Supplementary Material

for

Enhanced combined sewer overflow treatment by rapid magnetic flocculation–magnetic sedimentation: Efficiency and mechanism

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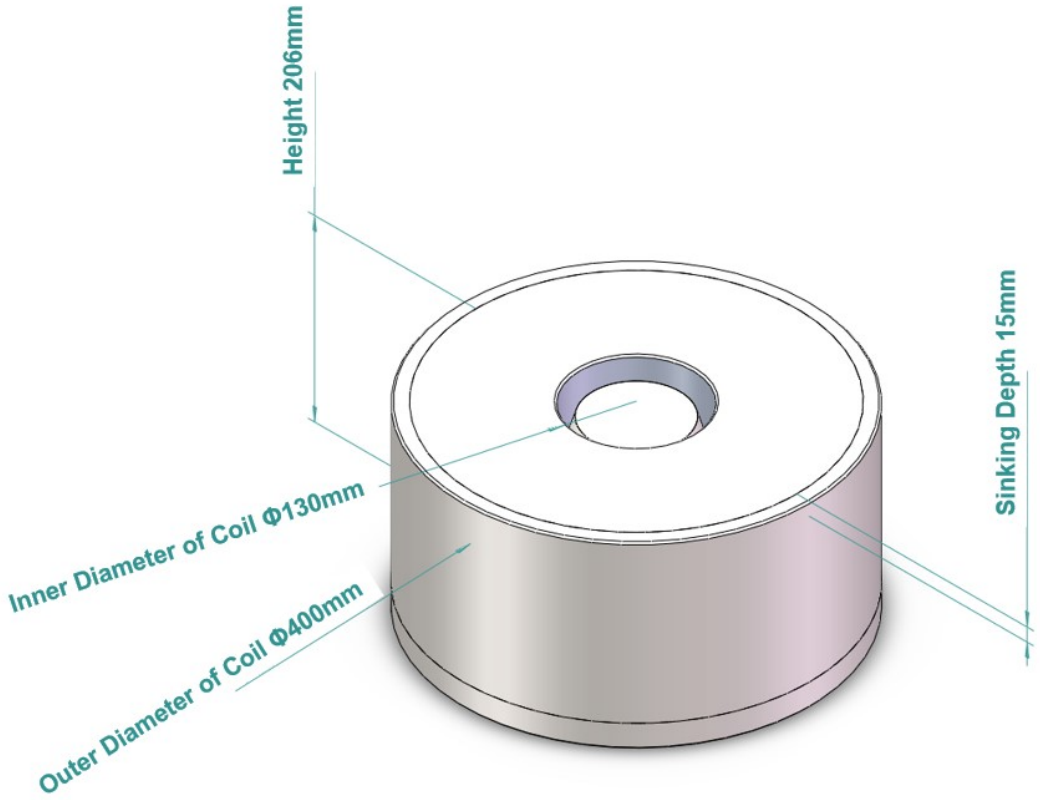
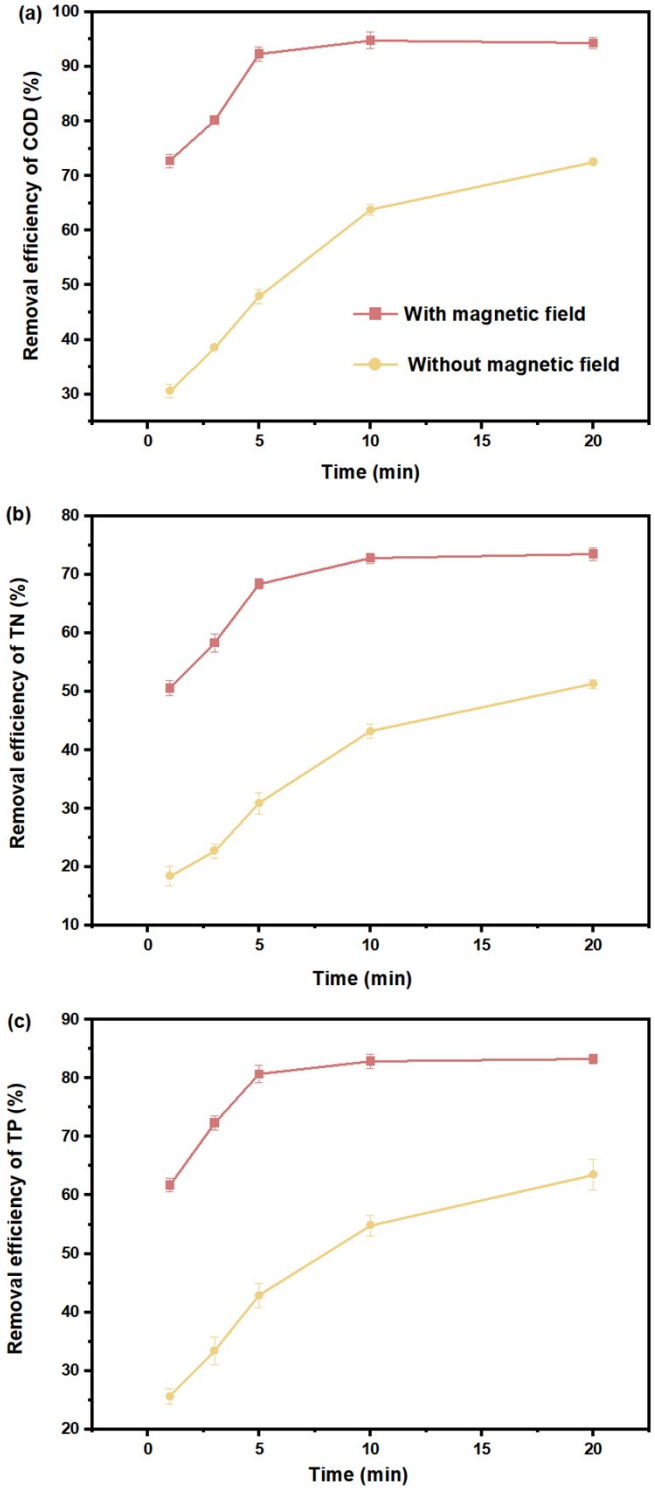


