

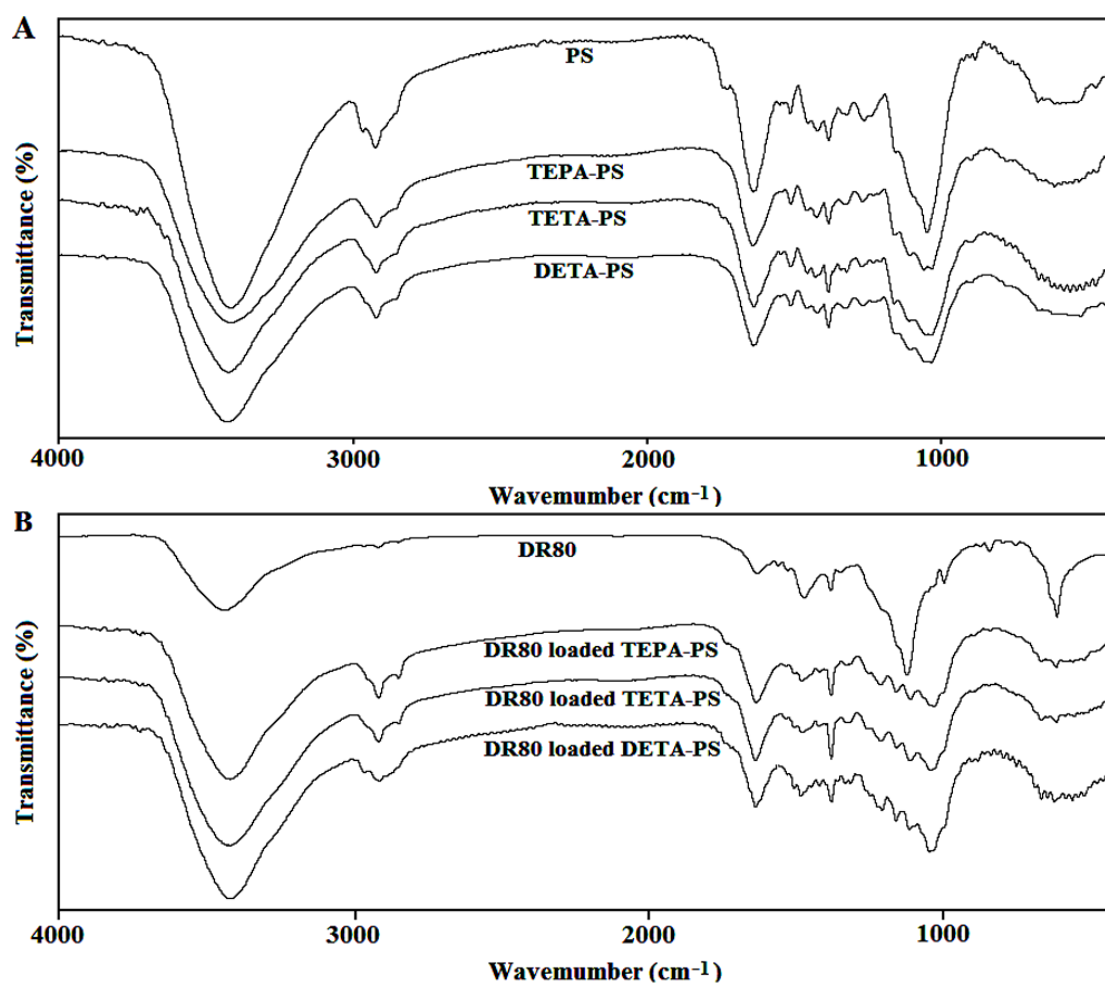


Fig. 1S. FTIR spectra of raw PS, TEPA-PS, TETA-PS and DETA-PS (A) and DR80 adsorption onto TEPA-PS, TETA-PS and DETA-PS (B) at the optimal conditions.

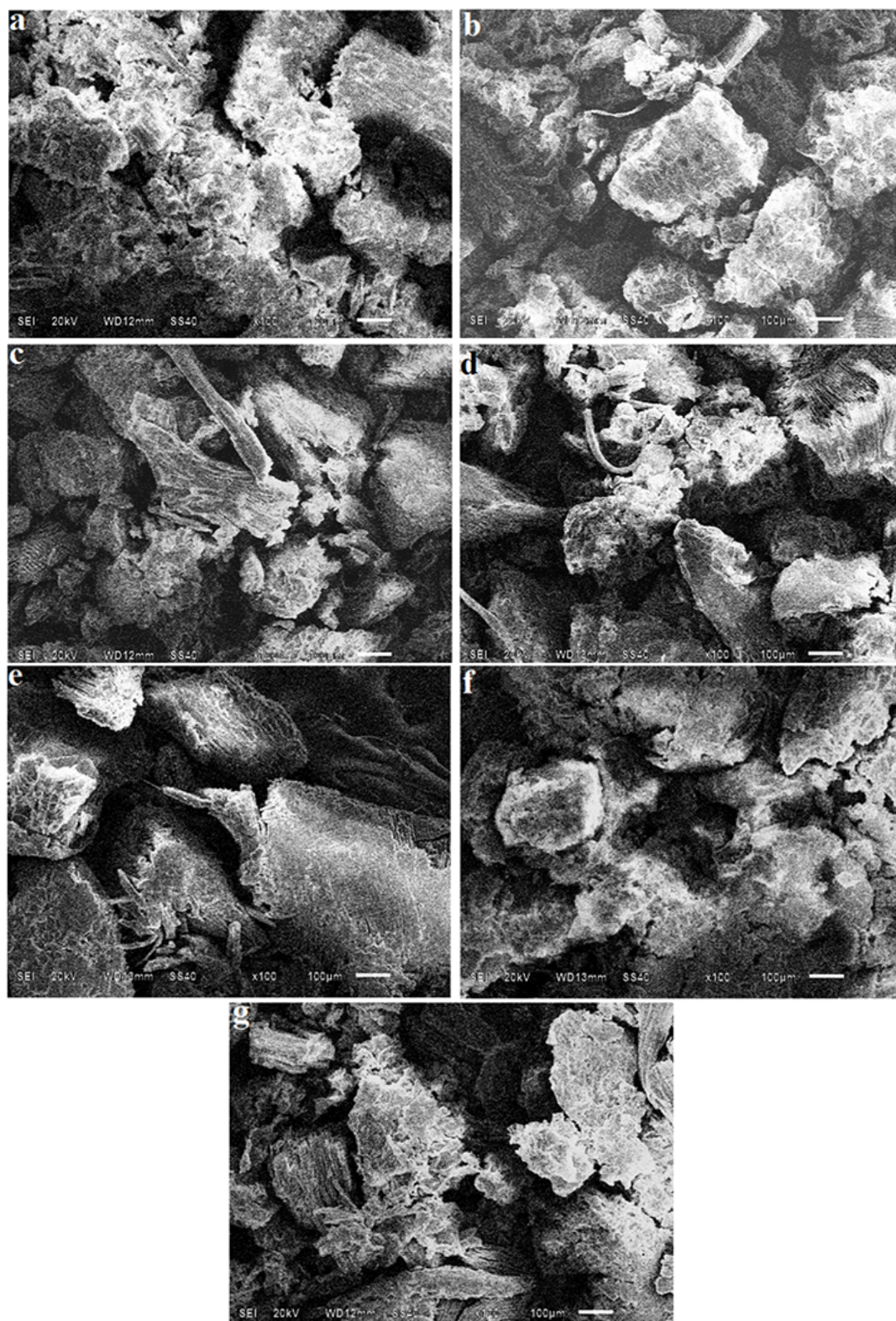


Fig. 2S. Scanning electron micrographs (SEM) of raw PS (a), TEPA-PS (b), TETA-PS (c), DETA-PS (d), TEPA-PS adsorbing DR80 (e), TETA-PS adsorbing DR80 (f), and DETA-PS adsorbing DR80 (g).

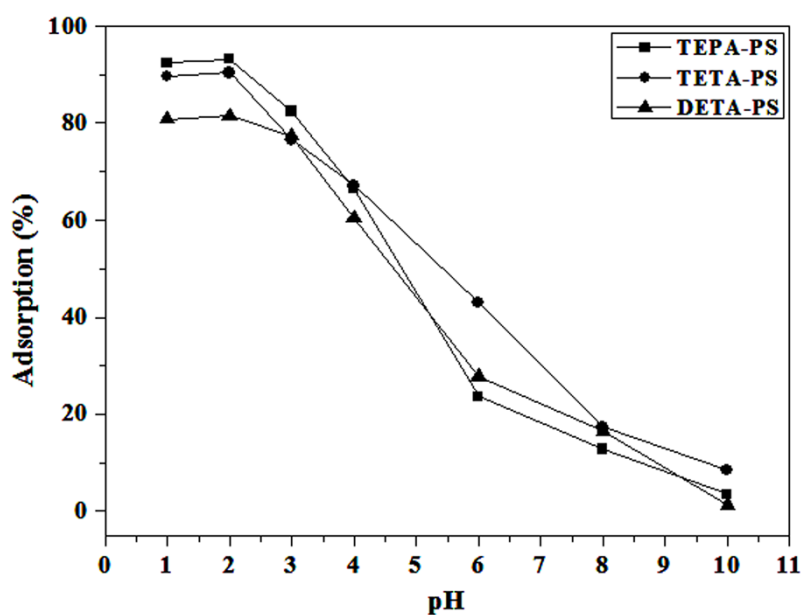


Fig. 3S The effects of pH for DR80 adsorption onto TEPA-PS, TETA-PS, or DETA-PS (initial concentration of DR80 = 140 mg/L, adsorbent dose = 20.0 mg/100mL, $T = 70^{\circ}\text{C}$ and $t = 180\text{min}$ for the DR80 system).

