O_{14}$ & $K_2C_2O_4$	1857	0.72	819	PSO	Langmuir	This work

SSA: Specific surface area

TPV: Total pore volume

PFO: Pseudo-first-order

PSO: Pseudo-second-order

Table S4. Comparison of MB adsorption performance of other materials in different reports.

Entry	Adsorbents	SSA (m^2/g)	q_e (mg/g)	Ref.
1	Porous silica materials (PSAM)	88	90	[12]
2	Metal organic framework materials (MOF-Fe)	448	149	[13]
3	Silicon carbon (MSC_{a13})	447	157	[14]
4	Al-incorporated magadiite (AlMag240)	19	220	[15]
5	Montmorillonite (MC)	62	289	[16]
6	Iron-oxide/polymer composite	890	298	[17]
7	Hydrolyzed polyacrylamide/cellulose nanocrystals (HPAM/CNC)	-	326	[18]
8	GO aerogels (GOA)	42	417	[19]
9	GO–hydrogel porous nanocomposites	-	769	[20]
10	Heavy bio-oil based activated carbon (HBACs)	1857	819	This work

SSA: Specific surface area

q_e: Adsorption capacity

Table S5. Comparison of binary activation and activation methods in other works.

Entry	Activation method	Temperature or Power	Time	SSA (m^2/g)	q_e (mg/g)	E.S.	S.P.	C.P.	Ref.
1	Physical activation (Carbon dioxide, CO_2)	I: 400 ℃ II: 800 ℃	I: 2 h II: 1 h	353	178	*	**	*	[21]
2	Chemical activation (Sulfuric acid, H_2SO_4)	I: 450 ℃ II: 800 ℃	I: 2 h II: 1 h	920	199	*	**	*	[22]
3	Chemical activation (Phosphoric acid, H_3PO_4)	I: 300 ℃ II: 500 ℃	I: 2 h II: 1 h	1975	799	*	**	***	[23]
4	Chemical activation (Sodium hydroxide, NaOH)	600 ℃	1 h	1135	359	*	***	**	[24]
5	Chemical activation (Potassium hydroxide, KOH)	700 ℃	2 h	1160	165	*	***	*	[25]
6	Chemical activation (Zinc chloride, $ZnCl_2$)	I: 500 ℃ II: 130 ℃ III: 700 ℃	I: 2 h II: 5 h III: 1.5 h	843	275	**	*	*	[26]
7	Microwave assisted activation (Phosphoric acid, H_3PO_4)	I: 500 ℃ II: 640 W	I: 30 min II: 10 min	1370	476	**	**	**	[27]
8	Microwave assisted activation (Zinc chloride, $ZnCl_2$)	I: 500 ℃ II: 130 ℃ III: 720 W	I: 2 h II: 5 h III: 20 min	598	200	**	*	*	[28]
9	Green single activation (Calcium citrate, $C_{12}H_{10}Ca_3O_{14}$)	800 ℃	2 h	922	411	***	***	**	[11]
10	Green single activation (Potassium oxalate, $K_2C_2O_4$)	800 ℃	1 h	1147	357	***	***	**	This work
11	Green binary activation ($C_{12}H_{10}Ca_3O_{14}$ and $K_2C_2O_4$)	800 ℃	1 h	1807	819	***	***	***	This work

I represents the first stage of the process

II represents the second stage of the process

III represents the third stage of the process

SSA: Specific surface area

q_e: Adsorption capacity

E.S.: Environmental Sustainability

S.P.: Simplification of process

C.P.: Comprehensive performance of adsorbent

* represents poor performance

** represents good performance

*** represents superior performance

Table S6. The performance comparison with other microporous and mesoporous benchmarks.

Entry	Samples	SSA (m^2/g)	V_{Total} (cm^3/g)	V_{Micro} (cm^3/g)	V_{Meso} (cm^3/g)	P_D (nm)	q_e (mg/g)	Ref.
1	M-MCM-41	910	0.78	-	0.78	4.5	575	[29]
2	Ti-SBA-15	1031	1.69	-	1.69	8.0	208	[30]
3	ZSM-5	734	0.853	0.25	0.58	3.0	271	[31]
4	ZSM-5	264	0.23	0.13	0.10	1.8	370	[32]
5	MFI	365	0.72	0.17	0.55	3.9	476	[32]
6	ZSM-5	320	0.20	0.14	0.05	3.91	90	[33]
7	MMZ	840	0.67	0.01	0.66	2.5	273	[33]
8	MOF	1338	1.09	0.72	0.37	3.3	41	[34]
9	PPAC	388	0.13	-	0.13	1.3	292	[35]
10	HBAC-5	1857	0.72	0.58	0.13	1.2	819	This work

SSA: Specific surface area

V_{Total}: Total pore volume

V_{Micro}: Micropore volume

V_{Meso}: Mesopore volume

P_D: Pore diameter

q_e: Adsorption capacity

Table S7. Results of HBAC-5 adsorbing different pollutant adsorbates.

Entry	**Adsorbate**	**q_e (mg/g)**
1	Methylene Blue (MB)	819
2	Congo red (CR)	266
3	Phenol	303
4	Mixed solution	788 (MB) 43 (CR) 122 (Phenol)

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