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APPENDIX A

Table A-1 : Dry moisture content (%) for various treatment of water hyacinth

Samples	Weight of samples		% dry moisture
	Before oven dry	After oven dry	
Untreated W.H.			
1	0.5270	0.4909	6.85
2	0.5144	04787	6.94
3	05158	0.4803	6.88
		Average value	6.89
0.4 N H_2SO_4 treated W.H.			
1	0.5694	0.5309	6.76
2	0.5600	05247	6.30
3	0.5554	0.5205	6.28
		Average value	6.45
2% CH_2O treated W.H.			
1	0.3076	0.3038	1.56
2	0.3093	0.3053	1.29
3	0.3073	0.3031	1.36
		Average value	1.40
5% CH_2O treated W.H.			
1	0.3010	0.2978	1.06
2	0.3054	0.3019	1.14
3	0.3007	0.3045	1.25
		Average value	1.15
10% CH_2O treated W.H.			
1	0.3015	0.2979	1.19
2	0.3056	0.3022	1.11
3	0.3013	0.3046	1.08
		Average value	1.12
20% CH_2O treated W.H.			
1	0.3001	0.2967	1.13
2	0.3052	0.3016	1.19
3	0.3019	0.3055	1.17
		Average value	1.16
30% CH_2O treated W.H.			
1	0.3164	0.3129	1.11
2	0.3095	0.3058	1.19
3	0.3115	0.3079	1.16
		Average value	1.15
37% CH_2O treated W.H.			
1	0.3035	0.2999	1.19
2	0.3103	0.3068	1.13
3	0.3071	0.3029	1.37
		Average value	1.23

Table A-2 : Degree of swelling for various treatment of water hyacinth (Solvent : H_2O)

Samples	D.W. of substrates	V_{ini}	V_{obs} after 48 hrs.	% of swelling
Untreated W.H.				
1	0.5021	7.00	15.00	+114.29
2	0.5050	7.10	16.00	+125.35
3	0.5045	7.10	15.00	+111.27
			Average value	+116.97
0.4 N H_2SO_4 treated W.H.				
1	0.5309	11.50	4.50	-60.87
2	0.5247	11.00	5.00	-54.55
3	0.5205	10.50	4.50	-57.14
			Average value	-57.52
2% CH_2O treated W.H.				
1	0.3074	4.75	4.75	0
2	0.3059	4.75	4.75	0
3	0.3087	4.75	4.50	-5.2
			Average value	-1.73
5% CH_2O treated W.H.				
1	0.3074	4.25	4.50	+5.88
2	0.3059	4.50	4.50	0
3	0.3087	4.50	4.50	0
			Average value	+1.96
10% CH_2O treated W.H.				
1	0.3111	4.75	4.50	-5.26
2	0.3117	4.75	4.50	-5.26
3	0.3112	4.75	4.50	-5.26
			Average value	-5.26
20% CH_2O treated W.H.				
1	0.3123	4.75	4.00	-15.79
2	0.3120	4.75	4.25	-10.53
3	0.3129	4.75	4.75	-15.79
			Average value	-14.04
30% CH_2O treated W.H.				
1	0.3142	4.75	3.75	-21.05
2	0.3137	4.75	3.75	-21.05
3	0.3144	4.75	3.75	-21.05
			Average value	-21.05
37% CH_2O treated W.H.				
1	0.3095	4.75	3.75	-21.05
2	0.3079	4.75	3.50	-26.32
3	0.3088	4.75	3.75	-21.05
			Average value	-22.81

Table A-3 : Degree of swelling for various treatment of water hyacinth (Solvent :10 % NaCl)

Samples	D.W. of substrates	V_{ini}	V_{obs} after 48 hrs.	% of swelling
Untreated W.H.				
1	0.3150	4.75	4.50	-5.26
2	0.3158	4.75	4.50	-5.26
3	0.3149	4.75	4.50	-5.26
			Average value	-5.26
0.4 N H_2SO_4 treated W.H.				
1	0.3179	4.75	3.75	-21.05
2	0.3167	4.75	3.75	-21.05
3	0.3183	4.75	3.75	-21.05
			Average value	-21.05
2% CH_2O treated W.H.				
1	0.3163	4.75	3.50	-26.32
2	0.3177	4.75	3.75	-21.05
3	0.3171	4.75	3.75	-21.05
			Average value	-22.81
5% CH_2O treated W.H.				
1	0.3148	4.75	3.75	-21.05
2	0.3157	4.75	3.75	-21.05
3	0.3154	4.75	3.75	-21.05
			Average value	-21.05
10% CH_2O treated W.H.				
1	0.3188	4.75	3.75	-21.05
2	0.3183	4.75	3.75	-21.05
3	0.3185	4.75	3.75	-21.05
			Average value	-21.05
20% CH_2O treated W.H.				
1	0.3145	4.75	3.75	-21.05
2	0.3139	4.75	3.50	-26.32
3	0.3153	4.75	3.75	-21.05
			Average value	-22.81
30% CH_2O treated W.H.				
1	0.3164	4.75	3.75	-21.05
2	0.3169	4.75	3.75	-21.05
3	0.3167	4.75	4.00	-15.79
			Average value	-19.30
37% CH_2O treated W.H.				
1	0.3181	4.75	3.75	-21.05
2	0.3174	4.75	3.75	-21.05
3	0.3178	4.75	3.75	-21.05
			Average value	-21.05

APPENDIX B

Batch experiments

Table B-1 : Effect of contact time on adsorption of heavy metal ions by 0.4 N. H_2SO_4 treated water hyacinth.