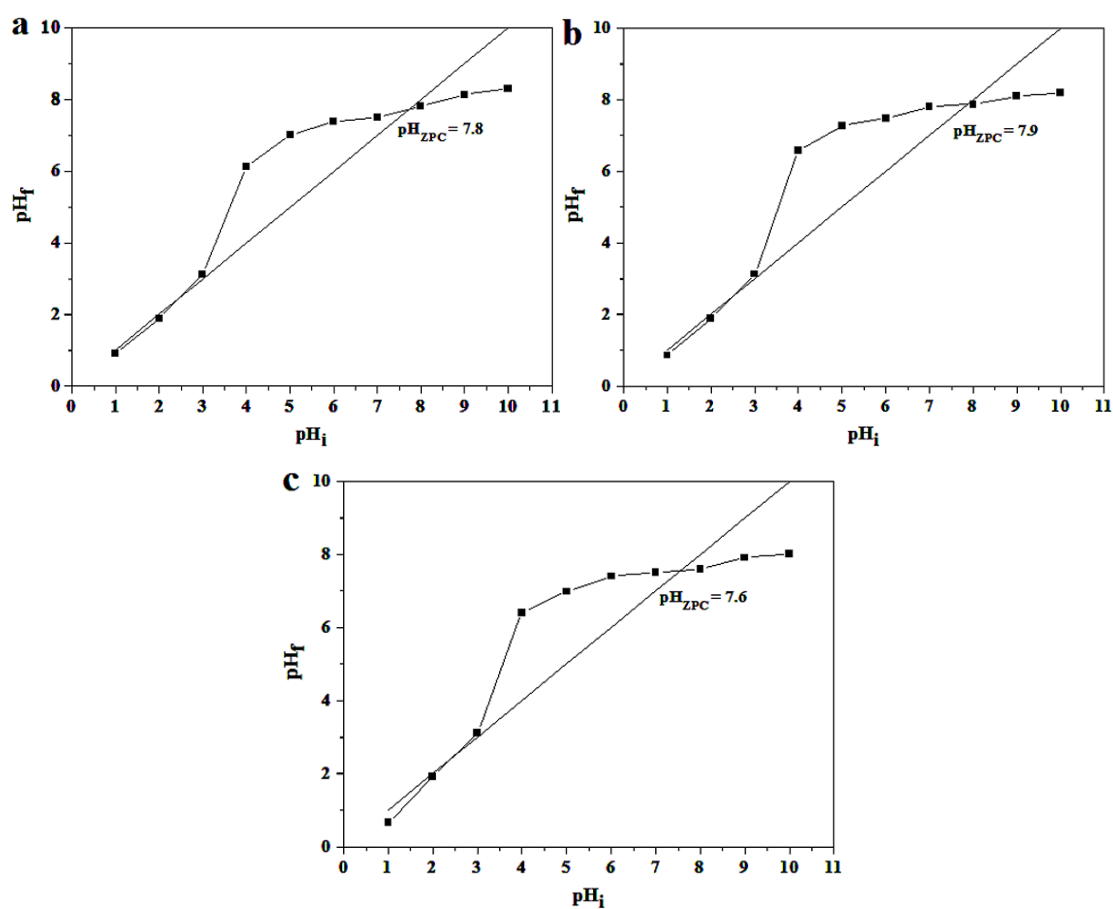


Fig. 4S Determination of the point of zero charge of TEPA-PS (a), TETA-PS (b), and DETA-PS (c).

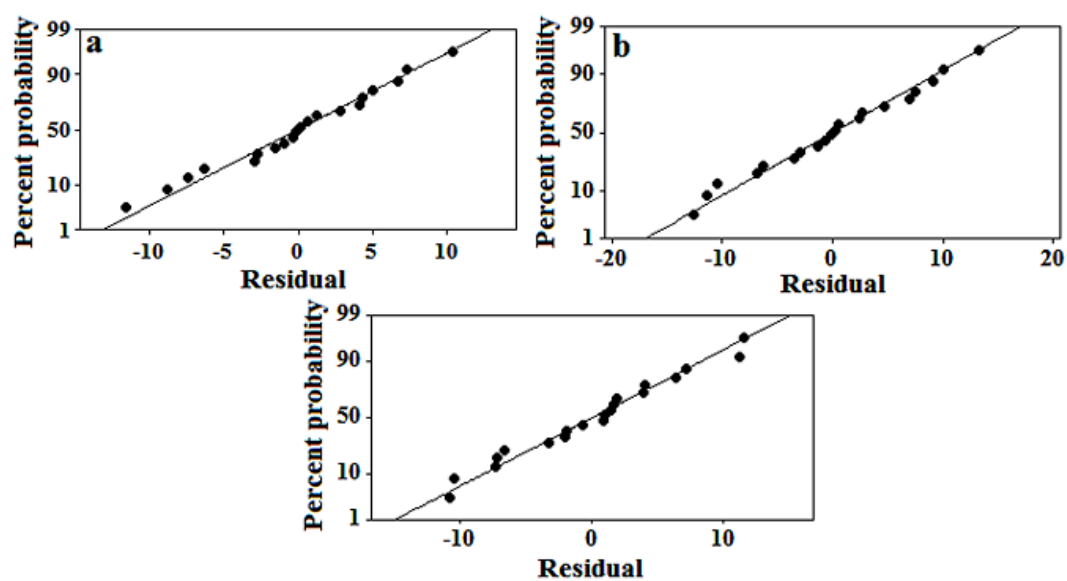
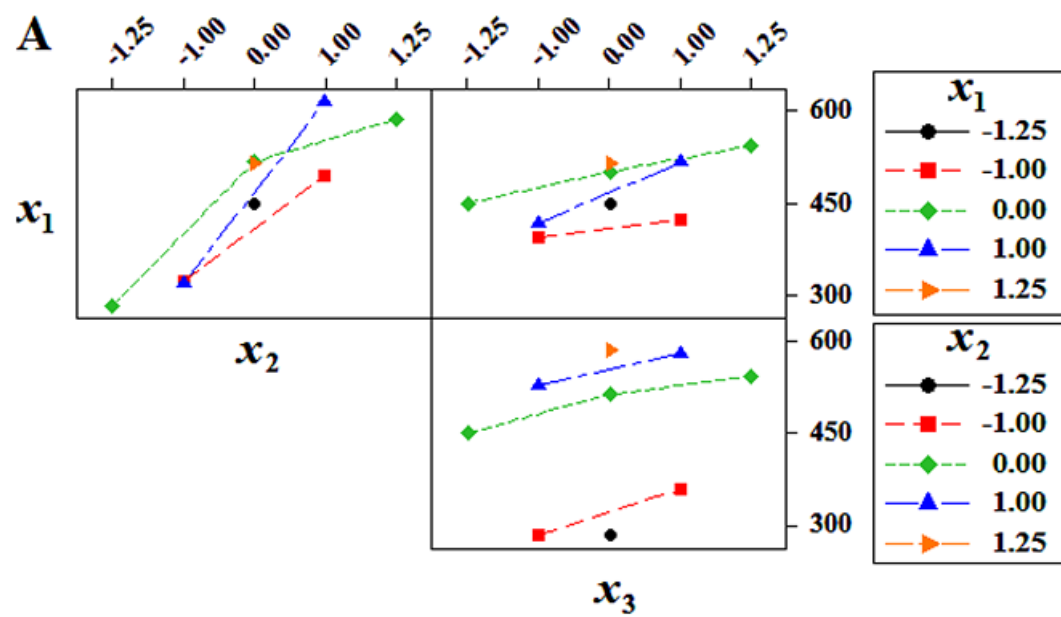


Fig. 5S. Normal probability plots of residuals for the adsorption capacities of DR80 onto TEPA-PS (a), TETA-PS (b), or DETA-PS (c).



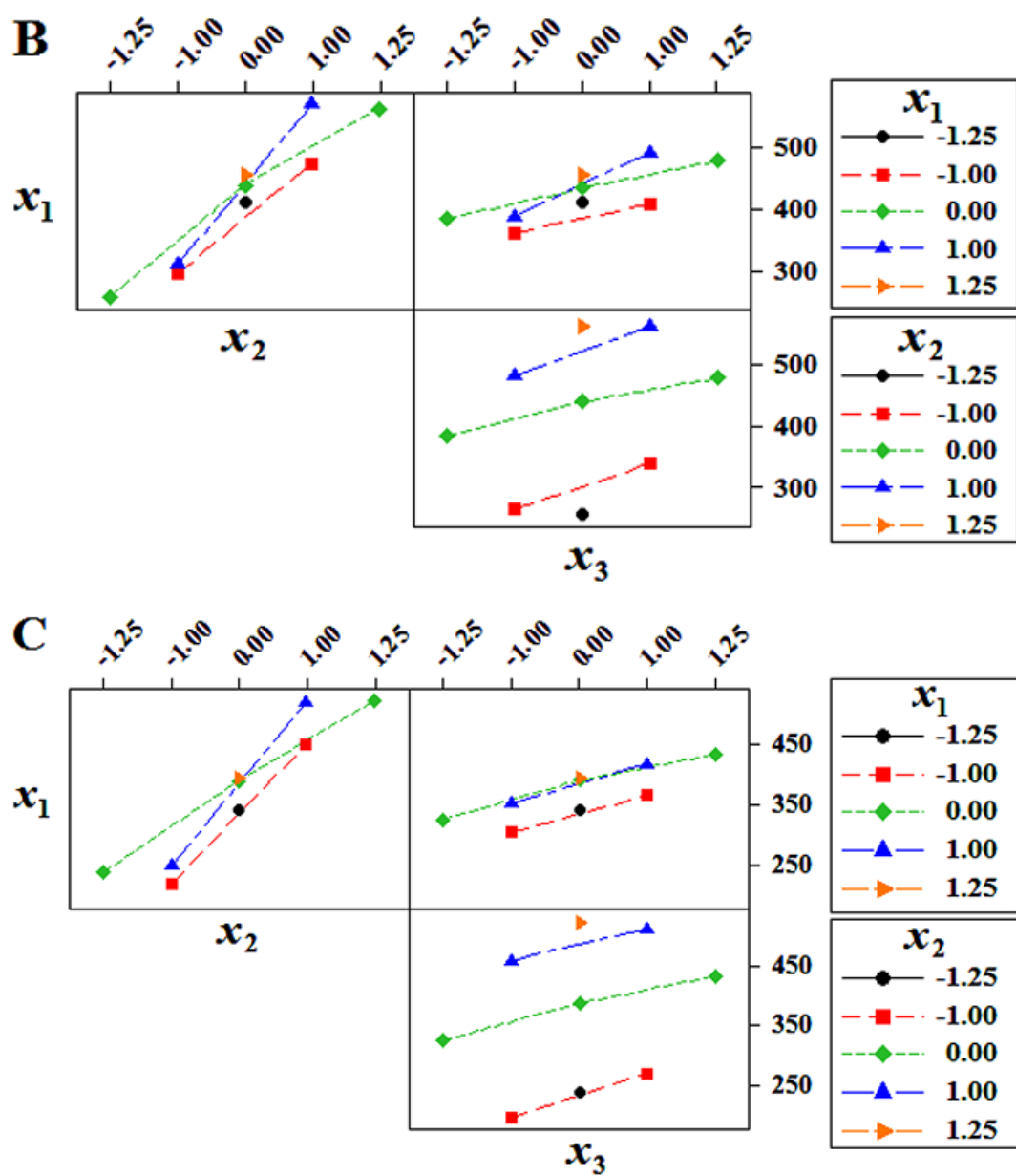


Fig.6S. Interaction effect plots for DR80 removal by TEPA-PS (A), TETA-PS (B), or DETA-PS (C) biosorbent.

