

8

APPENDICES

Chapter 7

Chapter 8 Appendix

Batch system:

- Table 8-1 represents the effect of pH
(40 min. contact time, initial conc. 200ppm, weight of resin 5 gm, rpm 350 & 25°C ± 2)

Table 8-1 Effect of pH

pH	%removal	
2.03	59.523	
3.04	61.702	
4.28solution	65.4545	optimum
4.88	63.82	
6.05	61.53	

- Table 8-2 represents the effect of amount of resin
(Two hours contact time, initial conc. 500ppm, pH 4.28, rpm 350 & 25°C ± 2)

Table 8-2 Effect of Amount of Resin

Amount of resin (gm)	%removal
2.5	60.7843
5	76.3157
7.5	86.0465
10	92
12.5	97.5609

- Table 8.3 represents the effect of rpm
(Two hours contact time, weight of resin 5 gm, initial conc. 500ppm, pH 4.28 & 25°C ± 2)

Table 8-3 Effect of Speed of Rotation

rpm	%removal
350	54.8387
400	58.3333
450	60.9375
500	62.5
550	67.647
600	70.2702

- Table 8-4 represents the effect of initial concentration
(Two hours contact time, weight of resin 5 gm, initial conc. 500ppm, pH 4.28 & 25°C ± 2)

Table 8-4 Effect of Initial Concentration

Initial concentration (ppm)	%removal
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100	99.378
200	97.337
300	96.753
400	92.537
500	79.692

- Table 8-5 represents the effects of temperature
(Two hours contact time, weight of resin 5 gm, initial conc. 500ppm, pH 4.28 & rpm 350)

Table 8-5 Effect of Temperature

Temperature (C°)	%removal
25	54.83
30	59.685
35	61.7647
40	80

- Table 8-6 represents the percentage removal of Cr(VI)
(Two hours contact time, weight of resin 5 gm, initial conc. (100 -500ppm), pH 4.28, temperature 25°C±2 & rpm 350)

Table 8-6 %removal of Cr(VI)

time (min.)	%removal (100ppm)	%removal (200ppm)	%removal (300ppm)	%removal (400ppm)	%removal (500ppm)
0	0	0	0	0	0
2	19.875	24.852	23.701	31.940	3.692
4	37.888	43.1952	35.389	41.492	23.384
6	50.621	54.142	53.246	52.238	40.307
8	61.801	65.680	61.688	70.149	40.923
10	70.186	72.485	67.532	70.746	50.769
12	76.708	76.331	69.155	71.940	52.615
14	82.919	78.698	72.727	75.522	57.230
20	91.304	86.982	80.519	81.194	65.846
25	94.720	90.532	89.285	83.582	69.538
30	96.583	93.195	93.181	87.462	72.923
40	98.136	96.745	96.103	90.447	76
60	99.068	97.041	96.428	91.044	78.461
90	99.378	97.337	96.753	92.238	80.307
120	99.378	97.337	96.753	92.537	79.692

- Table 8-7 represents the adsorption capacities
(Two hours contact time, weight of resin 5 gm, initial conc. (100 -500ppm), pH 4.28, temperature 25°C±2 & rpm 350)

Table 8-7 Adsorption Capacity

time (min.)	Capacity (100ppm)	Capacity (200ppm)	Capacity (300ppm)	Capacity (400ppm)	Capacity (500ppm)
0	0	0	0	0	0
2	7.814	20.512	26.739	52.258	7.326
4	14.896	35.653	39.926	67.887	46.398
6	19.902	44.688	60.073	85.470	79.975
8	24.297	54.212	69.597	114.774	81.196
10	27.594	59.829	76.190	115.750	100.732
12	30.158	63.003	78.021	117.704	104.395
14	32.600	64.957	82.051	123.565	113.553
20	35.897	71.794	90.842	132.844	130.647
25	37.240	74.725	100.732	136.752	137.973
30	37.973	76.923	105.128	143.101	144.688
40	38.583	79.853	108.424	147.985	150.793
60	38.949	80.097	108.791	148.962	155.677
90	39.072	80.341	109.157	150.915	159.340
120	39.072	80.341	109.157	151.404	158.119

- Tables from 8-8 to 8-12 represent the calculations of isotherm models (Two hours contact time, weight of resin 5 gm, initial conc. (100 -500ppm), pH 4.28, temperature 25°C±2 & rpm 350)

