Supporting Information

Effective Removal of Methylene Blue from Water Using Magnetic Lignite-Based Composite Hydrogel Beads

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The swelling properties of PAM/SA/HA/Fe$_3$O$_4$@Lignite hydrogel beads

The swelling ratio S_e of the hydrogel beads can be determined by comparing the weights of the hydrogel beads before and after swelling, and can be calculated using the following formula:

$$S_e = \frac{M_e - M_0}{M_0} \times 100\% \qquad \text{\\* MERGEFORMAT (S1)}$$

Here, M_0(g) represents the initial mass of the hydrogel microbeads, and M_e(g) represents the mass of the hydrogel microbeads after swelling.
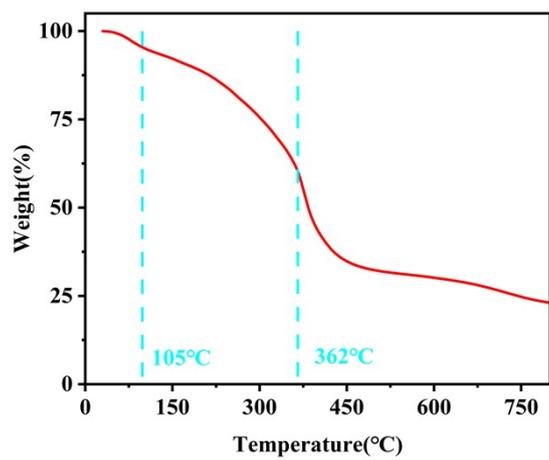
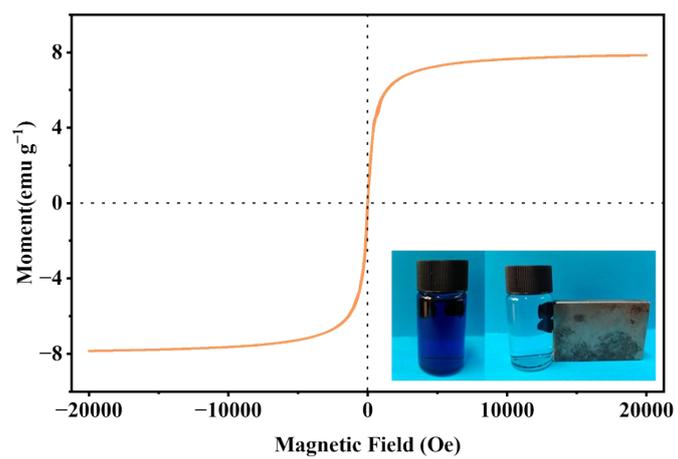**Fig. S1** The TGA curve of magnetic PAM/SA/HA/Fe$_3$O$_4$@Lignite hydrogel

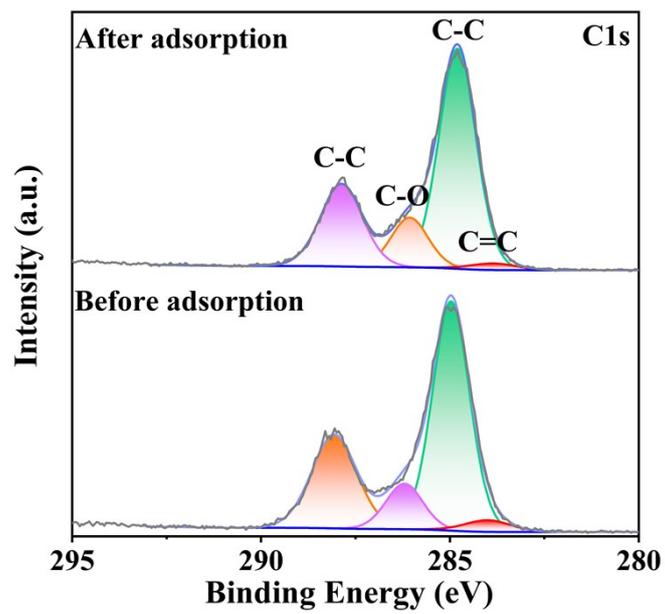**Fig . S2** Magnetization curve of PAM/SA/HA/Fe$_3$O$_4$@Lignite