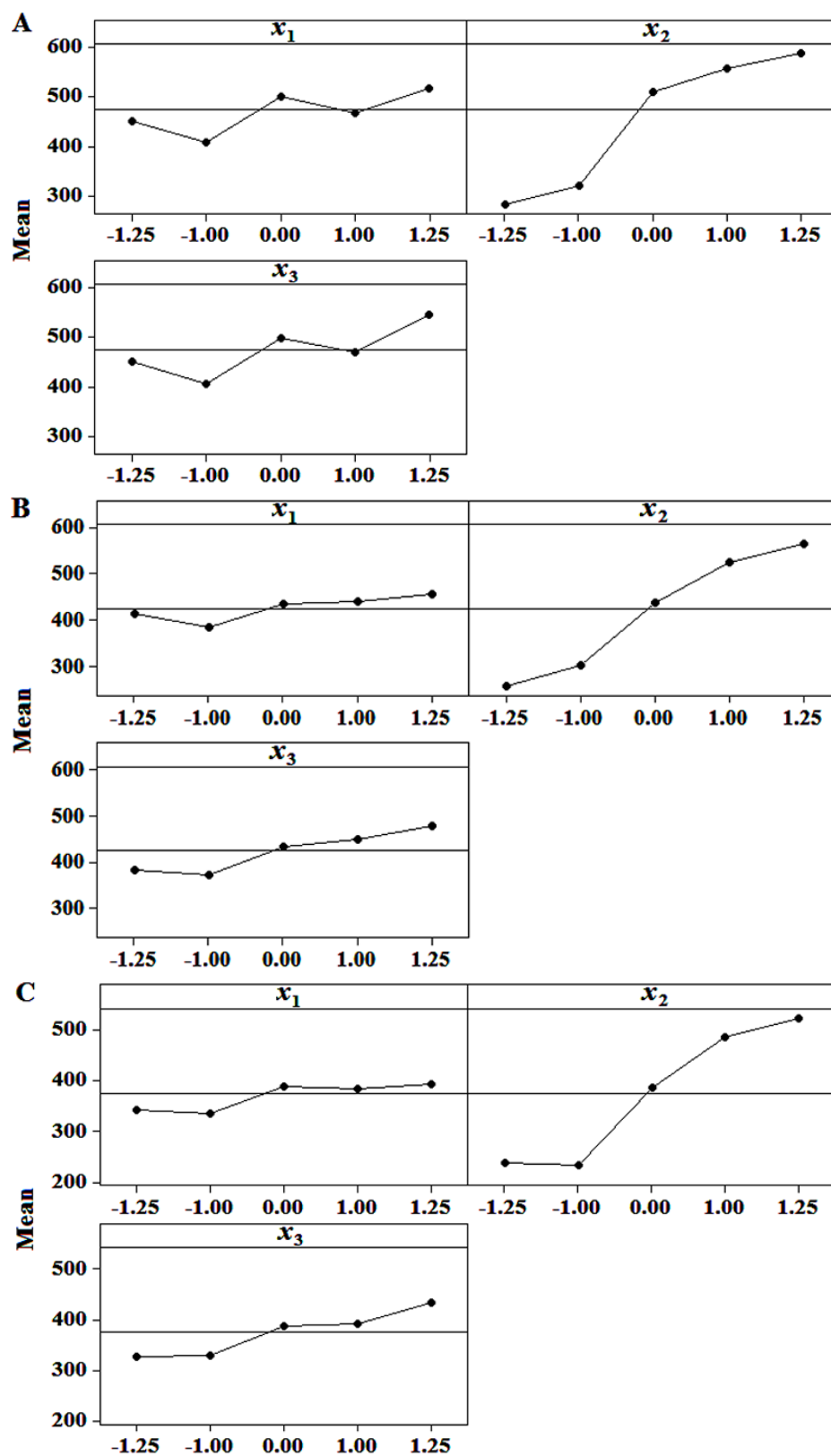


Fig.7S. Main effect plots for DR80 removal by TEPA-PS (A), TETA-PS (B), or DETA-PS (C) biosorbent.

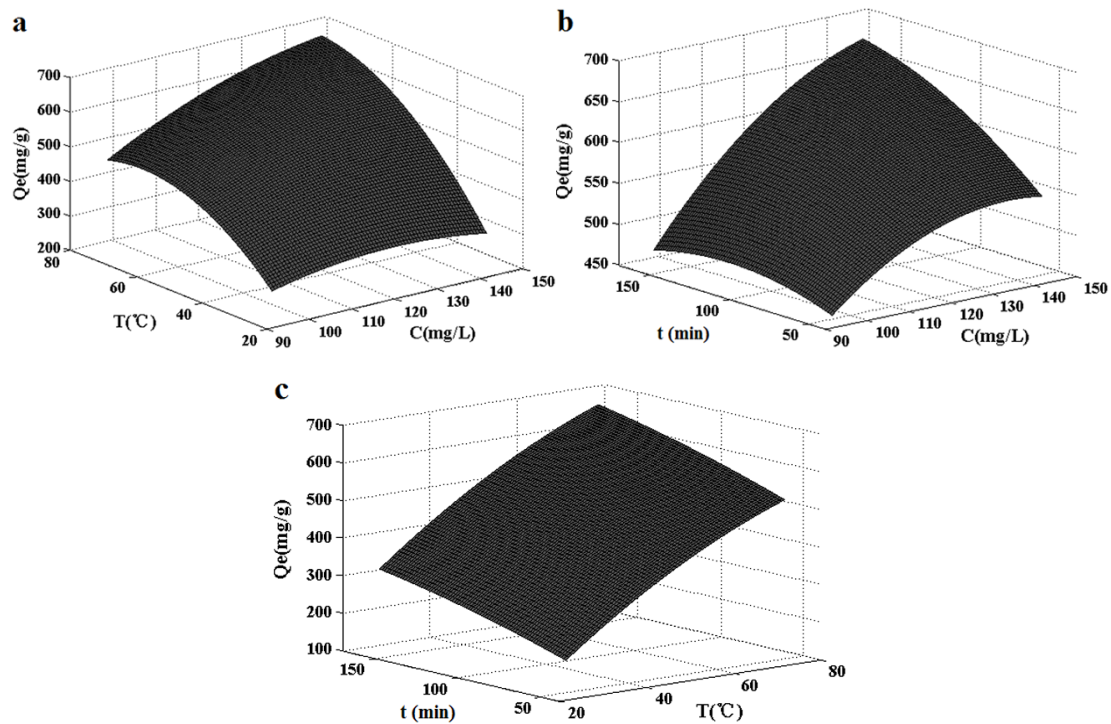


Fig. 8S. Response surface plots of the combined effects for DR80 removal by TEPA-PS: (a) initial concentration of DR80 (C) and temperature of adsorption reaction (T), $t = 150$ min; (b) C and the time of adsorption reaction (t), $T = 70^\circ\text{C}$; (c) T and t , $C = 140$ mg/L.

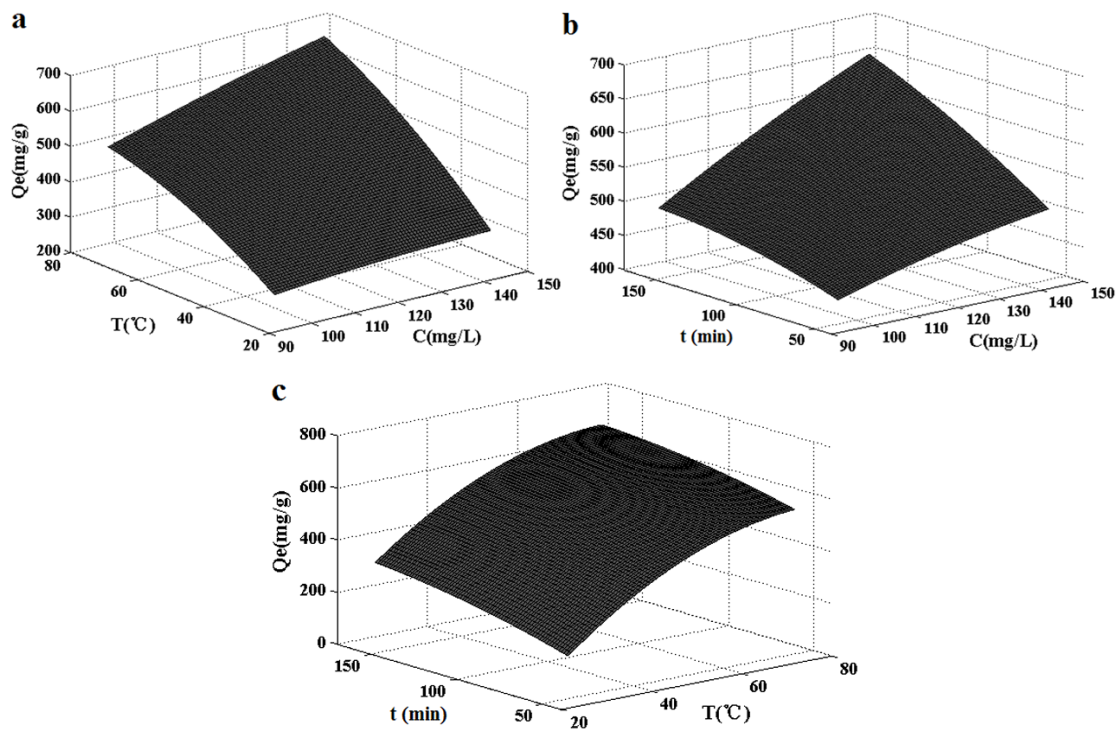


Fig. 9S. Response surface plots of the combined effects for DR80 removal by TETA-PS: (a) initial concentration of DR80 (C) and temperature of adsorption reaction (T), $t = 150$ min; (b) C and the time of adsorption reaction (t), $T = 70^\circ\text{C}$; (c) T and t , $C = 140$ mg/L.