Fig. S1. External dimensions of magnetic field generation system.



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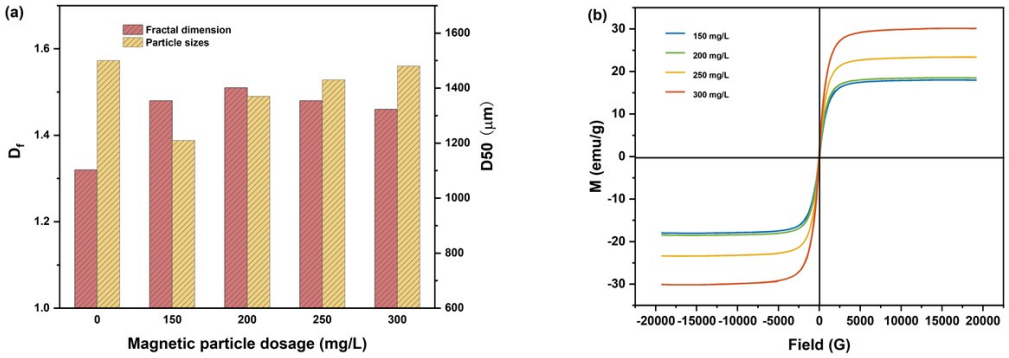
57 **Fig. S2.** Effects of settling method and settling time on the removal efficiency of COD, TN, and TP,