Table 8-8 Adsorption Isotherms Variables

Initial concentration (ppm)	Concentration at equilibrium (ppm)	Capacity (mg/g) Experimental	Ln (q _e)	Ln(C _e)	C _e /q _e (ppm/(mg/g))
100	0.610501	39.0720	3.66540	-0.49348	0.015625
200	5.494505	80.3418	4.386291	1.703749	0.068389
300	9.157509	109.157	4.692792	2.214574	0.083893
400	30.52503	151.404	5.019953	3.418547	0.201613
500	100.7326	158.119	5.063352	4.612469	0.637066

Table 8-9 Adsorption Isotherms Capacities

Initial concentration (ppm)	Concentration at equilibrium (ppm)	Capacity (mg/g) Experimental	Capacity (mg/g) Langmuir	Capacity (mg/g) Freundlich	Capacity (mg/g) Temkin	Capacity (mg/g) D-R
100	0.610501	39.0720	22.896	42.922	37.194	38.468
200	5.494505	80.341	98.173	80.994	92.740	117.999
300	9.157509	109.157	117.486	93.879	105.654	120.519
400	30.52503	151.404	148.071	132.948	136.090	121.963
500	100.7326	158.119	160.556	187.729	166.273	122.104

Table 8-10 Separation Factor R_L

Initial concentration (ppm)	R_L
100	0.036918138
200	0.018806214
300	0.012616566
400	0.009492365
500	0.007608336

Table 8-11 Error Analysis for Isotherm Models

Error analysis	Langmuir	Freundlich	Temkin	D-R
Chi square	15.368	10.069	3.991	30.827
HYBRID	11.400	10.317	4.085	32.770

Where $R = 8.314 \text{ Jmol}^{-1}\text{K}^{-1}$

Table 8-12 Calculation of Main Free Energy

initial concentration (ppm)	Concentration at equilibrium (ppm)	Capacity (mg/g) Experimental	$\ln q_e$	ϵ	ϵ^2
100	0.610500611	39.072	3.665	2403.297	5775836
200	5.494505495	80.341	4.386	414.2697	171619.3
300	9.157509158	109.157	4.692	256.773	65932.46
400	30.52503053	151.404	5.019	79.864	6378.276
500	100.7326007	158.119	5.063	24.474	598.989

Kinetic Studies

▪ Tables from 8-13 to 8-21 represent the calculations of kinetics studies (Two hours contact time, weight of resin 5 gm, initial conc. (100 -500ppm), pH 4.28, temperature $25^\circ\text{C}\pm 2$ & rpm 350)

Table 8-13 Pseudo First Order Model calculations

contact time (min.)	$\text{Log}(q_e - q_t)$ 100ppm	$\text{Log}(q_e - q_t)$ 200ppm	$\text{Log}(q_e - q_t)$ 300ppm	$\text{Log}(q_e - q_t)$ 400ppm	$\text{Log}(q_e - q_t)$ 500ppm
0	1.591	1.904	2.038	2.180	2.198
2	1.494	1.776	1.916	1.996	2.178
4	1.383	1.650	1.840	1.921	2.048

6	1.282	1.552	1.690	1.819	1.892
8	1.169	1.417	1.597	1.563	1.886
10	1.059	1.312	1.518	1.552	1.758
12	0.950	1.239	1.493	1.527	1.730
14	0.810	1.187	1.433	1.444	1.649
20	0.501	0.931	1.262	1.268	1.438
25	0.262	0.749	0.925	1.165	1.304
30	0.040	0.533	0.605	0.919	1.128
40	-0.311	-0.311	-0.135	0.533	0.864
60	-0.913	-0.612	-0.436	0.387	0.387

Table 8-14 Pseudo First Order Model parameters

initial concentration (ppm)	Capacity (mg/g) Experimental	Capacity (mg/g) pseudo First order	%SSE	R ²	k ₁ min ⁻¹
100	39.072	31.067	64.080	0.9809	0.1004108
200	80.341	63.973	267.924	0.9718	0.1011017
300	109.157	98.537	112.792	0.9694	0.101332
400	151.404	88.491	3958.041	0.9316	0.0700112
500	158.119	132.129	675.485	0.9841	0.0709324
		Σ	5078.323		
		%SSE	5.090		

Table 8-15 Pseudo Second Order Model calculations

contact time(min.)	t/q _t (100ppm)	t/q _t (200ppm)	t/q _t (300ppm)	t/q _t (400ppm)	t/q _t (500ppm)
2	0.255	0.0975	0.074	0.038	0.273
4	0.268	0.112	0.100	0.058	0.086
6	0.301	0.134	0.099	0.0702	0.075
8	0.329	0.147	0.114	0.069	0.098
10	0.362	0.167	0.131	0.086	0.099
12	0.397	0.190	0.1538	0.1019	0.114
14	0.429	0.215	0.1706	0.1133	0.123
20	0.557	0.278	0.220	0.1505	0.153
25	0.671	0.334	0.248	0.1828	0.181
30	0.790	0.39	0.285	0.2096	0.207
40	1.036	0.5009	0.368	0.27029	0.265
60	1.540	0.749	0.551	0.40278	0.385
90	2.303	1.120	0.824	0.596	0.564