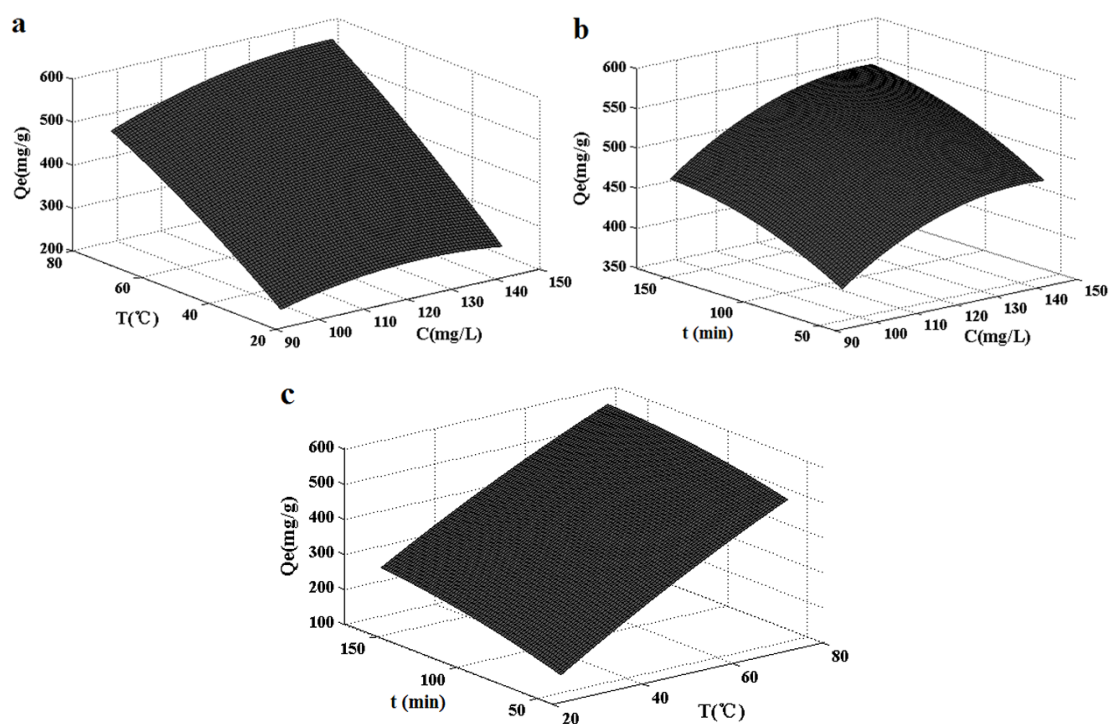
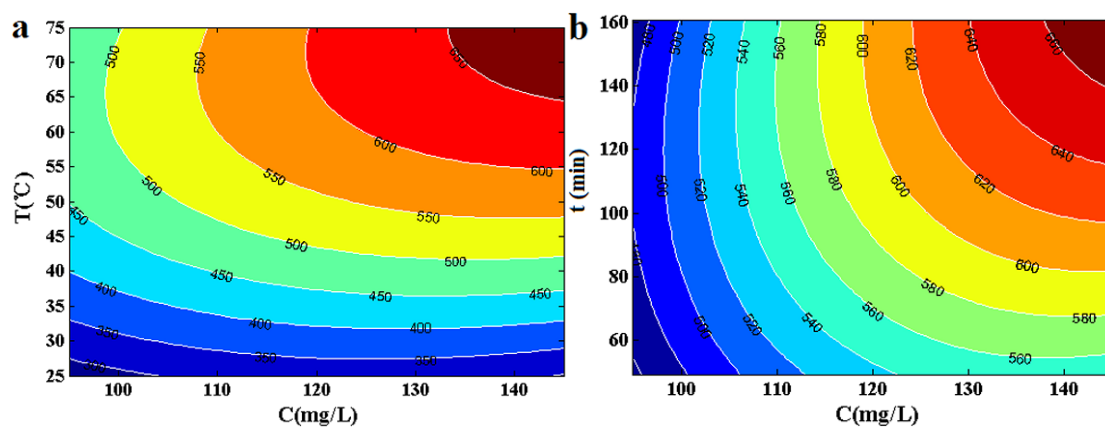


Fig. 10S. Response surface plots of the combined effects for DR80 removal by DETA-PS: (a) initial concentration of DR80 (C) and temperature of adsorption reaction (T), $t = 150$ min; (b) C and the time of adsorption reaction (t), $T = 70$ °C; (c) T and t , $C = 140$ mg/L.



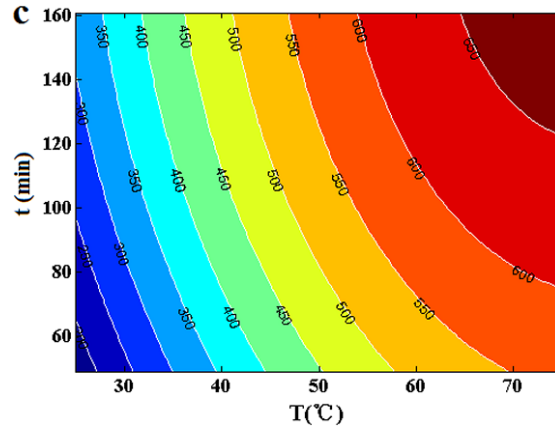


Fig. 11S. Contour plots of the combined effects for DR80 removal by TEPA-PS: (a) initial concentration of DR80 (C) and temperature of adsorption reaction (T), $t = 150\text{min}$; (b) C and the time of adsorption reaction (t), $T = 70^\circ\text{C}$; (c) T and t , $C = 140\text{ mg/L}$.

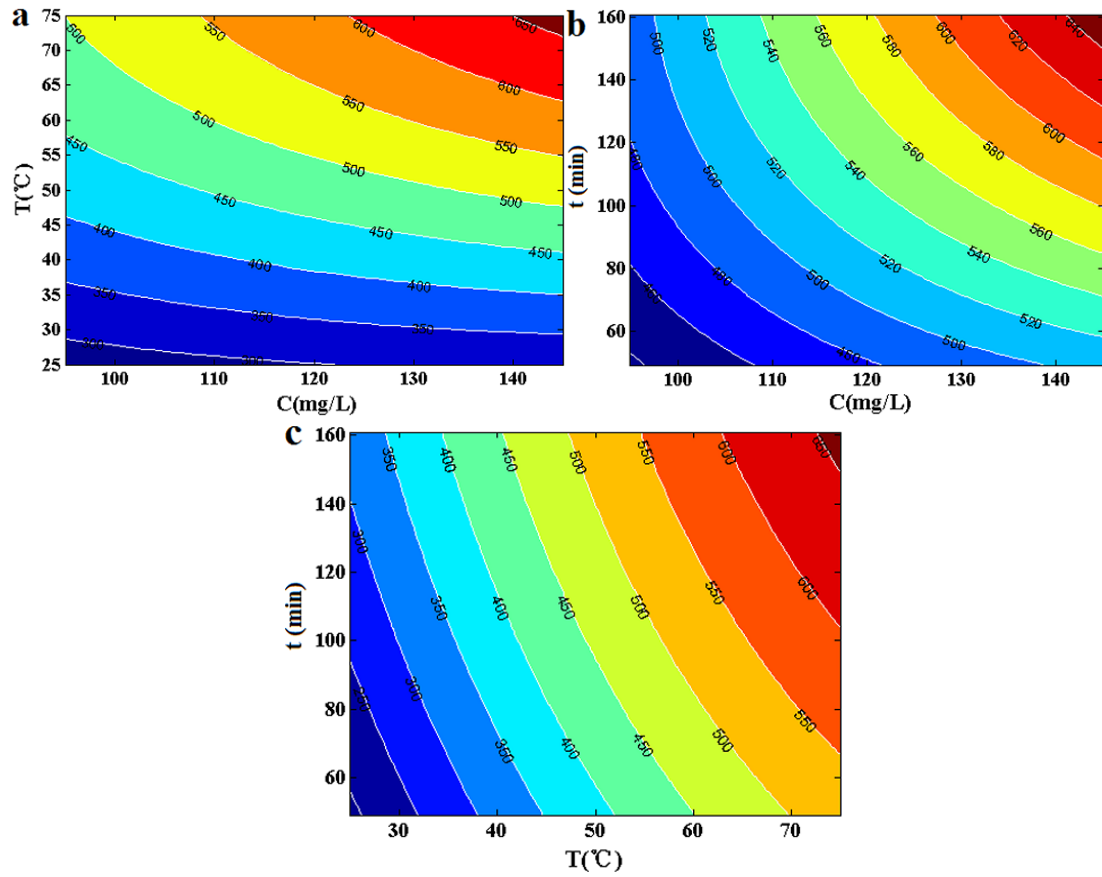


Fig. 12S. Contour plots of the combined effects for DR80 removal by TETA-PS: (a) initial concentration of DR80 (C) and temperature of adsorption reaction (T), $t = 150\text{min}$; (b) C and the time of adsorption reaction (t), $T = 70^\circ\text{C}$; (c) T and t , $C = 140\text{ mg/L}$.

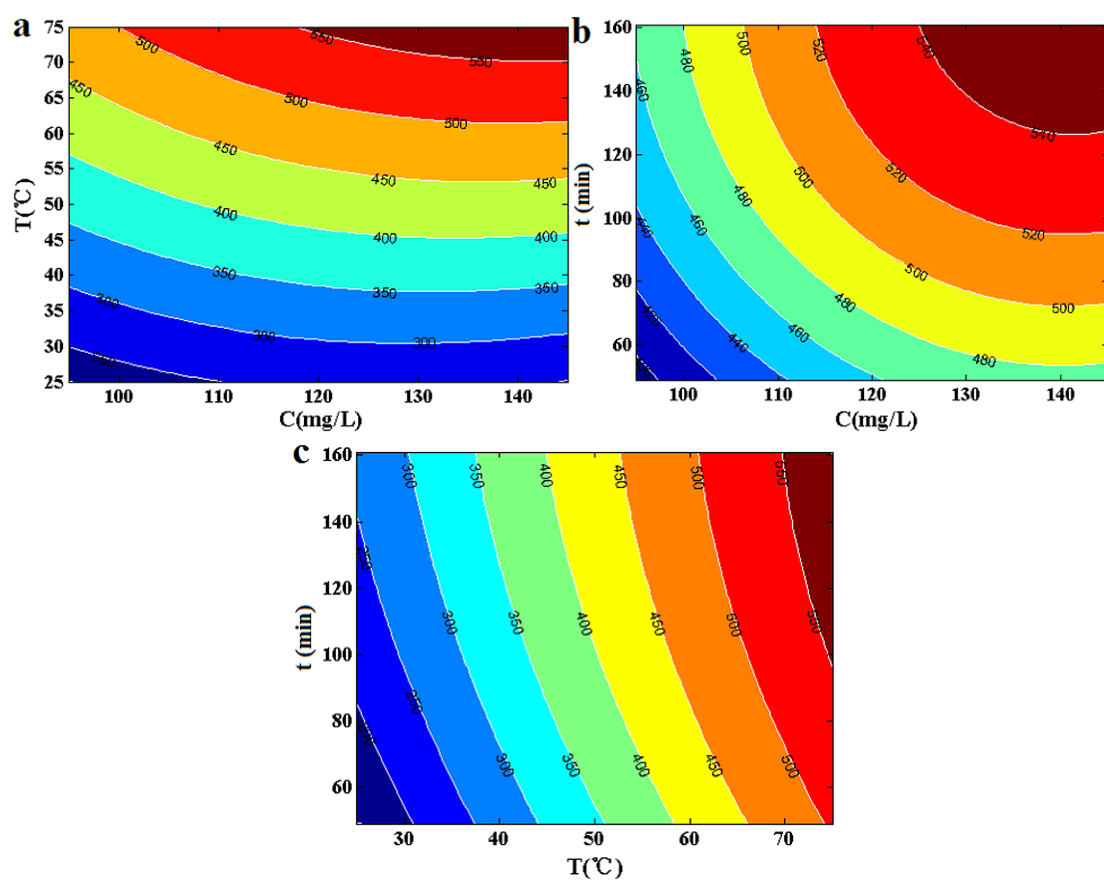
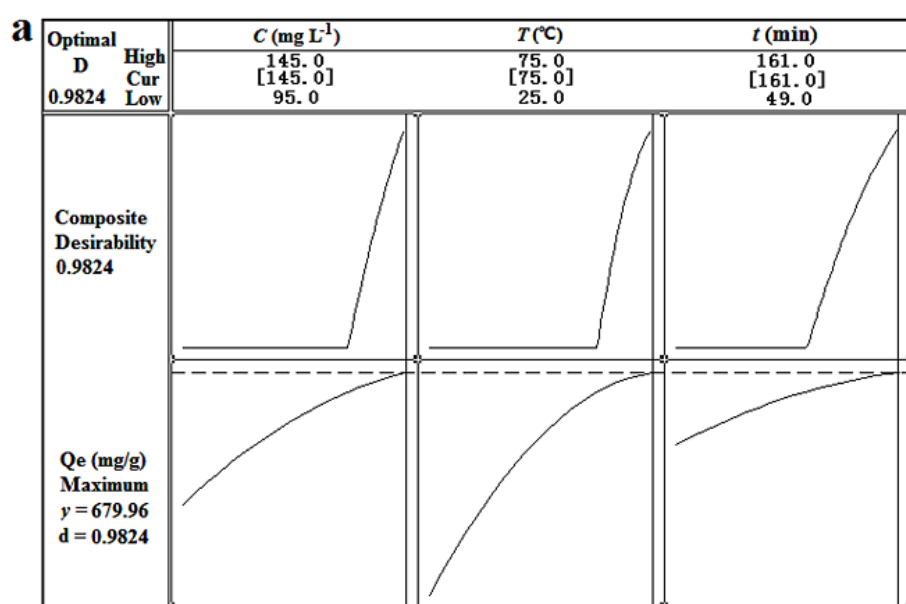


Fig. 13S. Contour plots of the combined effects for DR80 removal by DETA-PS: (a) initial concentration of DR80 (C) and temperature of adsorption reaction (T), $t = 150$ min; (b) C and the time of adsorption reaction (t), $T = 70^\circ\text{C}$; (c) T and t , $C = 140$ mg/L.