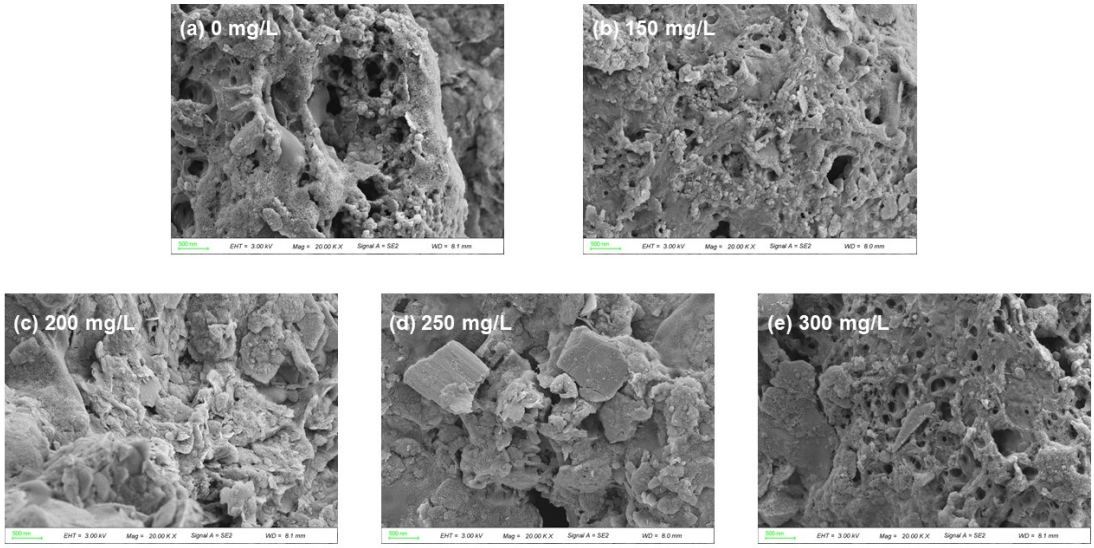
58 pH = 7.0 ± 0.1, T = 25 ± 1 °C.



59

60 **Fig. S3.** Particle sizes, fractal dimensions (a) and saturation magnetization intensity (b) of magnetic

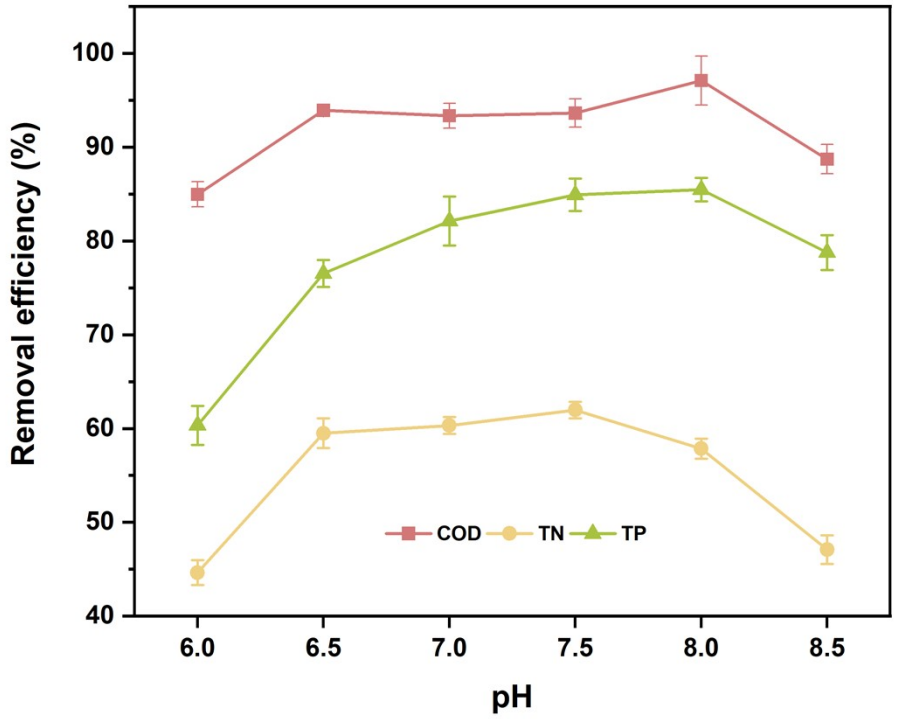
61 coagulation with different magnetic particle dosages, pH = 7.0 ± 0.1, T = 25 ± 1 °C.



