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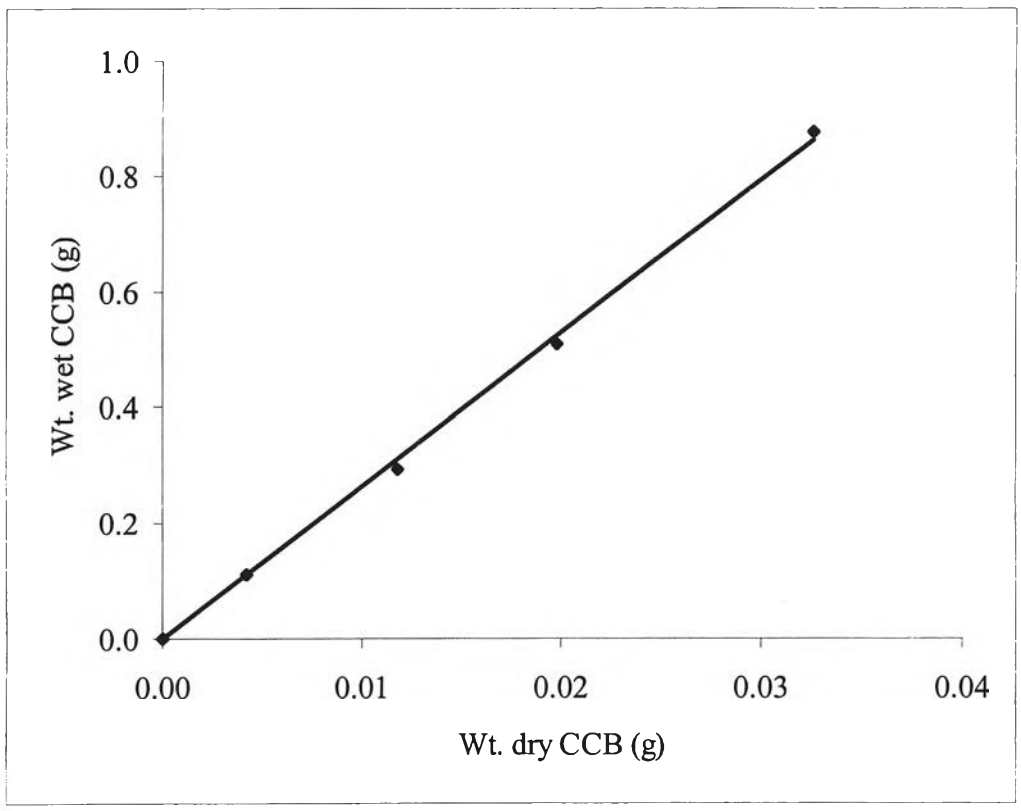
APPENDICES

Appendix A

Table A1 Relationship between wet CCB and dry CCB

Wt. wet CCB (g)	Wt. dry CCB (g)
0.000	0.000
0.112	0.004
0.296	0.012
0.508	0.020
0.875	0.033

Figure A1 Relationship between wet CCB and dry CCB.



Note: Wt. wet CCB = 26.4 * Wt. dry CCB
$R^2 = 0.998$

Appendix B

Degree of Cross-linking

$$\% \text{ Cross-linking} = \frac{W_{dry\ CCB} - W_{gel\ bead}}{W_{dry\ CCB}} * 100$$

where $W_{dry\ CCB}$ = weight of dry cross-linked chitosan bead (g)

$W_{gel\ bead}$ = weight of dry chitosan bead before cross-linking (g)

Note; For this calculation, chitosan beads both before and after cross-linked with glutaraldehyde solution should be prepared from the same batch.

Example: $W_{dry\ CCB}$ = 0.048 g.

$W_{gel\ bead}$ = 0.032 g.

Thus, % Cross-linking = (0.048 - 0.032) * 100/ 0.048 = 33.33%

Degree of Swelling

$$\% \text{ Swelling} = \frac{W_{wet\ CCB} - W_{dry\ CCB}}{W_{wet\ CCB}} * 100$$

where $W_{dry\ CCB}$ = weight of dry cross-linked chitosan bead (g)

$W_{wet\ CCB}$ = weight of wet cross-linked chitosan bead (g)

Example: $W_{dry\ CCB}$ = 0.004 g.

$W_{wet\ CCB}$ = 0.112 g.