Heavy metal ions	Elapsed time (min)							
	1	2	5	10	20	40	60	80
Cu^{2+}	0.43	1.70	2.97	2.33	2.02	2.02	2.33	2.33
	0.11	1.70	2.97	2.02	2.33	2.02	2.33	2.33
	0.43	2.02	2.65	2.33	2.33	1.70	2.02	2.33
	0.32	**1.80**	**2.86**	**2.23**	**2.23**	**1.91**	**2.23**	**2.33**
Ni^{2+}	1.60	2.01	2.07	2.16	2.19	2.16	2.07	1.96
	1.57	1.99	2.07	2.13	2.16	2.16	2.04	1.93
	1.57	2.01	2.10	2.13	2.19	2.19	2.04	1.96
	1.58	**2.00**	**2.08**	**2.14**	**2.18**	**2.17**	**2.05**	**1.95**
Zn^{2+}	2.40	2.46	2.66	2.49	2.53	2.47	2.37	2.30
	2.40	2.49	2.63	2.53	2.53	2.47	2.37	2.27
	2.43	2.46	2.63	2.49	2.49	2.47	2.34	2.27
	2.41	**2.47**	**2.64**	**2.50**	**2.51**	**2.47**	**2.36**	**2.28**

Table B-2 : Various CH_2O treated water hyacinth on synthetic solutions = 25 ppm

Heavy metal ions	Heavy metal ions adsorbed (mg/0.5g substrate)						
	Untreated W.H.	2 % CH_2O	5 % CH_2O	10 % CH_2O	20 % CH_2O	30 % CH_2O	37 % CH_2O
Cu^{2+}	0.96	1.60	1.60	1.76	1.84	1.85	1.85
	0.93	1.57	1.60	1.79	1.84	1.85	1.85
	0.93	1.60	1.63	1.76	1.85	1.84	1.85
Average value	**0.94**	**1.59**	**1.61**	**1.77**	**1.84**	**1.85**	**1.85**
Ni^{2+}	0.81	1.22	1.19	1.33	1.33	1.36	1.39
	0.81	1.19	1.22	1.36	1.36	1.39	1.42
	0.78	1.19	1.22	1.33	1.36	1.36	1.39
Average value	**0.80**	**1.20**	**1.21**	**1.34**	**1.35**	**1.37**	**1.40**
Zn^{2+}	0.98	1.38	1.42	1.55	1.55	1.61	1.68
	0.95	1.38	1.42	1.55	1.58	1.61	1.71
	0.95	1.35	1.42	1.58	1.58	1.58	1.68
Average value	**0.97**	**1.37**	**1.43**	**1.56**	**1.57**	**1.60**	**1.69**

Table B-3 : Various CH_2O treated water hyacinth on synthetic solutions = 50 ppm

Heavy metal ions	Heavy metal ions adsorbed (mg/0.5g substrate)						
	Untreated W.H.	2 % CH_2O	5 % CH_2O	10 % CH_2O	20 % CH_2O	30 % CH_2O	37 % CH_2O
Cu^{2+}	1.48	1.53	1.53	1.53	1.53	1.53	1.85
	1.17	1.53	1.21	1.53	1.85	1.53	1.85
	1.48	1.21	1.53	1.21	1.53	1.85	1.85
Average value	**1.38**	**1.42**	**1.42**	**1.42**	**1.64**	**1.64**	**1.85**
Ni^{2+}	1.29	1.90	2.31	2.46	2.49	2.49	2.49
	1.26	1.90	2.31	2.46	2.49	2.49	2.52
	1.29	1.87	2.34	2.43	2.46	2.49	2.49
Average value	**1.28**	**1.89**	**2.32**	**2.45**	**2.48**	**2.49**	**2.50**
Zn^{2+}	1.70	2.14	2.17	2.33	2.37	2.37	2.37
	1.70	2.10	2.17	2.33	2.37	2.37	2.40
	1.66	2.14	2.20	2.30	2.33	2.37	2.37
Average value	**1.69**	**2.13**	**2.18**	**2.32**	**2.36**	**2.37**	**2.38**

Table B-4 : Various CH_2O treated water hyacinth on synthetic solutions = 75 ppm

Heavy metal ions	Heavy metal ions adsorbed (mg/0.5g substrate)						
	Untreated W.H.	2 % CH_2O	5 % CH_2O	10 % CH_2O	20 % CH_2O	30 % CH_2O	37 % CH_2O
	1.12	2.94	3.26	3.26	2.94	3.26	3.57
Cu^{2+}	1.12	2.62	3.26	3.26	3.26	3.26	3.57
	1.12	2.94	2.94	3.26	3.26	2.94	3.26
Average value	**1.12**	**2.83**	**3.15**	**3.26**	**3.15**	**3.15**	**3.47**
	1.65	2.08	2.08	2.23	2.23	2.23	2.23
Ni^{2+}	1.59	2.05	2.08	2.23	2.26	2.23	2.23
	1.62	2.08	2.11	2.26	2.23	2.26	2.26
Average value	**1.62**	**2.07**	**2.09**	**2.24**	**2.24**	**2.24**	**2.24**
	2.19	2.64	2.61	2.70	2.77	2.77	2.80
Zn^{2+}	2.22	2.61	2.64	2.70	2.80	2.77	2.77
	2.22	2.61	2.61	2.74	2.77	2.80	2.80
Average value	**2.21**	**2.62**	**2.62**	**2.71**	**2.78**	**2.78**	**2.79**

Table B-5 : Various CH_2O treated water hyacinth on synthetic solutions = 100 ppm