62

63 **Fig. S4.** Morphological structures of the flocs generated by different magnetic particle dosages, pH

64 = 7.0 ± 0.1, T = 25 ± 1 ℃.



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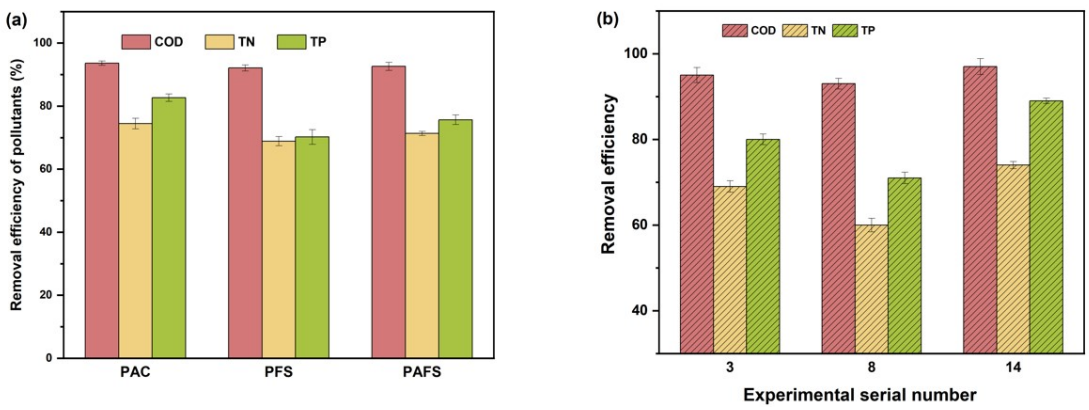
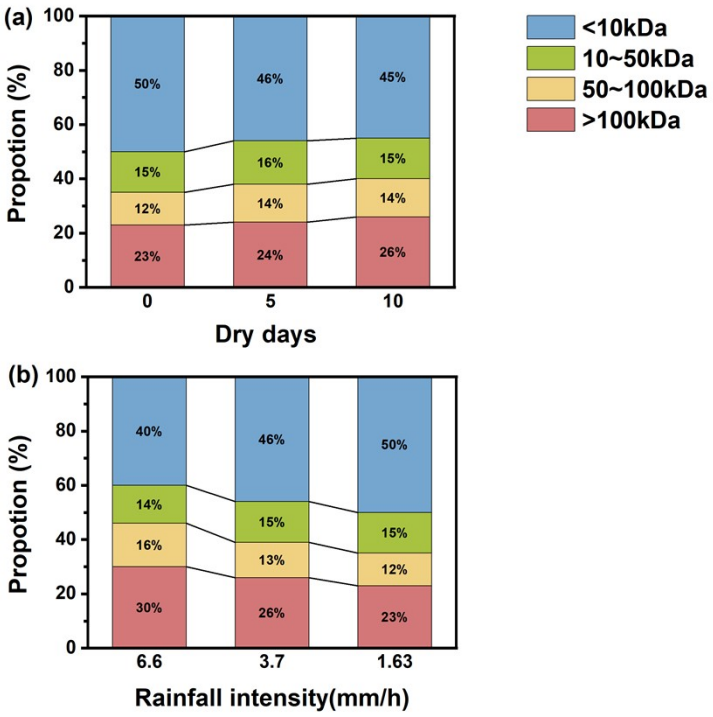
66 **Fig. S5.** Effects of pH on the removal efficiency of COD, TN, and TP, T = 25 ± 1 °C.