Thus, % Cross-linking = (0.112 - 0.004) * 100/ 0.112 = 96.43%

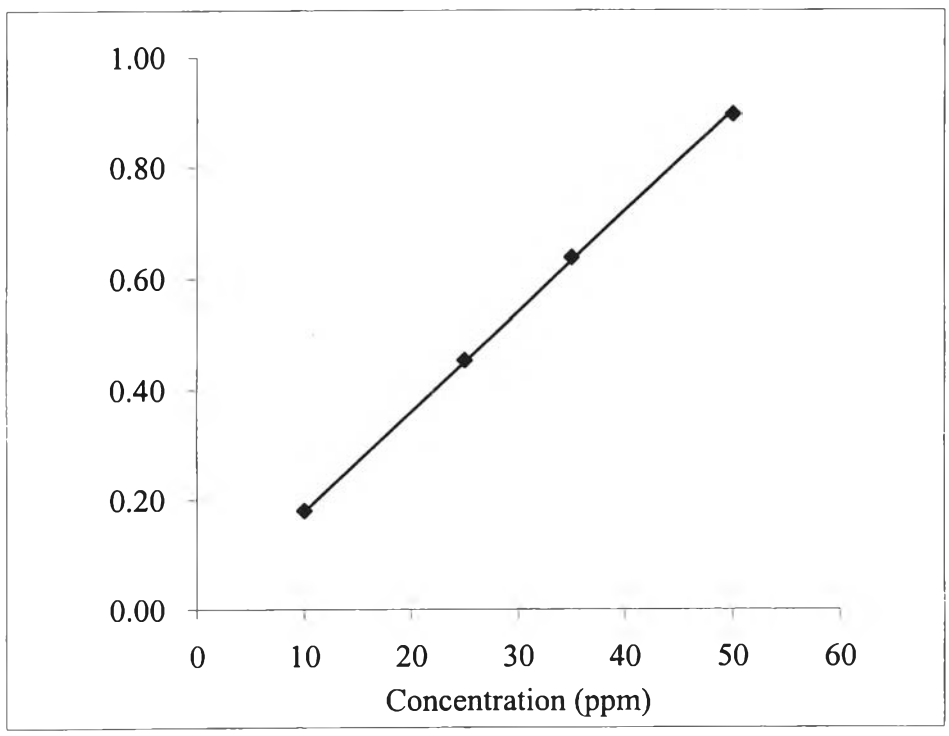
Appendix C

Calibration Curve of RR180

Table C1 Relationship between concentration of RR180 and absorbance at λ_{max} = 515 nm

Concentration (ppm)	Absorbance				SD
	1st	2nd	3rd	Ave.	
10	0.1845	0.1811	0.1816	0.1824	0.002
25	0.4563	0.4536	0.4549	0.4549	0.002
35	0.6395	0.6359	0.6375	0.6376	0.002
50	0.9117	0.8866	0.8892	0.8958	0.013

Figure C1 Calibration curve of RR180.



Note; Absorbance = 0.018 * Concentration

R^2 = 0.999

Appendix D

RR180 Adsorption Calculation

Table D1 Kinetic studies of RR180 adsorption at pH 2

Time	Absorbance				c dil	c exact	q	q	c/c0
min	1st	2nd	3rd	ave	ppm	ppm	ppm	mg/g	
0	0.7008	0.6961	0.7009	0.6993	38.85	194.24	0.00	0.00	1.00
10	0.5893	0.5940	0.5893	0.5909	32.83	164.13	30.11	49.52	0.84
20	0.4701	0.4678	0.4693	0.4691	26.06	130.30	63.94	105.17	0.67
30	0.4205	0.4199	0.4245	0.4216	23.42	117.12	77.12	126.84	0.60
60	0.3044	0.3041	0.3058	0.3048	16.93	84.66	109.58	180.24	0.44
90	0.2284	0.2315	0.2273	0.2291	12.73	63.63	130.61	214.82	0.33
120	0.2044	0.2041	0.2049	0.2045	11.36	56.80	137.44	226.06	0.29
240	0.1127	0.1124	0.1144	0.1132	6.29	31.44	162.81	267.77	0.16
480	0.1371	0.1371	0.1356	0.1366	7.59	37.94	156.30	257.07	0.20
660	0.0218	0.0219	0.0215	0.0217	1.21	6.04	188.20	309.55	0.03
1080	0.0155	0.0155	0.0154	0.0155	0.86	4.30	189.94	312.41	0.02

Initial concentration = 194.24 ppm (from the experiment)

Absorbance = 0.018 * Concentration

Wt. wet CCB = 26.4 * Wt. dry CCB

Ratio between CCB and RR180 = 0.16 g / 10 mL

Note; All samples were drawn out from supernatant phase and diluted with deionized water for 5 times.