120	3.071	1.493	1.099	0.792	0.758
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Table 8-16 Pseudo Second Order Model parameters

initial concentration (ppm)	Capacity (mg/g) Experimental	Capacity (mg/g) pseudo second order	%SSE	R ²	k ₂ gmg ⁻¹ min ⁻¹	h mgg ⁻¹ min ⁻¹
100	39.072	40.026	0.911	0.997	0.004881	8.474
200	80.341	87.655	53.484	0.998	0.002469	20.408
300	109.157	119.403	104.969	0.998	0.001422	22.222
400	151.404	161.290	97.736	0.999	0.0015	41.666
500	158.119	179.372	451.670	0.918	0.000362	14.492
		Σ	708.772			
		%SSE	1.901			

Table 8-17 Elovich Model calculations

ln(t)	Capacity (100ppm)	Capacity (200ppm)	Capacity (300ppm)	Capacity (400ppm)	Capacity (500ppm)
0.693	7.8144	20.512	26.739	52.258	7.326
1.386	14.896	35.653	39.926	67.887	46.398
1.791	19.902	44.688	60.073	85.470	79.975
2.079	24.297	54.212	69.597	114.774	81.196
2.302	27.594	59.829	76.190	115.750	100.732
2.484	30.158	63.003	78.021	117.704	104.395
2.639	32.6005	64.957	82.051	123.565	113.553
2.995	35.897	71.794	90.842	132.844	130.647
3.218	37.240	74.725	100.732	136.752	137.973
3.401	37.973	76.923	105.128	143.101	144.688
3.688	38.583	79.853	108.424	147.985	150.793
4.094	38.949	80.097	108.791	148.962	155.677
4.499	39.072	80.341	109.157	150.915	159.340
4.787	39.072	80.341	109.157	151.404	158.119

Table 8-18 Elovich Model parameters

initial concentration (ppm)	Capacity (mg/g) Experimental	Capacity (mg/g) Elovich model	%SSE	R ²	b _e gmg ⁻¹	a _e mgg ⁻¹ min ⁻¹
100	39.072	45.598	42.592	0.86	0.125	20.506
200	80.341	91.924	134.151	0.878	0.067	60.382
300	109.157	124.718	242.1391	0.904	0.046	58.443

400	151.404	169.141	314.602	0.879	0.0397	173.836
500	158.119	183.460	642.1369	0.912	0.027	43.848
		Σ	1375.622			
		%SSE	2.649			

Table 8-19 Intraparticle diffusion Model calculations

$t^{(0.5)}$	Capacity (100ppm)	Capacity (200ppm)	Capacity (300ppm)	Capacity (400ppm)	Capacity (500ppm)
0	0	0	0	0	0
1.414	7.814	20.512	26.739	52.258	7.326
2	14.896	35.653	39.926	67.887	46.398
2.449	19.902	44.688	60.0732	85.470	79.975
2.828	24.297	54.212	69.597	114.774	81.196
3.162	27.594	59.829	76.1907	115.750	100.732
3.4645	30.158	63.003	78.021	117.704	104.395
3.741	32.600	64.957	82.051	123.565	113.553
4.472	35.897	71.794	90.842	132.84	130.647
5	37.240	74.725	100.732	136.752	137.973
5.477	37.973	76.923	105.128	143.101	144.688
6.324	38.583	79.853	108.424	147.985	150.793
7.7459	38.949	80.097	108.791	148.962	155.677
9.486	39.072	80.341	109.157	150.915	159.340
10.954	39.072	80.341	109.157	151.404	158.119

Table 8-20 Intra particle diffusion Model parameters

initial concentration (ppm)	Capacity (mg/g) Experimental	Capacity (mg/g) Intra-particle D Model	%SSE	R ²	k _i mg/g min ^{1/2}	c
100	39.072	39.399	0.107	0.7143	0.2653	36.493
200	80.341	81.39	1.107	0.6021	0.7755	72.899
300	109.157	110.641	2.202	0.5665	1.0829	98.779
400	151.404	153.492	4.362	0.7111	2.0177	131.39
500	158.119	162.083	15.711	0.7941	3.1771	127.28
		Σ	23.490			
		%SSE	0.807			