Heavy metal ions	Heavy metal ions adsorbed (mg/0.5g substrate)						
	Untreated W.H.	2 % CH_2O	5 % CH_2O	10 % CH_2O	20 % CH_2O	30 % CH_2O	37 % CH_2O
	2.33	2.44	2.76	2.76	2.76	2.76	3.39
Cu^{2+}	2.02	2.12	2.76	2.44	2.76	3.08	3.39
	2.33	2.44	2.44	2.76	2.44	2.76	3.39
Average value	**2.24**	**2.33**	**2.65**	**2.65**	**2.65**	**2.87**	**3.39**
	2.04	2.71	2.74	2.74	2.83	2.83	2.83
Ni^{2+}	2.04	2.68	2.74	2.77	2.83	2.83	2.80
	2.07	2.71	2.71	2.74	2.80	2.83	2.83
Average value	**2.05**	**2.70**	**2.73**	**2.75**	**2.82**	**2.83**	**2.82**
	2.51	3.23	3.23	3.29	3.39	3.39	3.39
Zn^{2+}	2.54	3.26	3.23	3.33	3.36	3.39	3.42
	2.51	3.23	3.26	3.33	3.39	3.39	3.39
Average value	**2.52**	**3.24**	**3.24**	**3.32**	**3.38**	**3.39**	**3.40**

APPENDIX C

Column Experiments

Table : C-1

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 5.16 ppm of $CuSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	10.00	4.0	ND	0.000
2	20.00	3.9	ND	0.000
3	30.00	4.1	ND	0.000
4	40.00	4.0	ND	0.000
5	50.00	4.1	ND	0.000
6	60.00	4.2	ND	0.000
7	70.00	4.2	ND	0.000
8	80.00	4.3	ND	0.000
9	90.00	4.4	ND	0.000
10	100.00	4.3	ND	0.000
11	110.00	4.4	ND	0.000
12	120.00	4.4	ND	0.000
13	132.02	4.5	ND	0.000
14	132.26	4.6	0.182	0.035
15	132.50	4.5	0.205	0.040
16	132.74	4.6	0.699	0.135
17	132.98	4.5	0.831	0.161
18	133.22	4.5	0.726	0.141
19	133.46	4.7	1.152	0.223
20	133.70	4.7	1.138	0.221
21	133.94	4.7	1.327	0.257
22	134.18	4.7	1.466	0.284
23	134.42	4.6	1.674	0.324
24	134.66	4.7	1.945	0.377
25	134.90	4.6	2.381	0.461
26	135.14	4.7	2.543	0.493
27	135.38	4.7	2.731	0.529
28	135.62	4.7	2.808	0.544
29	135.86	4.7	2.766	0.536
30	136.10	4.6	2.979	0.577
31	136.34	4.7	3.135	0.608
32	136.58	4.7	3.160	0.612
33	136.82	4.7	3.269	0.634
34	137.06	4.9	3.849	0.746
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C_i, ppm)	C/C_0
35	137.30	4.9	3.957	0.767
36	137.54	4.8	4.149	0.804
37	137.78	4.9	4.265	0.827
38	138.02	4.9	4.356	0.844
39	138.26	4.9	4.419	0.856
40	138.50	5.0	4.516	0.875
41	138.74	5.0	4.533	0.878
42	138.98	5.0	4.577	0.887
43	139.22	5.1	4.938	0.957
44	139.46	5.0	4.966	0.962
45	139.70	5.2	5.010	0.971
46	139.94	5.3	5.012	0.971
47	140.18	5.3	5.003	0.970
48	140.42	5.2	5.037	0.976
49	140.66	5.3	5.297	1.027
50	140.90	5.3	5.292	1.026
51	141.14	5.3	5.335	1.032
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	5.16 ppm of $CuSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C, ppm)	C/C_0
1	0.24	0.334	0.065
2	0.48	265.250	51.405
3	0.72	12868.000	2493.798
4	0.96	171.200	33.178
5	1.20	5.502	1.066
6	1.44	3.382	0.655
7	1.68	2.235	0.433
8	1.92	1.777	0.344
9	2.16	1.448	0.281
10	2.40	1.316	0.255
11	2.64	1.067	0.207
12	2.88	0.983	0.191
13	3.12	0.877	0.170
14	3.36	0.875	0.170
15	3.60	0.785	0.152
16	3.84	0.738	0.143
17	4.08	0.658	0.128
18	4.32	0.651	0.126
19	4.56	0.579	0.112
20	4.80	0.583	0.113