67

68 **Fig. S6.** Validation experiments conducted on typical CSO with high pollution. pH 7.0 ± 0.1, T =

69 25 ± 1 °C.



70

71 **Fig. S7.** Effect of weather conditions on the molecular weight distribution of dissolved organic

72 matter in CSOs. The number of sunny days in the early stage for the samples in (a) was 0, while the

73 average rainfall intensity for the samples in (b) was 1.67 mm/h.

Tab. S1. Rainfall conditions of different CSOs.

	Rainfall duration /h	Accumulated rainfall /mm	Average rainfall intensity /mm·h^{-1}	Sunny days /d
1	2.5	16.5	6.6	0
2	15.0	55.5	3.7	0
3	10.0	16.3	1.63	0
4	7.5	12.0	1.6	5
5	6.0	9.0	1.5	10
6	4.0	30.0	7.5	0
7	3.0	33.4	11.1	0

Tab. S2. Specific parameters of magnetic field generation system.

DB-130C Unipolar electromagnet					
Input voltage	Output voltage	Output current	Maximum output power	Magnetic field intensity range	index of stability
220V	0-170V	0-10A	1700W	0-400mT	≤3%

Tab. S3. Level of factors.

Levels	Factors			
	PAC dosage / (mg/L)	PAM dosage / (mg/L)	Slow stirring rate / (r/min)	Slow stirring time / (min)
1	50	0.5	100	1.5
2	100	1	150	2
3	150	1.5	200	2.5
4	200	2	250	3

Tab. S4. Orthogonal experimental results.

Experimental Serial Number	PAC dosage / (mg/L)	PAM dosage / (mg/L)	Slow stirring rate / (rpm/min)	Slow stirring time / (min)	COD removal efficiency / (%)	TN removal efficiency / (%)	TP removal efficiency / (%)
1	50	0.5	100	1.5	73.83	40.10	49.70
2	50	1	150	2	79.65	36.89	47.36
3	50	1.5	200	2.5	84.88	42.78	45.02
4	50	2	250	3	85.46	40.64	46.19
5	100	0.5	150	2.5	84.30	42.24	56.72
6	100	1	100	3	82.55	41.17	60.23
7	100	1.5	250	1.5	84.88	42.78	55.55
8	100	2	200	2	81.39	38.50	56.72
9	150	0.5	200	3	83.13	43.31	62.52
10	150	1	250	2.5	86.62	42.78	64.32
11	150	1.5	100	2	83.13	40.10	57.89
12	150	2	150	1.5	79.65	37.96	61.40
13	200	0.5	250	2	83.72	37.96	61.98
14	200	1	200	1.5	83.13	43.85	73.68
15	200	1.5	150	3	84.88	41.71	67.83
16	200	2	100	2.5	83.13	43.85	69.00

Tab. S5. Experimental factor levels and codes.

Factors	Levels				
	-1.414	-1	0	1	1.414
Magnetic particle dosage (mg/L)	129.29	150	200	250	270.71
Magnetic field intensity (mT)	108.58	150	250	350	391.42

Tab. S6. CCD design and response values.

Run	Real values		Response		
	A (mg/L)	B (mT)	Y_1 (%)	Y_2 (%)	Y_3 (%)
1	150	150	91.5	72.7	79.54
2	250	150	92.1	75.2	85
3	150	350	92.7	75.5	85.34
4	250	350	93.3	78.7	86.02
5	129.29	250	92.4	73.9	83.64
6	270.71	250	93	78.4	85.68
7	200	108.59	92.7	76.5	84.66
8	200	391.42	93.3	80	87.04
9	200	250	93.2	80.3	87.39
10	200	250	93.6	81.3	88.27
11	200	250	93.5	79.4	86.45
12	200	250	93.7	80.5	87.23
13	200	250	93.9	81	87.96

Tab. S7. ANOVA for COD removal rate.