Example:

At 30 min, absorbance = 0.4245

From calibration curve, diluted concentration = 0.4245 / 0.018 = 23.42 ppm

5 Times dilution, exact concentration = 23.42 * 5 = 117.12 ppm

RR180 absorbed on CCB, $q = c_0 - c$ = 194.24 – 117.12 = 77.12 ppm

From Appendix A, q = 77.12 mg/L * (0.01 L) / (0.16 / 26.4 g.) =126.84 mg/g

Table D2 Equilibrium studies of RR180 adsorption at pH 2

C_0	Absorbance				Ce dilute	Ce exact	qe	qe
ppm	1st	2nd	3rd	ave	ppm	ppm	ppm	mg/g
201.51	0.0085	0.0084	0.0083	0.0084	0.47	2.33	199.18	328.46
437.56	0.0355	0.0345	0.0341	0.0347	1.93	19.28	418.28	689.78
697.01	0.0255	0.0256	0.0257	0.0256	1.42	28.44	668.57	1102.52
956.28	0.0652	0.0654	0.0654	0.0653	3.63	72.59	883.69	1457.28
1049.40	0.121	0.1214	0.1214	0.1213	6.74	134.74	914.66	1508.34
1709.73	0.2711	0.2679	0.2681	0.269	14.95	597.85	1111.87	1833.57
2240.87	0.5605	0.5629	0.5628	0.5621	31.23	1249.04	991.84	1635.62

Absorbance = 0.018 * Concentration

Wt. wet CCB = 26.4 * Wt. dry CCB

Ratio between CCB and RR180 = 0.16 g / 10 mL

Note; 1. All samples were drawn out from supernatant phase and diluted with deionized water.

2. At C_0 = 201.51, 437.56, 697.01, 956.28, 1049.40, 1709.73, 2240.87 were diluted with deionized for 5, 10, 20, 20, 20, 40 and 40 times , respectively.

Example;

At C_0 = 201.51 ppm, absorbance = 0.0084

From calibration curve, diluted concentration = 0.0084 / 0.018 = 0.47 ppm

5 Times dilution, exact concentration = 0.47 * 5 = 2.33 ppm

RR180 absorbed on CCB, $q_e = c_0 - c_e$ = 201.51 – 2.33 = 199.18 ppm

From Appendix A, q = 199.18 mg/L * (0.01 L) / (0.16 / 26.4 g.) =328.46 mg/g

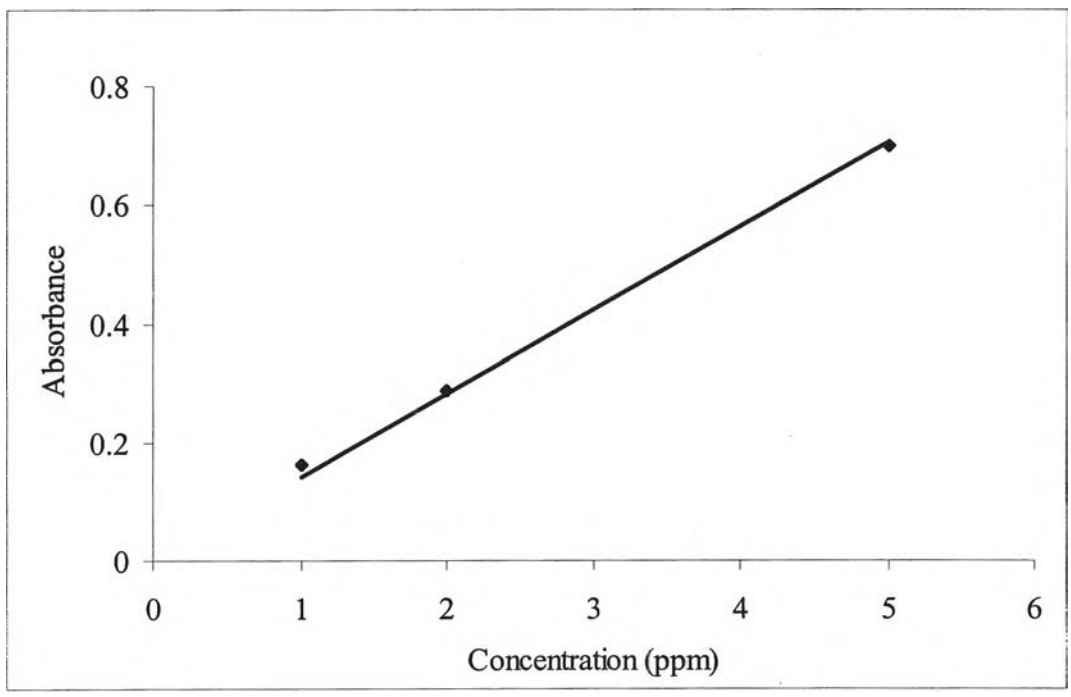
Appendix E

Calibration Curve of Cu^{2+} ions

Table E1 Relationship between concentration of RR180 and absorbance at λ_{max} = 324.8 nm