Table : C-2

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 5.12 ppm of $NiSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	10.00	3.9	ND	0.000
2	20.00	3.8	ND	0.000
3	30.00	4.2	ND	0.000
4	40.00	4.5	ND	0.000
5	50.00	4.8	ND	0.000
6	60.00	4.7	ND	0.000
7	71.62	4.9	ND	0.000
8	71.86	4.9	ND	0.000
9	72.10	4.9	ND	0.000
10	72.34	4.8	ND	0.000
11	72.58	4.8	ND	0.000
12	72.82	4.7	ND	0.000
13	73.06	4.8	ND	0.000
14	73.30	4.8	ND	0.000
15	73.54	4.8	ND	0.000
16	73.78	4.9	ND	0.000
17	74.02	4.8	ND	0.000
18	74.26	5.0	0.116	0.023
19	74.50	5.0	0.119	0.023
20	74.74	5.0	0.129	0.025
21	74.98	5.0	0.158	0.031
22	75.22	5.1	0.203	0.040
23	75.46	5.0	0.219	0.043
24	75.70	5.0	0.266	0.052
25	75.94	5.0	0.327	0.062
26	76.18	5.1	0.384	0.075
27	76.42	5.0	0.451	0.088
28	76.66	5.0	0.505	0.099
29	76.90	5.0	0.560	0.109
30	77.14	5.1	0.646	0.126
31	77.38	5.0	0.719	0.140
32	77.62	5.0	0.800	0.156
33	77.86	5.1	0.897	0.175
34	78.10	5.0	0.925	0.181
35	78.34	5.0	1.108	0.216
36	78.58	5.0	1.175	0.229
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
37	78.82	5.1	1.301	0.254
38	79.06	5.1	1.319	0.258
39	79.30	5.1	2.473	0.483
40	79.54	5.1	2.587	0.505
41	79.78	5.0	2.696	0.527
42	80.02	5.1	3.219	0.629
43	80.26	5.1	3.673	0.717
44	80.50	5.0	3.814	0.745
45	80.74	5.1	3.991	0.779
46	80.98	5.1	4.326	0.845
47	81.22	5.1	4.639	0.906
48	81.46	5.1	5.013	0.979
49	81.70	5.1	5.094	0.995
50	81.94	5.1	5.128	1.002
51	82.18	5.1	5.101	0.996
52	82.42	5.1	5.239	1.023
53	82.66	5.0	5.312	1.038
54	82.90	5.1	5.309	1.037
55	83.14	5.0	5.373	1.049
56	83.38	5.1	5.216	1.019
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	5.12 ppm. of $NiSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C; ppm)	C/C_0
1	0.24	0.040	0.008
2	0.48	88.000	17.188
3	0.72	6876.000	1342.969
4	0.96	103.900	20.293
5	1.20	2.467	0.482
6	1.44	1.294	0.253
7	1.68	0.898	0.175
8	1.92	0.768	0.150
9	2.16	0.763	0.149
10	2.40	0.564	0.110
11	2.64	0.518	0.101
12	2.88	0.496	0.097
13	3.12	0.469	0.092
14	3.36	0.467	0.091
15	3.60	0.433	0.085
16	3.84	0.408	0.080
17	4.08	0.397	0.078
18	4.32	0.417	0.081
19	4.56	0.372	0.073
20	4.80	0.349	0.068

Table : C-3

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 4.92 ppm of $ZnSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C; ppm)	C/C_0
1	10.00	3.1	ND	0.000
2	20.00	3.2	ND	0.000
3	30.00	3.4	ND	0.000
4	40.00	3.6	ND	0.000
5	50.00	3.9	ND	0.000
6	60.00	4.0	ND	0.000
7	70.00	4.3	ND	0.000
8	80.00	4.4	ND	0.000
9	90.00	4.7	ND	0.000
10	106.71	4.9	ND	0.000
11	106.95	4.9	0.053	0.011
12	107.19	4.9	0.054	0.011
13	107.43	4.9	0.063	0.013
14	107.67	4.9	0.069	0.014
15	107.91	4.9	0.086	0.017
16	108.15	4.9	0.098	0.020
17	108.39	4.9	0.121	0.025
18	108.63	5.0	0.141	0.029
19	108.87	4.9	0.162	0.033
20	109.11	4.9	0.190	0.039
21	109.35	4.9	0.197	0.040
22	109.59	5.0	0.242	0.049
23	109.83	4.9	0.287	0.058
24	110.07	4.9	0.333	0.068
25	110.31	4.9	0.381	0.077
26	110.55	4.9	0.446	0.091
27	110.79	4.9	0.479	0.097
28	111.03	4.9	0.532	0.108
29	111.27	5.0	0.600	0.122
30	111.51	5.0	0.654	0.133
31	111.75	5.0	0.707	0.144
32	111.99	5.0	0.774	0.157
33	112.23	5.0	0.831	0.169
34	112.47	5.0	0.901	0.183
35	112.71	5.0	0.944	0.193
36	112.95	5.0	1.018	0.207
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C; ppm)	C/C_0
37	113.19	5.0	1.090	0.222
38	113.43	5.1	1.141	0.232
39	113.67	5.0	1.208	0.246
40	113.91	5.0	1.263	0.257
41	114.15	5.1	1.343	0.273
42	114.39	5.0	1.398	0.284
43	114.63	5.0	1.293	0.263
44	114.87	5.1	1.437	0.292
45	115.11	5.0	1.661	0.338
46	115.35	5.1	1.903	0.387
47	115.59	5.1	2.176	0.442
48	115.83	5.1	2.097	0.426
49	116.07	5.2	2.220	0.451
50	116.31	5.1	3.497	0.711
51	116.55	5.1	3.593	0.730
52	116.79	5.1	4.359	0.886
53	117.03	5.1	4.533	0.921
54	117.27	5.2	4.917	0.999
55	117.51	5.1	4.832	0.982
56	117.75	5.1	4.919	1.000
57	117.99	4.9	5.014	1.019
58	118.23	4.8	5.092	1.035
59	118.47	4.9	5.011	1.018
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	4.92 ppm. of $ZnSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C; ppm)	C/C_0
1	0.24	0.044	0.009
2	0.48	92.700	18.841
3	0.72	7057.500	1434.451
4	0.96	94.450	19.197
5	1.20	4.312	0.876
6	1.44	1.369	0.278
7	1.68	0.837	0.170
8	1.92	0.757	0.154
9	2.16	0.517	0.105
10	2.40	0.451	0.092
11	2.64	0.358	0.073
12	2.88	0.352	0.072
13	3.12	0.334	0.068
14	3.36	0.304	0.062
15	3.60	0.376	0.076
16	3.84	0.310	0.063
17	4.08	0.257	0.052
18	4.32	0.224	0.046
19	4.56	0.247	0.050
20	4.80	0.240	0.049