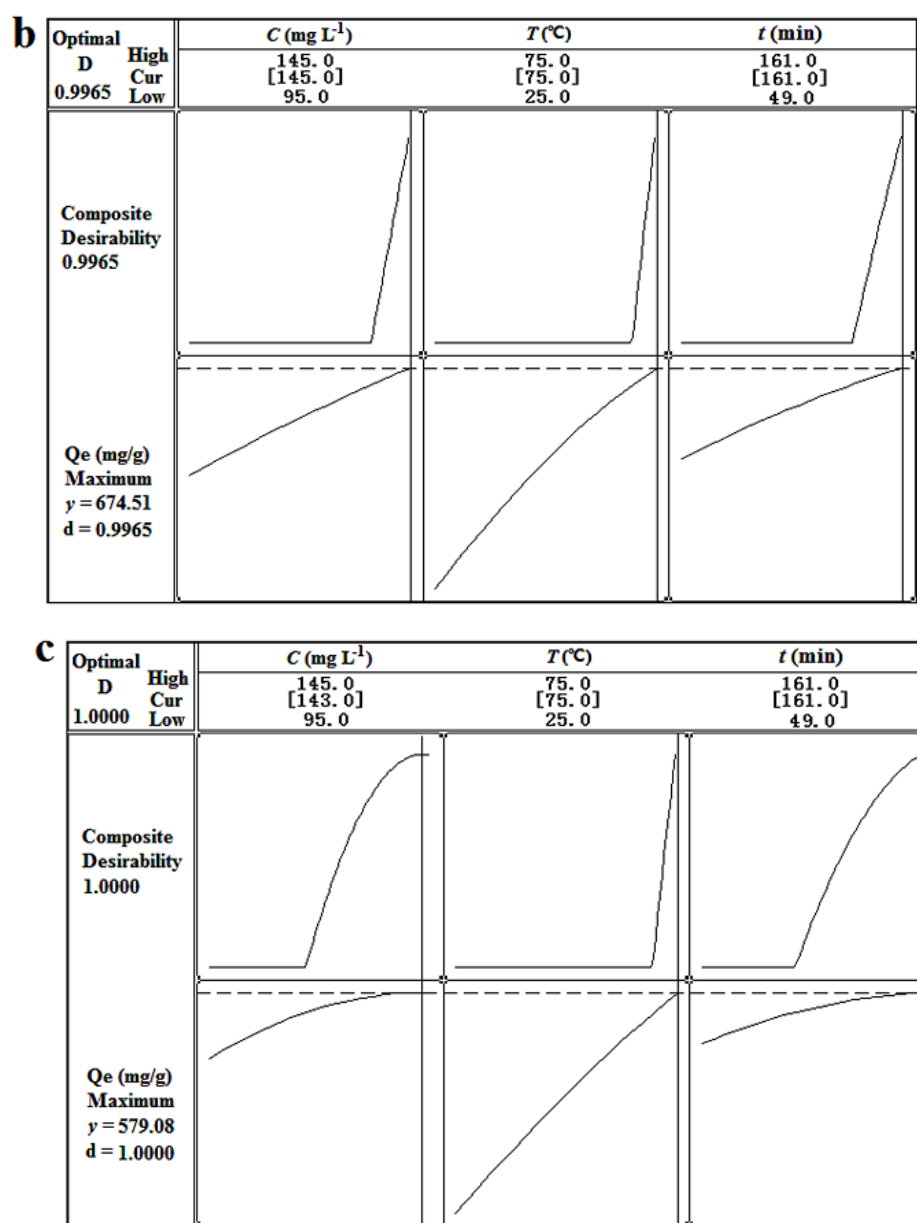


Fig. 14S. Optimization plots for DR80 adsorption by TEPA-PS (a), TETA-PS (b), or DETA-PS (c) biosorbent.

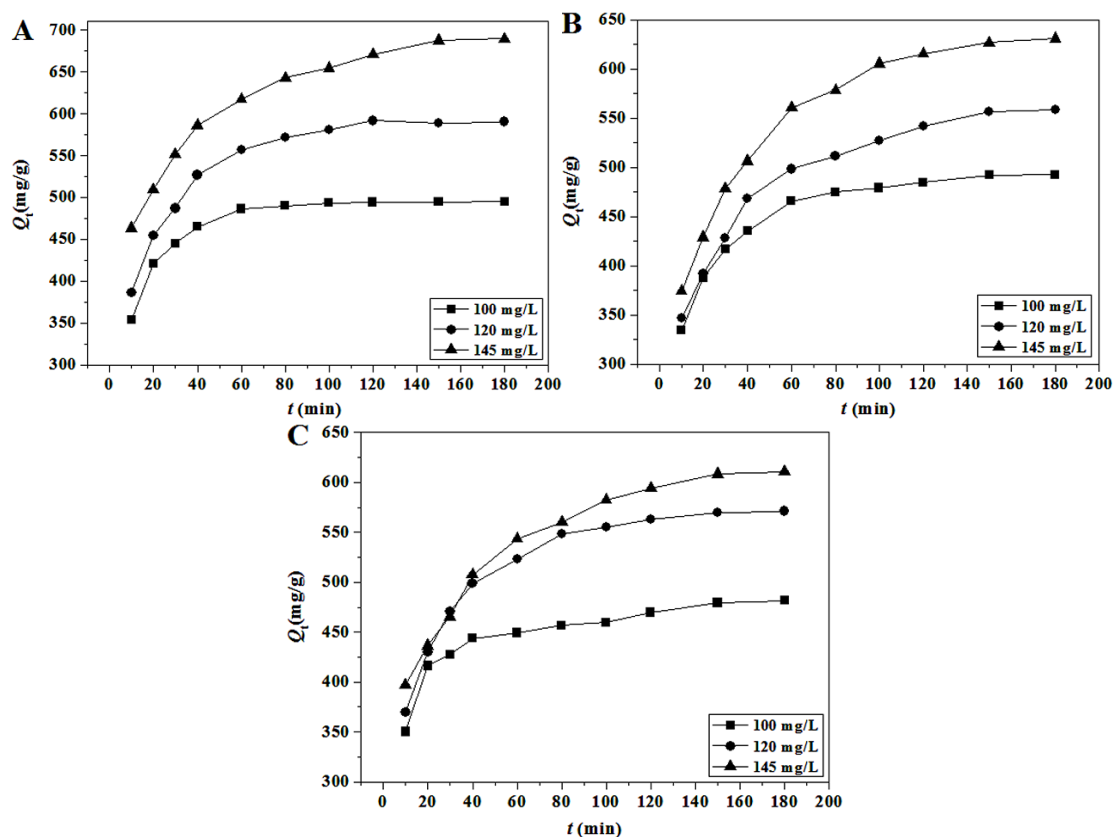
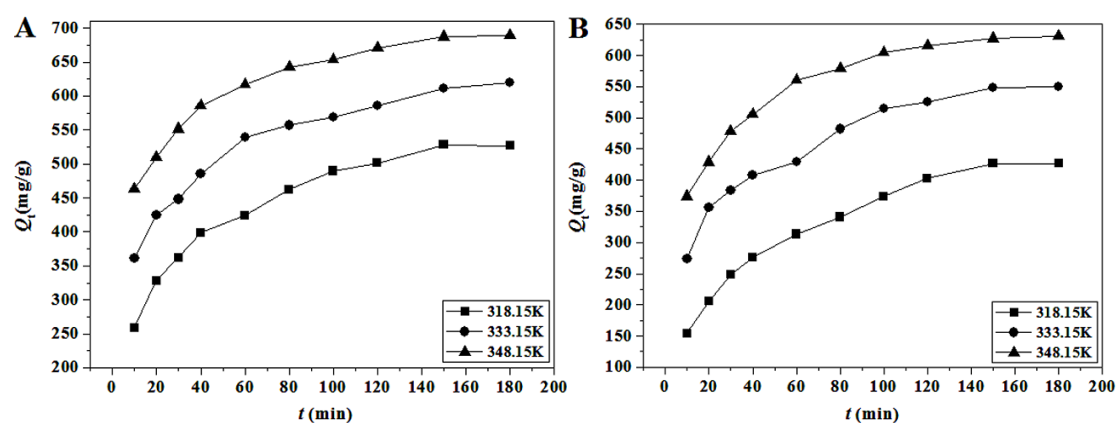


Fig. 15S. The adsorption capacities of DR80 onto TEPA-PS (A), TETA-PS (B) and DETA-PS (C) versus time at different initial concentrations of the dye (adsorbent dose = 20.0 mg/100mL, pH = 2.0, and $T = 75^\circ\text{C}$), respectively.



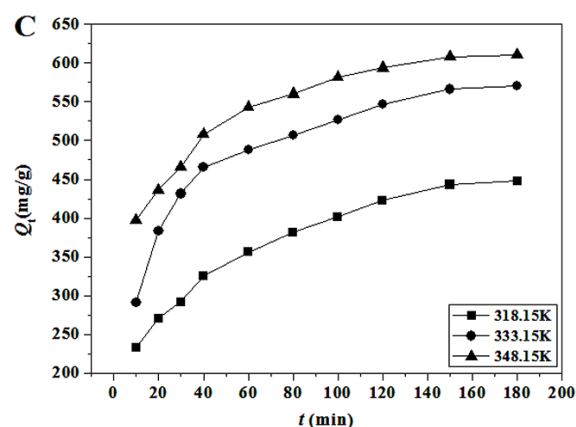


Fig. 16S. The adsorption capacities of DR80 onto TEPA-PS (A), TETA-PS (B) and DETA-PS (C) versus time at different temperatures (adsorbent dose = 20.0 mg/100mL, pH = 2.0, and $C_{\text{DR80}} = 145\text{mg/L}$), respectively.