Item	Sum of squares	Degrees of freedom	Mean square	F-value	Prob. > F
Model	4.74	4	1.18	9.58	0.0038
Residual	0.99	8	0.12	—	—
Lack of fit	0.72	4	0.18	2.69	0.18
Pure error	0.27	4	0.07	—	—

Notes: R^2: determination coefficient, R^2_{Adj}: adjusted R^2, R^2_{Pred}: predetermined R^2, CV: coefficient of variation, AP: adequate precision. Values for the reduced model with significant coefficients, R^2 = 0.8273, R^2_{Adj} = 0.7410, R^2_{Pred} = 0.3181, CV = 0.3782 %, AP = 7.4149.

Tab. S8. ANOVA for TN removal rate.

Item	Sum of squares	Degrees of freedom	Mean square	F-value	Prob. > F
Model	91.13	4	22.78	22.34	0.0002
Residual	8.16	8	1.02	—	—
Lack of fit	5.95	4	1.49	2.69	0.18
Pure error	2.21	4	0.55	—	—

Notes: R^2: determination coefficient, R^2_{Adj}: adjusted R^2, R^2_{Pred}: predetermined R^2, CV: coefficient of variation, AP: adequate precision. Values for the reduced model with significant coefficients, R^2 = 0.9178, R^2_{Adj} = 0.8768, R^2_{Pred} = 0.6778, CV = 1.2948 %, AP = 11.6617.

Tab. S9. ANOVA for TP removal rate.

Item	Sum of squares	Degrees of freedom	Mean square	F-value	Prob. > F
Model	49.47	4	12.37	7.17	0.0093
Residual	13.79	8	1.72	—	—
Lack of fit	11.80	4	2.95	5.95	0.0561
Pure error	1.98	4	0.49	—	—

Notes: R^2: determination coefficient, R^2_{Adj}: adjusted R^2, R^2_{Pred}: predetermined R^2, CV: coefficient of variation, AP: adequate precision. Values for the reduced model with significant coefficients, R^2 = 0.8723, R^2_{Adj} = 0.7811, R^2_{Pred} = 0.2661, CV = 1.2533 %, AP =8.8269.

Tab. S10. Significance of quadratic model coefficient of COD removal rate.

Independent variables	Degrees of freedom	Standard error	Prob. > F
A	1	0.13	0.0954
B	1	0.13	0.0185
AB	1	0.19	0.9999
A^2	1	0.14	0.0061
B^2	1	0.14	0.0256

Tab. S11. Significance of quadratic model coefficient of TN removal rate.

Independent variables	Degrees of freedom	Standard error	Prob. > F
A	1	0.38	0.0055
B	1	0.38	0.0075
AB	1	0.54	0.7741
A^2	1	0.41	0.0004
B^2	1	0.41	0.0064

Tab. S12. Significance of quadratic model coefficient of TP removal rate.

Independent variables	Degrees of freedom	Standard error	Prob. > F
A	1	0.37	0.02079
B	1	0.37	0.0122
AB	1	0.53	0.0614
A^2	1	0.40	0.0039
B^2	1	0.40	0.0280

Tab. S13. Water quality of CSOs under different weather conditions (Number corresponds to Table S1)

	COD (mg/L)	SCOD (mg/L)	TN (mg/L)	STN (mg/L)	TP (mg/L)	STP (mg/L)	NH_3-N (mg/L)	SNH_3-N (mg/L)
1	1210	112	36	10	1100	22.6	6.1	20.3
2	810	82	23.5	6.8	700	13.5	6.3	17.2
3	172	38	18.7	11.8	270	8.55	6.8	11.3
4	400	52	20.5	10.1	500	17.1	9.2	15.5
5	460	47	21.7	10.6	560	13.8	7.3	15.1
6	1130	104	31	9	1200	18.4	6.7	18.7
7	1400	140	42	11.7	1600	12.3	3.4	18.9