Table : C-4

Substrate : 5 % CH_2O treated W.H.
Effective size : 60-80 mesh.
Synthetic solution (C_0) : 10.46 ppm of $CuSO_4$
pH : 5.00
Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	5.00	4.2	ND	0.000
2	10.00	4.4	ND	0.000
3	15.00	4.7	ND	0.000
4	20.00	4.7	ND	0.000
5	25.00	4.8	ND	0.000
6	30.00	4.0	ND	0.000
7	35.00	3.8	ND	0.000
8	40.00	3.6	ND	0.000
9	45.00	3.4	ND	0.000
10	50.00	3.1	ND	0.000
11	55.00	3.5	ND	0.000
12	60.00	3.6	ND	0.000
13	65.00	3.5	ND	0.000
14	70.00	3.9	ND	0.000
15	78.54	4.0	ND	0.000
16	78.78	4.1	0.133	0.013
17	79.02	4.2	0549	0.052
18	79.26	4.2	0.900	0.086
19	79.50	4.2	1.390	0.133
20	79.74	4.0	1.416	0.135
21	79.98	3.9	1.569	0.150
22	80.22	3.9	1.943	0.186
23	80.46	3.8	2.302	0.220
24	80.70	3.8	2.205	0.211
25	80.94	3.6	2.391	0.229
26	81.18	3.5	2.506	0.240
27	81.42	3.6	2.588	0.247
28	81.66	3.5	2.747	0.263
29	81.90	3.5	2.973	0.284
30	82.14	3.6	3.788	0.362
31	82.38	3.5	4.808	0.460
32	82.62	3.6	5.128	0.490
33	82.86	3.8	5.826	0.557
34	83.10	3.8	5.912	0.565
35	83.34	3.9	6.799	0.650
36	83.58	4.1	6.978	0.667
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
37	83.82	4.0	7.187	0.687
38	84.06	4.1	7.857	0.751
39	84.30	4.2	8.314	0.795
40	84.54	4.2	8.778	0.839
41	84.78	4.3	9.293	0.888
42	85.02	4.2	9.775	0.935
43	85.26	4.3	10.381	0.992
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	10.46 ppm. of $CuSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (B.V.)	Conc. of effluent (C; ppm)	C/C_0
1	0.24	0.003	0.003
2	0.48	0.024	0.024
3	0.72	4858.000	464.436
4	0.96	145.700	13.929
5	1.20	3.916	0.374
6	1.44	2.139	0.204
7	1.68	1.418	0.136
8	1.92	1.224	0.117
9	2.16	0.978	0.092
10	2.40	0.737	0.070
11	2.64	0.621	0.059
12	2.88	0.508	0.048
13	3.12	0.388	0.037
14	3.36	0.278	0.026
15	3.60	0.263	0.025
16	3.84	0.342	0.032
17	4.08	0.167	0.016
18	4.32	0.144	0.014
19	4.56	0.145	0.014
20	4.80	0.133	0.013

Table : C-5

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 10.57 ppm of $NiSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	5.00	3.3	ND	0.000
2	10.00	3.2	ND	0.000
3	15.00	3.4	ND	0.000
4	20.00	3.6	ND	0.000
5	25.00	3.8	ND	0.000
6	30.00	3.9	ND	0.000
7	33.42	4.2	ND	0.000
8	33.66	4.1	0.569	0.056
9	33.90	4.2	0.746	0.071
10	34.14	4.2	0.815	0.077
11	34.38	4.2	0.976	0.092
12	34.62	4.2	1.095	0.104
13	34.86	4.2	1.248	0.118
14	35.10	4.2	1.360	0.129
15	35.34	4.1	1.582	0.150
16	35.58	4.1	1.718	0.163
17	35.82	4.2	1.857	0.176
18	36.06	4.3	2.890	0.273
19	36.30	4.4	3.494	0.331
20	36.54	4.4	3.724	0.352
21	36.78	4.3	3.129	0.296
22	37.02	4.3	2.835	0.249
23	37.26	4.3	2.935	0.278
24	37.50	4.3	3.092	0.293
25	37.74	4.3	3.257	0.308
26	37.98	4.3	3.416	0.323
27	38.22	4.4	3.567	0.337
28	38.46	4.3	3.705	0.351
29	38.70	4.3	3.869	0.366
30	38.94	4.3	4.047	0.383
31	39.18	4.4	4.200	0.397
32	39.42	4.4	4.394	0.416
33	39.66	4.4	4.636	0.439
34	39.90	4.4	4.822	0.456
35	40.14	4.5	4.880	0.462
36	40.38	4.4	4.956	0.469
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C_i, ppm)	C/C_o
37	40.62	4.5	5.278	0.499
38	40.86	4.6	5.716	0.541
39	41.10	4.7	5.722	0.541
40	41.34	4.6	5.636	0.533
41	41.58	4.5	5.626	0.532
42	41.82	4.6	5.638	0.533
43	42.06	4.6	5.678	0.537
44	42.30	4.5	5.734	0.542
45	42.54	4.5	5.826	0.551
46	42.78	4.5	5.700	0.539
47	43.02	4.5	6.455	0.611
48	43.26	4.6	8.200	0.776
49	43.50	4.6	8.391	0.794
50	43.74	4.7	8.816	0.834
51	43.98	4.6	8.932	0.845
52	44.22	4.7	9.339	0.884
53	44.46	4.8	9.371	0.887
54	44.70	4.8	9.355	0.885
55	44.94	4.8	9.564	0.905
56	45.18	4.7	9.512	0.900
57	45.42	4.8	9.558	0.904
58	45.66	4.7	9.717	0.919
59	45.90	4.8	9.752	0.923
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	10.57 ppm. of $NiSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C, ppm)	C/C_0
1	0.24	11.535	1.091
2	0.48	2247.000	212.583
3	0.72	4060.000	384.106
4	0.96	49.960	4.727
5	1.20	2.150	0.203
6	1.44	0.725	0.069
7	1.68	0.343	0.032
8	1.92	0.224	0.021
9	2.16	0.179	0.017
10	2.40	0.148	0.014
11	2.64	0.126	0.012
12	2.88	0.081	0.008
13	3.12	0.079	0.007
14	3.36	0.067	0.006
15	3.60	0.044	0.004
16	3.84	0.064	0.006
17	4.08	0.060	0.006
18	4.32	0.057	0.005
19	4.56	0.043	0.004
20	4.80	0.038	0.004