Concentration (ppm)	Absorbance				SD
	1st	2nd	3rd	Ave.	
1	0.162	0.161	0.162	0.1617	0.0006
2	0.287	0.287	0.285	0.2863	0.0012
5	0.7	0.696	0.699	0.6983	0.0021

Figure E1 Calibration curve of Cu^{2+} ions.



Note; Absorbance = 0.1409 * Concentration

R^2 = 0.997

Appendix F

Cu^{2+} ions Adsorption Calculation

Table F1 Kinetic studies of Cu^{2+} ions adsorption at pH 4

Time	absorbance				c dil	c exact	q	q	c/c_0
min	1st	2nd	3rd	av	ppm	ppm	ppm	mg/g	
0	0.287	0.287	0.287	0.287	2.04	101.85	0.00	0.00	1.00
10	0.277	0.277	0.275	0.2763	1.96	98.06	3.79	5.58	0.96
20	0.268	0.267	0.27	0.2683	1.90	95.22	6.62	9.76	0.93
30	0.267	0.267	0.267	0.267	1.89	94.75	7.10	10.46	0.93
60	0.249	0.248	0.249	0.2487	1.76	88.24	13.60	20.05	0.87
90	0.248	0.249	0.249	0.2487	1.76	88.24	13.60	20.05	0.87
120	0.25	0.249	0.249	0.2493	1.77	88.48	13.37	19.70	0.87
180	0.226	0.227	0.227	0.2267	1.61	80.44	21.41	31.56	0.79
360	0.232	0.233	0.234	0.233	1.65	82.68	19.16	28.25	0.81
1140	0.213	0.212	0.214	0.213	1.51	75.59	26.26	38.71	0.74
1440	0.207	0.206	0.206	0.2063	1.46	73.22	28.63	42.20	0.72

Initial concentration = 101.85 ppm (from the experiment)

Absorbance = 0.1409 * Concentration

Wt. wet CCB = 26.4 * Wt. dry CCB

Ratio between CCB and RR180 = 0.16 g / 10 mL

Note; All samples were drawn out from supernatant phase and diluted with deionized water for 50 times.

Example;

At 10 min, absorbance = 0.2763

From calibration curve, diluted concentration = 0.2763 / 0.1409 = 1.96 ppm

50 Times dilution, exact concentration = 1.96 * 50 = 98.06 ppm

Cu^{2+} ions absorbed on CCB, $q = c_0 - c$ = 101.85 – 98.06 = 3.79 ppm

From Appendix A, q = 3.79 mg/L * (0.01 L) / (0.16 / 26.4 g.) =5.58 mg/g

Table F2 Equilibrium studies of Cu^{2+} ions adsorption at pH 4

C_0	absorbance				ce dil	ce exact	qe	qe
ppm	1st	2nd	3rd	av	ppm	ppm	ppm	mg/g
29.10	0.068	0.068	0.068	0.068	0.48	24.13	4.97	8.17
50.00	0.108	0.109	0.108	0.1083	0.77	38.44	11.56	19.01
69.71	0.138	0.137	0.138	0.1377	0.98	48.85	20.85	34.30
102.41	0.22	0.221	0.22	0.2203	1.56	78.19	24.23	39.85
1029.59	0.278	0.28	0.28	0.2793	1.98	991.25	38.35	63.07

Absorbance = 0.1409 * Concentration

Wt. wet CCB = 26.4 * Wt. dry CCB

Ratio between CCB and RR180 = 0.16 g / 10 mL

Note; 1. All samples were drawn out from supernatant phase and diluted with deionized water.

2. At C_0 = 29.10, 50.00, 69.71, 102.41and 1029.59 were diluted with deionized for 50, 50, 50, 50, and 500 times, respectively.

Example:

At C_0 = 29.10 ppm, absorbance = 0.068

From calibration curve, diluted concentration = 0.068 / 0.1409 = 0.48 ppm

50 Times dilution, exact concentration = 0.48 * 50 = 24.13 ppm

RR180 absorbed on CCB, $q_e = c_0 - c_e$ = 29.10 – 24.13 = 4.97 ppm

From Appendix A, q = 4.97 mg/L * (0.01 L) / (0.16 / 26.4 g.) = 8.17 mg/g

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