Fig . S3 The C1s spectra of PAM/SA/HA/Fe$_3$O$_4$@Lignite hydrogel beads before and after adsorption
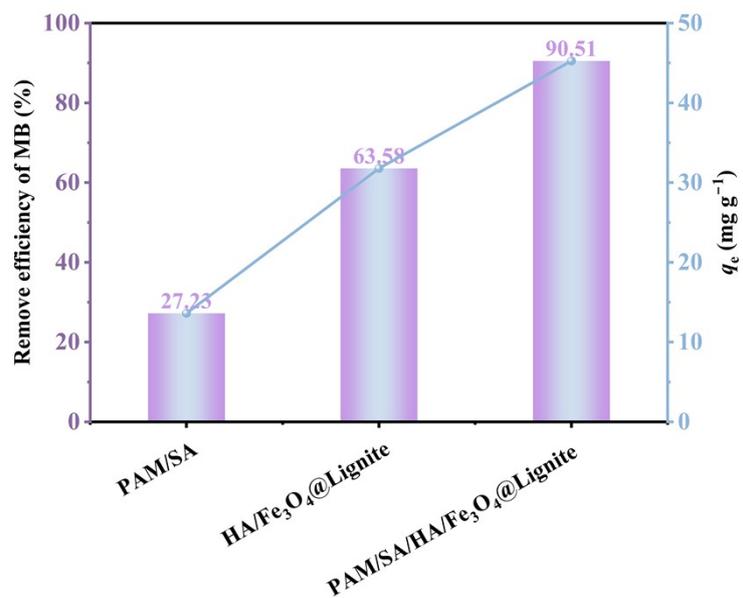
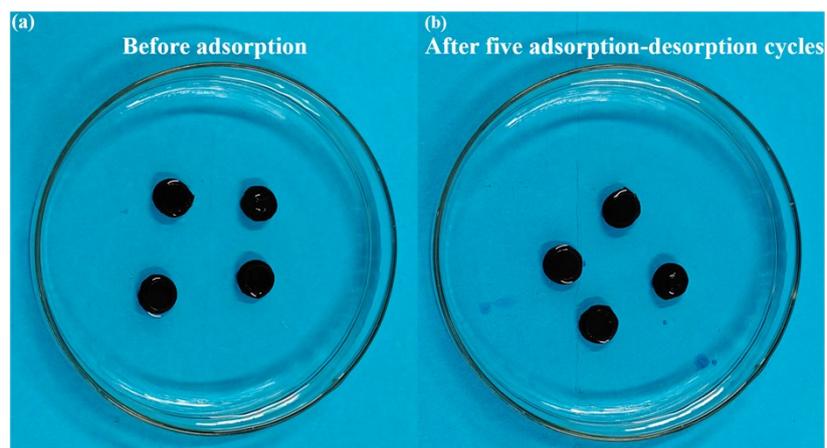**Fig. S4** Adsorption of MB by each component in PAM/SA/HA/Fe$_3$O$_4$@Lignite hydrogel beads

Figure. S5 (a) Photograph of PAM/SA/HA/Fe$_3$O$_4$@Lignite magnetic hydrogel prior to adsorption,(b) Photograph of PAM/SA/HA/ Fe$_3$O$_4$@ Lignite magnetic hydrogel after five adsorption-desorption cycles
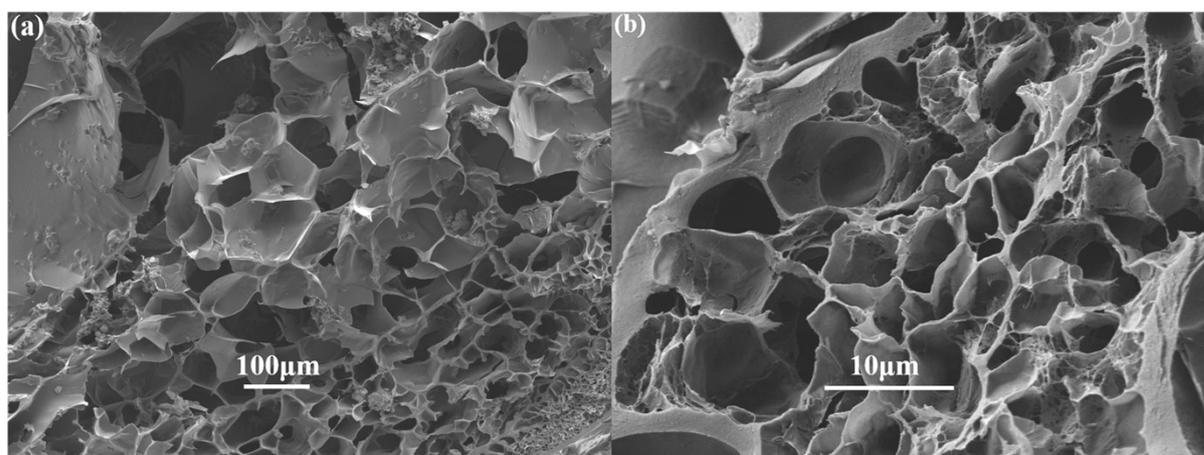