Table : C-6

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 10.49 ppm of $ZnSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C; ppm)	C/C_0
1	5.00	3.6	ND	0.000
2	10.00	3.8	ND	0.000
3	15.00	3.8	ND	0.000
4	20.00	3.5	ND	0.000
5	25.00	3.6	ND	0.000
6	30.00	3.6	ND	0.000
7	35.00	3.8	ND	0.000
8	39.15	3.9	ND	0.000
9	39.39	4.1	0.438	0.042
10	39.63	4.1	0.783	0.075
11	39.87	4.2	0.907	0.086
12	40.11	4.2	1.281	0.122
13	40.35	4.2	1.789	0.171
14	40.59	4.1	1.775	0.169
15	40.83	4.1	2.243	0.214
16	41.07	4.0	2.464	0.235
17	41.31	4.2	2.472	0.236
18	41.55	4.1	2.828	0.270
19	41.79	4.1	2.945	0.281
20	42.03	4.1	3.170	0.302
21	42.27	4.2	3.024	0.288
22	42.51	4.2	3.360	0.320
23	42.75	4.1	3.663	0.349
24	42.99	4.2	3.847	0.367
25	43.23	1.1	4.142	0.395
26	43.47	4.3	5.201	0.496
27	43.71	4.3	5.264	0.502
28	43.95	4.2	5.997	0.572
29	44.19	4.2	6.407	0.611
30	44.43	4.1	5.495	0.524
31	44.67	4.2	5.668	0.540
32	44.91	4.2	6.921	0.660
33	45.15	4.2	6.735	0.642
34	45.39	4.3	7.398	0.705
35	45.63	4.2	7.274	0.693
36	45.87	4.3	7.463	0.711
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C_i, ppm)	C/C_0
37	46.11	4.5	7.166	0.683
38	46.35	4.5	8.203	0.782
39	46.59	4.6	8.234	0.785
40	46.83	4.5	8.336	0.795
41	47.07	4.6	8.502	0.810
42	47.31	4.9	8.771	0.836
43	47.55	4.8	8.878	0.846
44	47.79	4.9	9.289	0.886
45	48.03	4.9	9.313	0.888
46	48.27	5.1	9.508	0.906
47	48.51	5.0	9.123	0.870
48	48.75	5.1	9.274	0.884
49	48.99	5.1	9.832	0.937
50	49.23	5.0	9.932	0.947
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	10.49 ppm. of $ZnSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C_i ppm)	C/C_0
1	0.24	0.079	0.008
2	0.48	0.256	0.024
3	0.72	7752.000	738.990
4	0.96	586.000	55.863
5	1.20	1.611	0.154
6	1.44	0.460	0.044
7	1.68	0.284	0.027
8	1.92	0.231	0.022
9	2.16	0.192	0.018
10	2.40	0.159	0.015
11	2.64	0.150	0.014
12	2.88	0.146	0.014
13	3.12	0.138	0.013
14	3.36	0.140	0.013
15	3.60	0.136	0.013
16	3.84	0.137	0.013
17	4.08	0.130	0.012
18	4.32	0.136	0.013
19	4.56	0.130	0.012
20	4.80	0.133	0.013

Table : C-7

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 20.86 ppm of $CuSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	2.00	3.0	ND	0.000
2	4.00	3.1	ND	0.000
3	6.00	3.1	ND	0.000
4	8.00	3.2	ND	0.000
5	10.00	3.2	ND	0.000
6	12.00	3.2	ND	0.000
7	14.00	3.3	ND	0.000
8	16.00	3.2	ND	0.000
9	18.00	3.2	ND	0.000
10	20.00	3.2	ND	0.000
11	22.00	3.3	ND	0.000
12	24.00	3.4	ND	0.000
13	26.02	3.6	ND	0.000
14	26.26	3.9	0.967	0.046
15	26.50	3.9	1.022	0.049
16	26.74	3.9	0.401	0.019
17	26.98	3.9	0.222	0.011
18	27.22	3.9	0.136	0.007
19	27.46	3.9	0.119	0.006
20	27.70	3.9	0.152	0.007
21	27.94	3.9	0.288	0.014
22	28.18	3.9	0.599	0.029
23	28.42	3.9	1.294	0.062
24	28.66	3.9	2.190	0.105
25	28.90	3.9	3.331	0.160
26	29.14	4.4	4.362	0.209
27	29.38	4.0	1.208	0.058
28	29.62	4.0	1.406	0.067
29	29.86	4.0	1.316	0.063
30	30.10	4.1	1.649	0.079
31	30.34	4.0	9.710	0.465
32	30.58	4.0	10.825	0.519
33	30.82	4.1	10.810	0.518
34	31.06	4.0	12.600	0.604
35	31.30	4.0	13.195	0.633
36	31.54	4.0	14.545	0.697
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C; ppm)	C/C_0
37	31.78	4.1	15.080	0.723
38	32.02	4.0	16.145	0.774
39	32.26	4.1	14.825	0.711
40	32.50	4.1	15.900	0.762
41	32.74	4.1	16.485	0.790
42	32.98	4.1	16.795	0.805
43	33.22	4.1	17.192	0.824
44	33.46	4.2	17.311	0.830
45	33.70	4.1	17.506	0.839
46	33.94	4.2	17.750	0.851
47	34.18	4.2	18.920	0.907
48	34.42	4.2	19.531	0.936
49	34.66	4.2	19.649	0.942
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	20.86 ppm. of $CuSO_4$
pH	:	5.00
Flow rate	:	10 ml/min