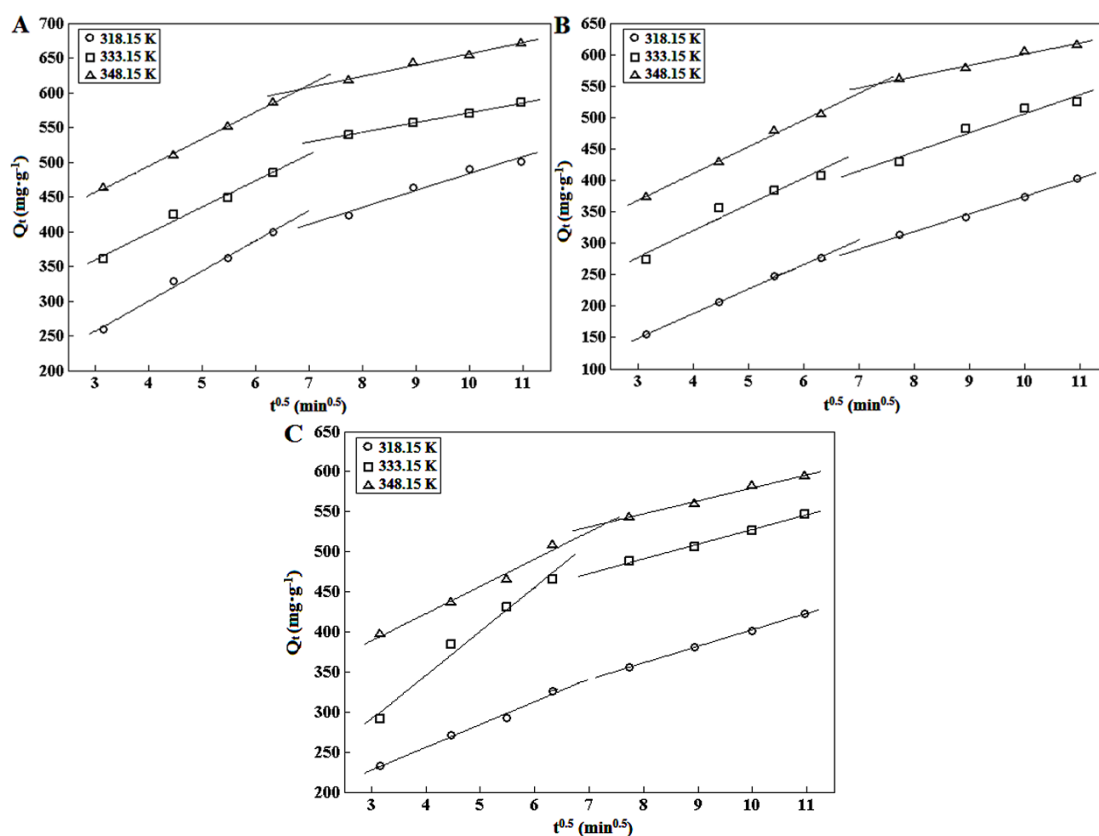


Fig. 17S. Intraparticle diffusion model for DR80 by TEPA-PS (A), TETA-PS (B), or DETA-PS (C) at different temperatures ($C_{\text{DR80}} = 145\text{mg/L}$, pH = 2.0, agitation speed = 180 rpm).

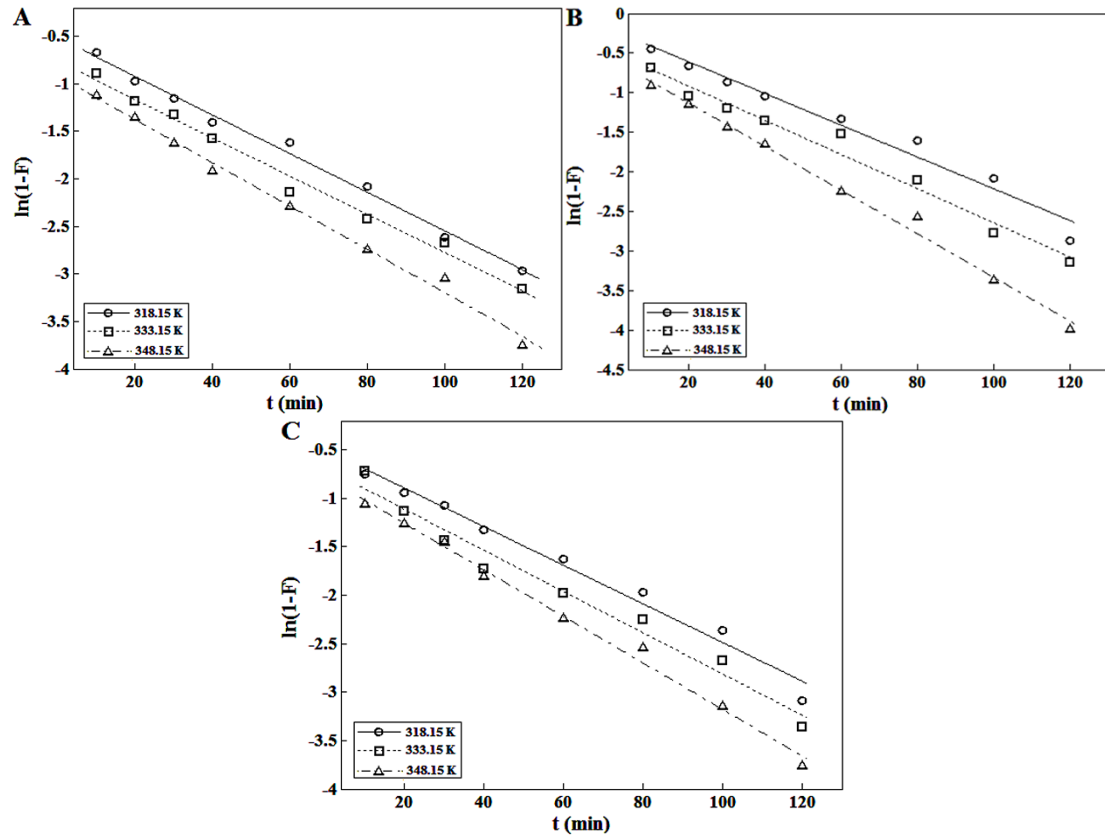
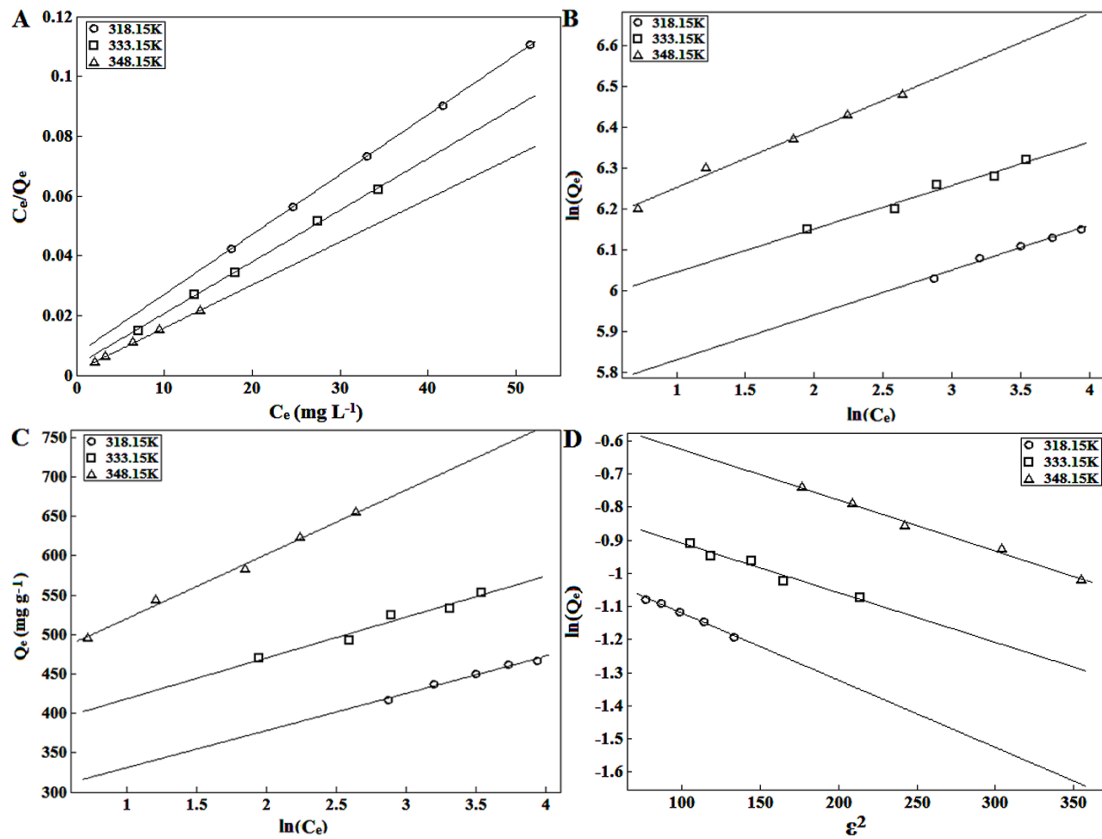


Fig. 18S. Liquid film diffusion model for DR80 by TEPA-PS (A), TETA-PS (B), or DETA-PS (C) at different temperatures ($C_{\text{DR80}} = 145\text{mg/L}$, $\text{pH} = 2.0$, agitation speed = 180 rpm).