Table 8-21 Error Analysis for Kinetics Models

error analysis	pseudo First order	pseudo second order	Elovich model	Intra-particle D Model
%SSE	5.090	1.901	2.649	0.807

Fixed bed

- Table 8-22 represents the effect of bed depth

Conditions (bed heights = 4, 7 & 12cm were equivalent to 2.5, 5 & 7.5 gm of resin ,flow rate 60 ml/min, temperature 25°C±2 , initial concentration 500ppm & pH 4.28)

Table 8-22 Effect of Bed Depth

time (min)	C_t/C_o (4 cm)	C_t/C_o (7 cm)	C_t/C_o (12 cm)
5	0	0	0
10	0.046	0	0
15	0.623	0	0
20	0.794	0	0
25	0.828	0.090	0
30	0.841	0.454	0
35	0.9035	0.763	0.0497
40	0.928	0.887	0.133
45	0.934	0.912	0.295
50	0.996	0.937	0.573
55	0.993	0.950	0.791
60		0.965	0.934
65		0.990	0.968
70		0.996	0.971
75			0.978
80			0.984
85			0.984

- Table 8-23 represents the effect of different flow rates

Conditions (bed heights = 7 cm was equivalent to 5 gm of resin, flow rate 35,48,68 & 95 ml/min, temperature 25°C±2, initial concentration 500ppm & pH 4.28)

Table 8-23 Effect of Different Flow rates

time (min)	C_t/C_o (35ml/min)	C_t/C_o (45ml/min)	C_t/C_o (48 ml/min)	C_t/C_o (60ml/min)	C_t/C_o (68ml/min)	C_t/C_o (95ml/min)
5	0	0	0	0	0	0.0079
10	0	0	0	0	0	0.0930
15	0	0	0	0	0	0.4521
20	0	0	0	0.0903	0	0.7367
25	0	0.0026	0	0.4548	0.1957	0.9069
30	0	0.0105	0.0307	0.7632	0.4342	0.9920
35	0	0.0422	0.1230	0.8878	0.7155	0.9813
40	0	0.0949	0.3384	0.9127	0.8103	-
45	0.0154	0.2744	0.5876	0.9376	0.8134	-

50	0.0493	0.4511	0.6	0.9501	0.8593	-
55	0.0925	0.6992	0.7261	0.9657	0.8501	-
60	0.1697	0.7810	0.7415	0.9906	0.8532	-
65	0.2253	0.9076	0.7846	0.9968	0.8807	-
70	0.4043	0.9788	0.9969	-	0.8868	-
75	0.5617	0.9525	0.9846	-	0.9082	-
80	0.6203	0.9445	-	-	0.8929	-
85	0.7129	0.9525	-	-	0.9327	-
90	0.7407	-	-	-	0.9510	-
95	0.7654	-	-	-	0.9877	-
100	0.7777	-	-	-	0.9938	-
105	0.8086	-	-	-	-	-
110	0.8456	-	-	-	-	-
115	0.8641	-	-	-	-	-
120	0.9012	-	-	-	-	-
125	0.9320	-	-	-	-	-
130	0.9814	-	-	-	-	-
135	0.9876	-	-	-	-	-
140	0.9969	-	-	-	-	-

Calculations of Adsorption Capacity by Yoon-Nelson Model.

It was based on the definition that 50% breakthrough occurs at $t = \tau$. Thus, the adsorption bed should be completely saturated at $t = 2\tau$. [18]

$$q_0 = \frac{q_{(total)}}{w} = \frac{\frac{1}{2} C_0 [(Q/1000)(2\tau)]}{w} = \frac{C_0 \cdot Q \cdot \tau}{1000 \cdot w}$$

Table 8-24 Calculations of Adsorption Capacity by Yoon-Nelson Model.

Q (ml/min)	resin (g)	Z (cm)	C _o	q _{total} (mg/g)	τ (min)	q _{max} (mg/g)
different heights						
60	2.5	4	490	71.854	2.444	28.741
60	5	7	490	810.793	27.578	162.159
60	7.5	12	490	1449.596	49.306	193.280
20	10	16	542	1766.117	162.926	176.612
35	5	7	495	1307.767	75.484	261.553
45	5	7	578	1578.343	60.682	315.669
48	5	7	519	1340.631	53.815	268.126
68	5	7	499	1166.453	34.376	233.291
95	5	7	504	1181.477	24.676	236.295
48	7.5	12	499	3283.362	137.081	437.782
60	7.5	12	490	1449.596	49.306	193.280

- The breakthrough curves for the three models (Adam-Bohart, Thomas and Yoon- Nelson) were about 30 graphs for the whole flow rates studied so, a typical curve of one flow rate has been represented in the chapter of result and discussion.