Sample No.	Bed Volume (BV.)	Conc. of effluent (C, ppm)	C/C_0
1	0.24	0.182	0.009
2	0.48	240.000	11.505
3	0.72	11895.000	570.230
4	0.96	340.900	16.342
5	1.20	5.576	0.267
6	1.44	1.978	0.095
7	1.68	1.279	0.061
8	1.92	0.925	0.044
9	2.16	0.710	0.034
10	2.40	0.559	0.027
11	2.64	0.458	0.022
12	2.88	0.392	0.019
13	3.12	0.304	0.015
14	3.36	0.285	0.014
15	3.60	0.251	0.012
16	3.84	0.234	0.011
17	4.08	0.225	0.011
18	4.32	0.209	0 010
19	4.56	0.202	0.010
20	4.80	0.195	0.009

Table : C-8

Substrate : 5 % CH_2O treated W.H.
Effective size : 60-80 mesh.
Synthetic solution (C_0) : 18.89 ppm of $NiSO_4$
pH : 5.00
Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	2.00	4.0	ND	0.000
2	4.00	4.0	ND	0.000
3	6.00	4.1	ND	0.000
4	8.00	3.7	ND	0.000
5	10.00	3.5	ND	0.000
6	12.00	3.6	ND	0.000
7	14.00	3.6	ND	0.000
8	16.47	3.7	ND	0.000
9	16.71	3.6	0.584	0.031
10	16.95	3.7	0.977	0.052
11	17.19	3.7	2.439	0.129
12	17.43	3.8	2.650	0.140
13	17.67	3.7	4.927	0.261
14	17.91	3.8	5.329	0.282
15	18.15	3.8	5.380	0.285
16	18.39	3.8	7.815	0.414
17	18.63	3.9	9.435	0.499
18	18.87	3.9	9.398	0.498
19	19.11	3.9	15.320	0.811
20	19.35	3.9	16.926	0.896
21	19.59	4.0	16.900	0.895
22	19.83	3.9	17.611	0.932
23	20.07	3.9	17.014	0.901
24	20.31	4.0	17.873	0.946
25	20.55	4.1	18.162	0.961
26	20.79	4.1	18.317	0.970
27	21.03	4.1	18.642	0.987
28	21.27	4.1	18.603	0.985
29	21.51	4.3	18.530	0.981
30	21.75	4.3	18.739	0.992
31	21.99	4.4	18.982	1.005
32	22.23	4.3	18.723	0.991
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	18.89 ppm. of $NiSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C, ppm)	C/C_0
1	0.24	0.347	0.018
2	0.48	1764.000	93.383
3	0.72	3158.000	167.178
4	0.96	2.492	0.132
5	1.20	1.538	0.081
6	1.44	0.932	0.049
7	1.68	0.527	0.028
8	1.92	0.424	0.022
9	2.16	0.321	0.017
10	2.40	0.180	0.010
11	2.64	0.139	0.007
12	2.88	0.108	0.006
13	3.12	0.076	0.004
14	3.36	0.042	0.002
15	3.60	0.011	0.001
16	3.84	0.005	0.000
17	4.08	0.010	0.001
18	4.32	0.019	0.001
19	4.56	0.102	0.005
20	4.80	0.069	0.004

Table : C-9

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 19.41 ppm of $ZnSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (B.V.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	2.00	4.2	ND	0.000
2	4.00	3.2	ND	0.000
3	6.00	3.5	ND	0.000
4	8.00	3.7	ND	0.000
5	10.00	3.6	ND	0.000
6	12.00	3.7	ND	0.000
7	14.00	3.9	ND	0.000
8	16.00	4.0	ND	0.000
9	18.00	4.0	ND	0.000
10	19.58	3.9	ND	0.000
11	19.82	3.9	0.680	0.035
12	20.06	3.9	1.025	0.053
13	20.30	3.9	1.485	0.077
14	20.54	3.9	2.088	0.108
15	20.78	3.9	2.682	0.138
16	21.02	4.0	3.258	0.168
17	21.26	4.0	4.350	0.224
18	21.50	4.0	5.020	0.259
19	21.74	4.2	8.615	0.444
20	21.98	4.1	10.235	0.527
21	22.22	4.2	9.575	0.493
22	22.46	4.3	10.135	0.522
23	22.70	4.1	10.665	0.549
24	22.94	4.1	10.265	0.529
25	23.18	4.2	10.180	0.524
26	23.42	4.2	10.310	0.531
27	23.66	4.2	10.550	0.544
28	23.90	4.2	10.815	0.557
29	24.14	4.2	10.960	0.565
30	24.38	4.2	16.950	0.873
31	24.62	4.2	16.860	0.869
32	24.86	4.2	17.930	0.924
33	25.10	4.2	18.240	0.940
34	25.34	4.2	17.490	0.901
35	25.58	4.2	17.142	0.883
36	25.82	4.2	17.699	0.912
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_o
37	26.06	4.2	17.918	0.923
38	26.30	4.1	17.962	0.925
39	26.54	4.2	18.080	0.931
40	26.78	4.3	17.913	0.923
41	27.02	4.2	17.875	0.921
42	27.26	4.2	17.231	0.888
43	27.50	4.2	17.656	0.910
44	27.74	4.3	18.112	0.933
45	27.98	4.2	18.432	0.950
46	28.22	4.2	18.051	0.930
47	28.46	4.2	18.601	0.958
48	28.70	4.2	18.433	0.950
49	28.94	4.2	18.940	0.976
50	29.14	4.2	19.077	0.983
51	29.42	4.2	19.381	0.999
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	19.41 ppm. of $ZnSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C; ppm)	C/C_0
1	0.24	12.890	0664
2	0.48	16.100	0.829
3	0.72	4326.000	222.875
4	0.96	39.550	3.142
5	1.20	1.296	0.067
6	1.44	0.571	0.029
7	1.68	0.441	0.023
8	1.92	0.277	0.014
9	2.16	0.219	0.011
10	2.40	0.177	0.009
11	2.64	0.152	0.008
12	2.88	0.128	0 007
13	3.12	0.664	0.034
14	3.36	0.102	0.005
15	3.60	0.157	0.008
16	3.84	0.067	0.003
17	4.08	0.016	0.001
18	4.32	0.016	0.001
19	4.56	0.010	0.001
20	4.80	0.006	0.000