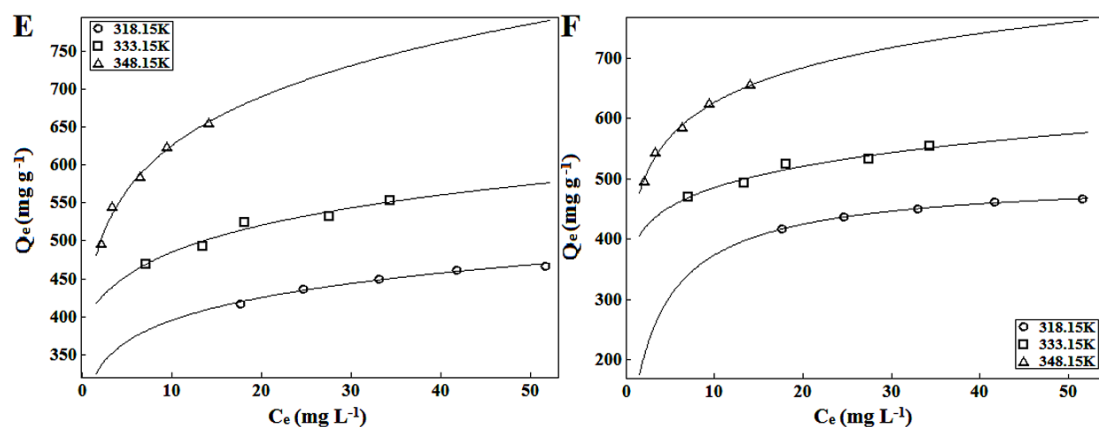
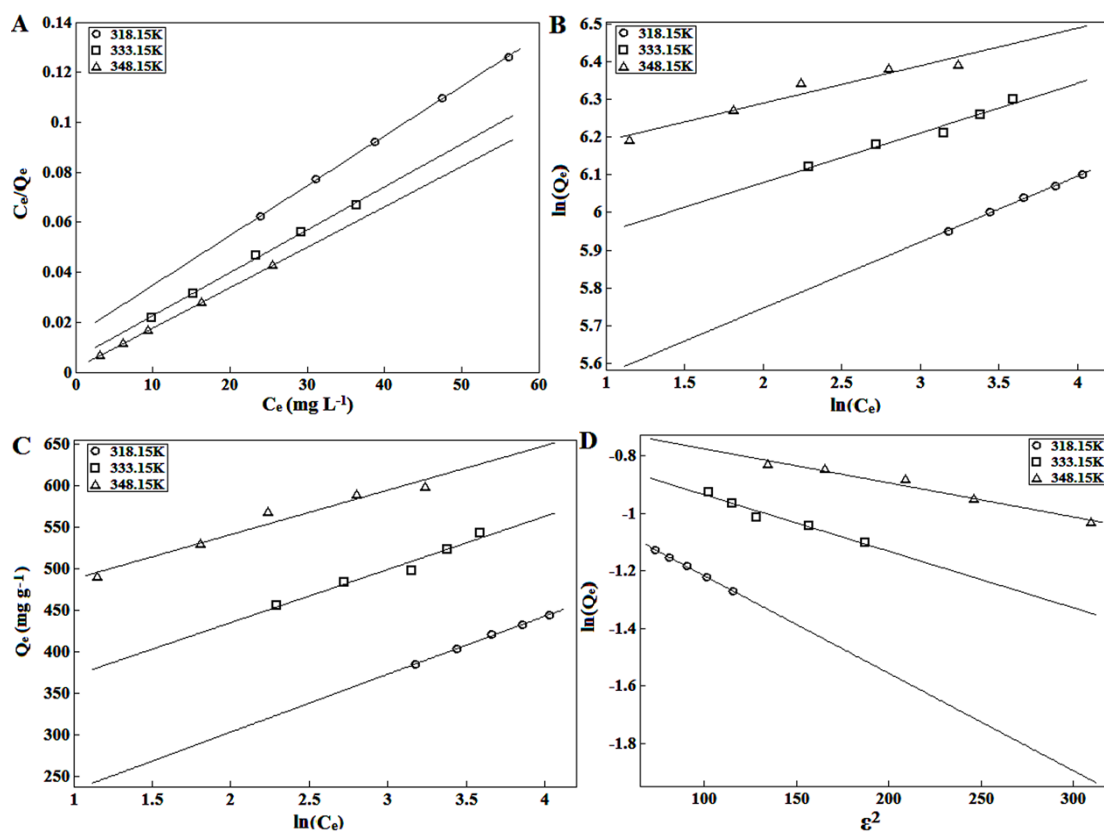


Fig.19S. Adsorption isotherms of DR80 onto TETA-PS using Langmuir (A), Freundlich (B), Temkin (C), Dubinin-Radushkevich (D), Redlich-Peterson (E), or Sips (F) models at different temperatures (adsorbent dose = 20.0 mg/100mL, pH = 2.0, $T = 75^\circ\text{C}$, $t = 161\text{min}$, agitation speed = 180 rpm).



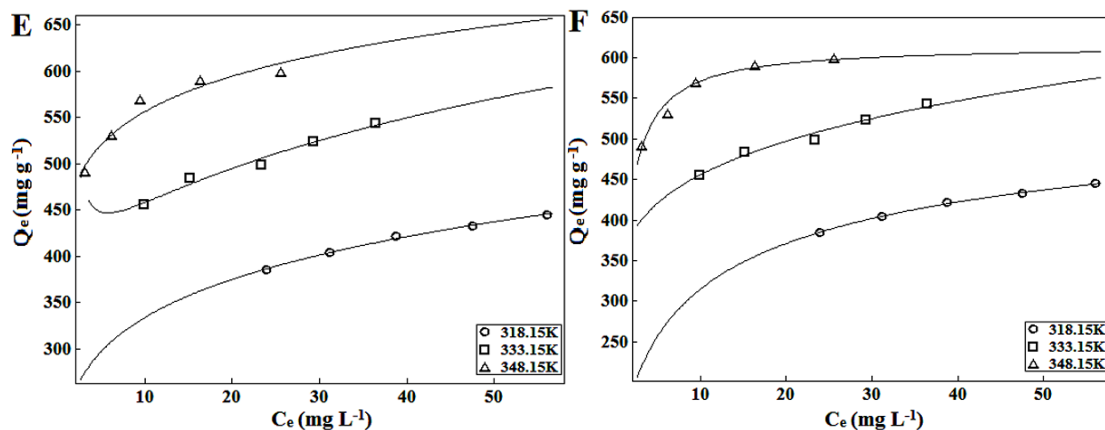


Fig.20S. Adsorption isotherms of DR80 onto DETA-PS using Langmuir (A), Freundlich (B), Temkin (C), Dubinin-Radushkevich (D), Redlich-Peterson (E), or Sips (F) models at different temperatures (adsorbent dose = 20.0 mg/100mL, pH = 2.0, $T = 75^\circ\text{C}$, $t = 161\text{min}$, agitation speed = 180 rpm).

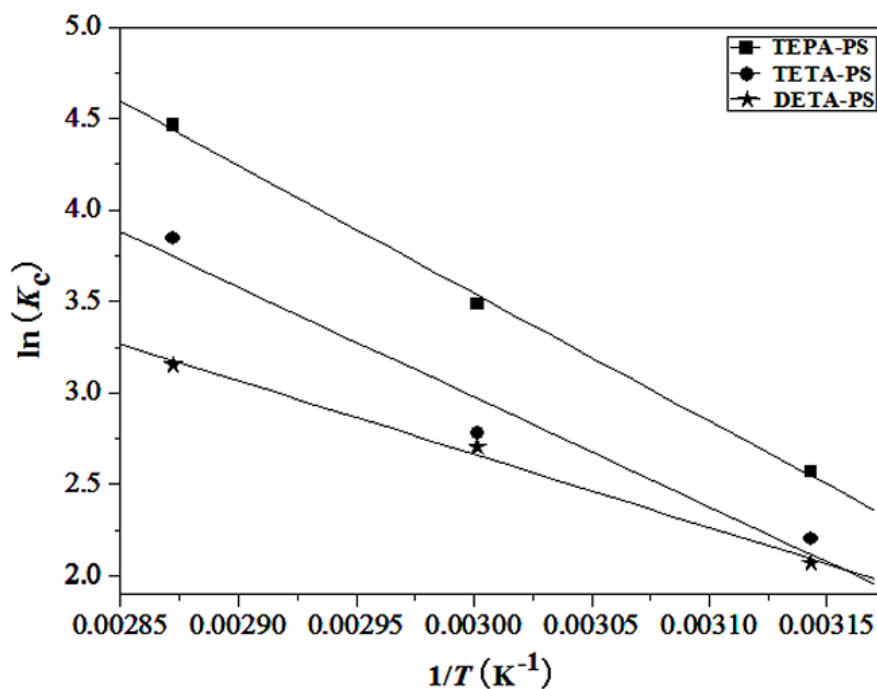


Fig. 21S. Van't Hoff plots for DR80 adsorption on TEPA-PS (■), TETA-PS (●), or DETA-PS (★) (initial concentration of DR80 = 145mg/L, adsorbent dosage = 20.0mg/100mL, pH = 2.0, $T = 75^\circ\text{C}$, $t = 161\text{min}$).

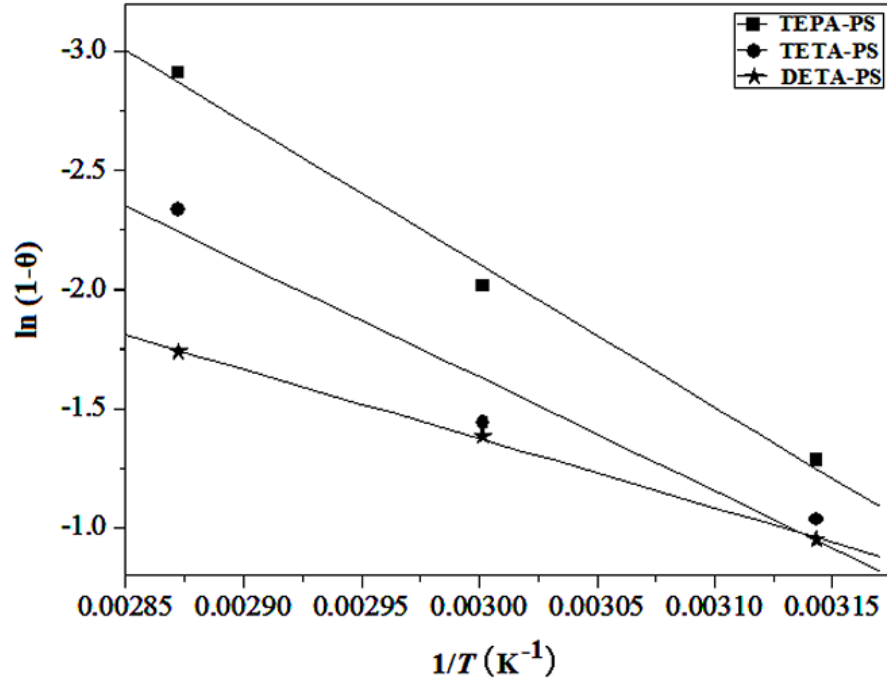


Fig. 22S. Plots of $\ln(1-\theta)$ vs. $1/T$.