Figure. S6 SEM of PAM/SA/HA/ Fe$_3$O$_4$@ Lignite magnetic hydrogel after five adsorption-desorption cycles
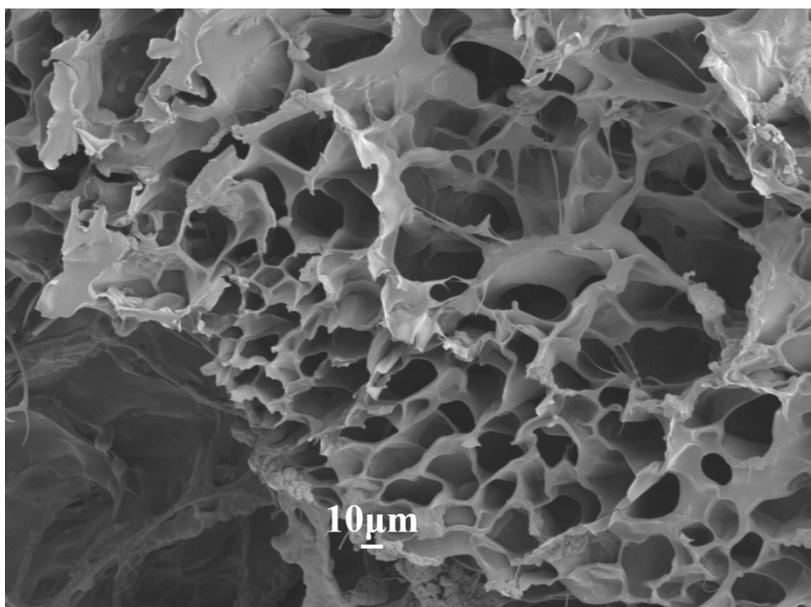
Fig. S7 SEM images of PAM/SA/HA/Fe$_3$O$_4$@Lignite hydrogel beads

Table S1. Fixed parameters under different experiments

Experiment Name	Fixed parameters
contact time	m=0.20g,pH=7,V=100mL,C_0=50mg L^{-1} and 100 mg L^{-1}.
initial dye concentration	m=0.20 g,pH=7,V=100 mL.
pH	m=0.20 g,V=100 mL, C_0=100 mg L^{-1}.
adsorbent dosage	C_0=100 mg L^{-1},V=100 mL,pH=7.
temperature	m=0.20 g,C_0=50-500 mg L^{-1},V=100 mL,pH=7.

Table S2. Parameters related to the D-R adsorption isotherm

Temperature	293K	298K	303K	308K	313K
q_d	120.582	124.604	129.132	134.116	139.599
$K_{ad}(\times 10^{-2})$	0.743	0.688	0.594	0.403	0.329
E_p	8.203	8.524	9.175	11.139	12.328
R^2	0.765	0.757	0.748	0.738	0.726

Table S3. Adsorption performance and capacity loss of PAM/SA/HA/Fe$_3$O$_4$@Lignite hydrogel beads after 5 cycles of adsorption

Number of cycles	1	2	3	4	5
q_e (mg g^{-1})	47.85	46.24	44.47	42.64	41.07
Remove efficiency of MB (%)	95.7	92.47	88.94	85.28	82.14
Capacity of loss (%)			13.56		