- Table 8-25 represents the bed utilities and length of MTZ

Table 8-25 Bed Utilities and length of MTZ

C_o (ppm)	Q (ml/min)	Z (cm)	bed utilities (min)	L = Δ t (min)
different heights				
490	60	4	0.4169	10
490	60	7	0.9676	20
490	60	12	1.0085	30
542	20	16	0.9985	145
495	35	7	1.0079	85
578	45	7	1.0263	45
519	48	7	1.0121	35
499	68	7	1.0072	30
504	95	7	1.0238	20
499	48	12	1.0022	75
490	60	12	1.0085	30

Table 8-26 comparison among adsorption capacities of experimental and Thomas, Yoon-Nelson models

C_o (ppm)	Q (ml/min)	Z (cm)	Thomas model	Expremental	Yoon-Nelson Model
			q_o (mg/g)	q_{max} (mg/g)	q_{max} (mg/g)
different heights					
490	60	4	43.683	39.111	28.741
490	60	7	164.244	163.152	162.159
490	60	12	193.458	173.002	193.280
542	20	16	186.333	153.218	176.612
495	35	7	280.706	125.090	261.553
578	45	7	327.672	270.897	315.669
519	48	7	260.775	235.544	268.126
499	68	7	242.253	253.337	233.291
504	95	7	145.405	155.411	236.295
499	48	12	452.275	397.632	437.782
490	60	12	193.458	170.382	193.280

ARABIC

SUMMARY

الملخص العربي

أيونات الفلزات الثقيلة هي واحدة من الملوثات الرئيسية لموارد مياه الإنسان. الكروم سداسي التكافؤ يعد واحد من هذه الأيونات وكما هو معروف أن تكون سامة على صحة الإنسان والبيئة. هناك العديد من التقنيات المستخدمة للحد من محتوى أيونات الكروم في مياه الصرف، والطريقة الأكثر فعالية و هو استخدام راتنج التبادل الأيوني لامتزاز الكروم سداسي التكافؤ من مياه الصرف الصناعي.

في هذه الدراسة، تم استخدام نوع هلام قوي Diaion قاعدة الراتنج SA20A لامتزاز الكروم (VI) من المحاليل المائية. تحت تأثير العوامل المختلفة مثل تركيز ايون الكروم السداسي والرقم الهيدروجيني، وزن الراتنج، سرعة الموتر، ودرجة الحرارة

تم اختبار البيانات عند الاتزان باستخدام ثلاث نماذج Langmuir، Freundlich و Temkin، و قد أظهرت النتائج ان محور التحوار Langmuir عند حرارة ثابتة يكون مناسب لعملية الامتزاز أحادي الطبقة مع معامل ارتباط عالية وكانت أقصى سعة محققة ($q_{max} = 166.6 \text{mg/g}$).

تم تطبيق معادلة الحركة من الدرجة الأولى و معادلة الحركة من الدرجة الثانية و نماذج Elovich و أخيرا intraparticle. وأظهرت الدراسات الحركية أن الامتزاز يتبع معادلة الحركة الدرجة الثانية بمعامل ارتباط عالي إلى البيانات التجريبية.

واجريت التجارب الامتزاز المستمر باستخدام fixed bed لتقييم أداء الراتنج (Diaion SA20A) لإزالة الكروم (VI) من المحاليل المائية وتم دراسة العوامل المختلفة مثل سرعة سريان المحلول و ارتفاع bed. كلما زادت السرعة يقل زمن breakthrough و كلما زاد من ارتفاع fixed bed، ويحصل تأخير في زمن breakthrough.

ليتم تحليل أداء fixed bed تم تطبيق النماذج الرياضية مثل Adam-Bohart، توماس، يون-نيلسون و BDST، من بينها كان توماس نموذج مناسب لوصف عملية الامتزاز.

تم كتابة المراجع وفقا للجمعية الأمريكية لعلم النفس، ونظام الباحث العلمي من جوجل.

المشرفون

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حسن عبد المنعم فرج

أستاذ فى الهندسة الكيمائية

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جامعة الاسكندرية

كلية الهندسة

ازالة الكروم السداسى من المخلفات الصناعية السائلة
باستخدام التبادل الايونى

رسالة علمية

مقدمه إلى

كلية الهندسة - جامعة الأسكندرية

استيفاءً جزئياً للحصول على درجة

الماجستير

فى

الهندسة الكيميائية

مقدمة من

المهندسة/ فاطمة حسن جابر مصباح

2015