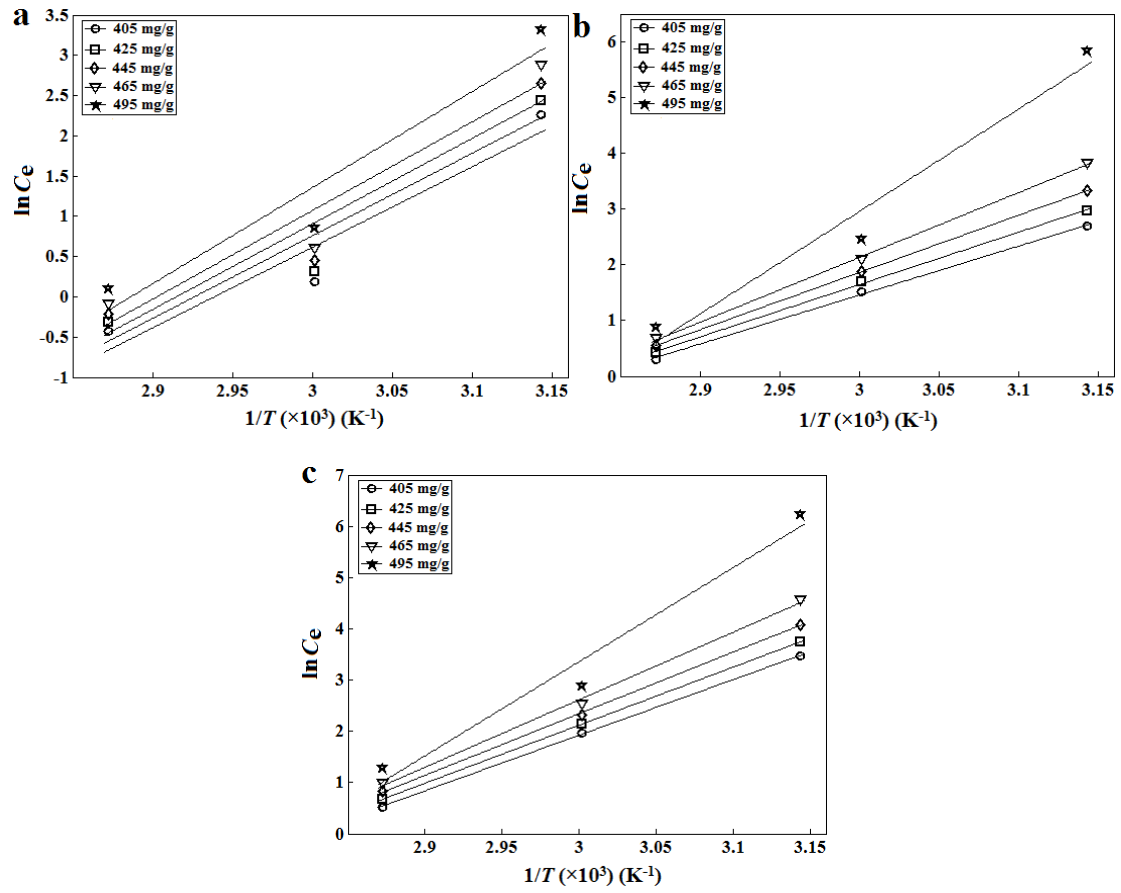


Fig.23S. Adsorption isotherms for determining isosteric heat of DR80 adsorption onto TEPA-PS

(a), TETA-PS (b), or DETA-PS (c). Q_c : 405mg/g (○); 425mg/g (□); 445mg/g (◇); 465mg/g (▽);

495mg/g (★).

Table 1S Statistical parameters of central composite design for the TEPA-PS, TETA-PS and DETA-PS systems.

system	parameter	Term									
		Constant	x_1	x_2	x_3	x_1^2	x_2^2	x_3^2	$x_1 x_2$	$x_1 x_3$	$x_2 x_3$
TEPA-PS	Coefficient	521.828	28.737	118.690	33.075	-22.010	-51.338	-12.685	30.830	17.825	-5.758
	Sum of squares	-	9187	156721	12170	10359	18118	953	7604	2542	265
	<i>T</i> -value	180.20	12.38	51.14	14.25	-6.92	-16.14	-3.99	11.27	6.51	-2.10
	PC*	-	4.22	71.92	5.58	4.75	8.31	0.44	3.49	1.17	0.12
TETA-PS	Coefficient	440.773	24.859	114.541	38.221	-4.168	-19.313	-5.726	21.083	14.415	1.362
	Sum of squares	-	6875	145956	16252	802	2616	194	3556	1662	15
	<i>T</i> -value	117.44	8.27	38.08	12.71	-1.01	-4.69	-1.39	5.94	4.06	0.38
	PC*	-	3.86	82.03	9.13	0.45	1.47	0.11	2.00	0.93	0.01
DETA-PS	Coefficient	394.553	24.309	123.496	35.121	-16.563	-9.049	-8.795	10.555	0.963	-5.215
	Sum of squares	-	6574	169670	13723	3077	745	477	891	7	218
	<i>T</i> -value	118.58	9.12	46.31	13.17	-4.53	-2.48	-2.46	3.36	0.31	-1.66
	PC*	-	3.36	86.84	7.02	1.57	0.38	0.24	0.46	0.00	0.11

$$\square \quad * PC(\%) = \frac{SS}{\sum SS} \times 100$$

Table 2S Analysis of variance (ANOVA) of the three fitted quadratic polynomial models.

Source	Degrees of freedom	Sum of squares	Adj. Sum of squares	Adj. Mean squares	F-value	p-value ($F > F_{0.05}$)	Remarks
TEPA-PS							
Regression	9	217919	217919	24213	404	0.000	Significant
x_1	1	9187	9187	9187	153.3	0.000	Significant
x_2	1	156721	156721	156721	2615.7	0.000	Significant
x_3	1	12170	12170	12170	203.1	0.000	Significant
x_1^2	1	10359	2869	2869	47.9	0.000	Significant
x_2^2	1	18118	15610	15610	260.5	0.000	Significant
x_3^2	1	953	953	953	15.9	0.003	Significant
$x_1 x_2$	1	7604	7604	7604	126.9	0.000	Significant
$x_1 x_3$	1	2542	2542	2542	42.4	0.000	Significant
$x_2 x_3$	1	265	265	265	4.4	0.062	
Residual error	10	599	599	59.9			
Lack of fit	5	556	556	111.2	12.87	0.007	Significant
Pure error	5	43	43	8.6			
Total	19	218518					
TETA-PS							
Regression	9	177928	177928	19770	196	0.000	Significant
x_1	1	6875	6875	6875	68.3	0.000	Significant
x_2	1	145956	145956	145956	1450.3	0.000	Significant
x_3	1	16252	16252	16252	161.5	0.000	Significant
x_1^2	1	802	103	103	1.02	0.336	
x_2^2	1	2616	2209	2209	22.0	0.001	Significant
x_3^2	1	194	194	194	1.93	0.195	
$x_1 x_2$	1	3556	3556	3556	35.3	0.000	Significant
$x_1 x_3$	1	1662	1662	1662	16.5	0.002	Significant
$x_2 x_3$	1	15	15	15	0.15	0.709	
Residual error	10	1006	1006	100.6			
Lack of fit	5	950	950	190.1	16.99	0.004	Significant
Pure error	5	56	56	11.2			
Total	19	178934					
DETA-PS							
Regression	9	195383	195383	21709	274	0.000	Significant
x_1	1	6574	6574	6574	83.1	0.000	Significant
x_2	1	169670	169670	169670	2145	0.000	Significant
x_3	1	13723	13723	13723	173.5	0.000	Significant
x_1^2	1	3077	1625	1625	20.5	0.001	Significant
x_2^2	1	745	485	485	6.13	0.033	Significant
x_3^2	1	477	477	477	6.03	0.034	Significant
$x_1 x_2$	1	891	891	891	11.27	0.007	Significant
$x_1 x_3$	1	7	7	7	0.09	0.766	
$x_2 x_3$	1	218	218	218	2.75	0.128	
Residual error	10	791	791	79.1			
Lack of fit	5	720	720	143.9	10.09	0.012	Significant

Pure error	5	71	71	14.3
Total	19	196174		

Table 3S Comparison of intraparticle and liquid film diffusion model parameters at three concentration and temperature levels for DR80 removal by different biosorbents.

		parameter							parameter						
		C_0 (mg·L ⁻¹)	k_{d1} mg·(g·min ^{0.5}) ⁻¹	k_{d2} mg·(g·min ^{0.5}) ⁻¹	B_1	B_2	R_1	R_2	T/K	k_{d1} mg·(g·min ^{0.5}) ⁻¹	k_{d2} mg·(g·min ^{0.5}) ⁻¹	B_1	B_2	R_1	R_2
intraparticle diffusion model	TEPA-PS	100	40.22	9.72	230.52	405.86	0.9830	0.9457	318.15	43.58	24.48	125.15	239.12	0.9955	0.9837
		120	43.53	10.72	252.08	474.43	0.9962	0.9923	333.15	37.97	14.01	245.33	430.97	0.9912	0.9979
		145	39.04	16.19	337.86	494.08	0.9991	0.9927	348.15	39.04	16.19	337.86	494.08	0.9991	0.9927
	TETA-PS	100	32.12	5.76	237.24	421.76	0.9911	0.9935	318.15	39.00	28.06	31.65	93.73	0.9993	0.9973
		120	37.74	13.65	225.49	391.32	0.9974	0.9973	333.15	41.81	30.29	152.30	202.62	0.9754	0.9729
		145	42.58	17.85	240.04	422.03	0.9980	0.9899	348.15	42.58	17.85	240.04	422.03	0.9980	0.9899
	DETA-PS	100	28.61	6.00	270.49	402.41	0.9506	0.9731	318.15	28.50	20.72	141.77	195.44	0.9945	0.9996
		120	40.94	11.96	243.44	434.53	0.9975	0.9609	333.15	55.08	18.36	125.27	344.18	0.9910	0.9979
		145	34.07	16.20	286.36	417.65	0.9918	0.9958	348.15	34.07	16.20	286.36	417.65	0.9918	0.9958
		k_{fd}/min^{-1}			intercept		R	k_{fd}/min^{-1}			intercept		R		
Liquid film diffusion model	TEPA-PS	100	0.0537		-0.7660		0.9962	318.15	0.0203		-0.5164		0.9965		
		120	0.0326		-0.8033		0.9980	333.15	0.0201		-0.7662		0.9945		
		145	0.0228		-0.9207		0.9962	348.15	0.0228		-0.9207		0.9962		
Liquid film diffusion model	TETA-PS	100	0.0273		-1.0366		0.9915	318.15	0.0201		-0.2106		0.9840		
		120	0.0229		-0.7926		0.9940	333.15	0.0216		-0.4895		0.9885		
		145	0.0275		-0.5836		0.9960	348.15	0.0275		-0.5836		0.9960		
Liquid film diffusion model	DETA-PS	100	0.0192		-1.5299		0.9571	318.15	0.0199		-0.4960		0.9908		
		120	0.0294		-0.8201		0.9975	333.15	0.0213		-0.6869		0.9866		
		145	0.0240		-0.7804		0.9965	348.15	0.0240		-0.7804		0.9965		

Table 4S Comparison of the maximum adsorption capacities for DR80 removal onto various adsorbents

adsorbent	Adsorption capacity ($\text{mg}\cdot\text{g}^{-1}$)	refs
Orange peel	21.05, 21.052	1, 2
Egg shell membrane	161.29	3
Soy meal hull	178.57	4
Mixture almond shells	22.422	5
SA/n-TiO ₂	130	6
Polyurethane foam (PUF)	4.50	7
Canola Hull	8.7032	8
Mentha pulegium	52.356	9
PAC	3448	10
SF-CNT	120.48	11
AC/DDAC	526.32	12
TEPA-PS, TETA-PS and DETA-PS	719.42, 694.44 and 617.28	present study

References

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