Table : C10

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 52.65 ppm of $CuSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	0.24	3.1	ND	0.000
2	0.48	3.0	ND	0.000
3	0.72	3.1	ND	0.000
4	0.96	3.2	ND	0.000
5	1.20	3.2	ND	0.000
6	1.44	3.3	ND	0.000
7	1.68	3.2	ND	0.000
8	1.92	3.3	ND	0.000
9	2.16	3.3	ND	0.000
10	2.40	3.2	ND	0.000
11	2.64	3.2	ND	0.000
12	2.88	3.2	ND	0.000
13	3.12	3.3	ND	0.000
14	3.36	3.3	ND	0.000
15	3.60	3.2	ND	0.000
16	3.84	3.3	ND	0.000
17	4.08	3.3	ND	0.000
18	4.32	3.4	ND	0.000
19	4.56	3.2	ND	0.000
20	4.80	3.3	ND	0.000
21	5.04	3.4	ND	0.000
22	5.28	3.5	ND	0.000
23	5.52	3.5	ND	0.000
24	5.76	3.6	ND	0.000
25	6.00	3.5	ND	0.000
26	6.24	3.5	ND	0.000
27	6.48	3.5	ND	0.000
28	6.72	3.5	ND	0.000
29	6.96	3.6	ND	0.000
30	7.20	3.6	ND	0.000
31	7.44	3.6	ND	0.000
32	7.68	3.6	ND	0.000
33	7.92	3.7	ND	0.000
34	8.16	3.8	ND	0.000
35	8.40	3.9	ND	0.000
36	8.64	3.8	ND	0.000
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
37	8.88	3.8	ND	0.000
38	9.12	3.9	ND	0.000
39	9.36	4.0	ND	0.000
40	9.60	4.0	ND	0.000
41	9.84	3.9	0.680	0.013
42	10.08	3.8	0.709	0.013
43	10.32	4.0	0.801	0.015
44	10.56	4.1	0.825	0.016
45	10.80	4.0	0.954	0.018
46	11.04	4.1	1.427	0.027
47	11.28	4.1	4.125	0.078
48	11.52	4.1	15.825	0.301
49	11.76	4.0	27.250	0.518
50	12.00	4.1	31.575	0.600
51	12.24	4.1	45.550	0.865
52	12.48	4.1	52.450	0.996
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	52.65 ppm. of $CuSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C_i, ppm)	C/C_0
1	0.24	1.391	0.026
2	0.48	170.000	3.229
3	0.72	11360.000	215.764
4	0.96	174.600	3.316
5	1.20	102.000	1.937
6	1.44	1.856	0.035
7	1.68	1.064	0.020
8	1.92	0.703	0.013
9	2.16	0.566	0.011
10	2.40	0.492	0.009
11	2.64	3.804	0.072
12	2.88	1.043	0.020
13	3.12	0.535	0.010
14	3.36	0.230	0.004
15	3.60	0.200	0.004
16	3.84	0.210	0.004
17	4.08	0.204	0.004
18	4.32	0.165	0.003
19	4.56	0.187	0.004
20	4.80	0.161	0.003

Table : C-11

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 51.75 ppm. of $NiSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (B.V.)	pH	Conc. of effluent (C; ppm)	C/C_0
1	0.24	4.4	ND	0.000
2	0.48	4.2	ND	0.000
3	0.72	4.3	ND	0.000
4	0.96	4.1	ND	0.000
5	1.20	4.0	ND	0.000
6	1.44	4.0	ND	0.000
7	1.68	4.0	ND	0.000
8	1.92	4.0	ND	0.000
9	2.16	4.0	ND	0.000
10	2.40	4.0	ND	0.000
11	2.64	4.0	ND	0.000
12	2.88	4.0	ND	0.000
13	3.12	3.9	ND	0.000
14	3.36	4.0	ND	0.000
15	3.60	3.7	ND	0.000
16	3.84	3.7	ND	0.000
17	4.08	3.7	ND	0.000
18	4.32	3.7	0.087	0.002
19	4.56	3.6	0.173	0.003
20	4.80	3.6	2.881	0.056
21	5.04	3.5	11.598	0.224
22	5.28	3.5	20.415	0.394
23	5.52	3.6	27.342	0.528
24	5.76	3.6	32.745	0.633
25	6.00	3.6	37.515	0.725
26	6.24	3.6	40.155	0.776
27	6.48	3.6	43.200	0.835
28	6.72	3.6	44.700	0.864
29	6.96	3.4	46.605	0.901
30	7.20	3.5	49.080	0.948
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	51.75 ppm. of $NiSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C_i, ppm)	C/C_0
1	0.24	2.096	0.041
2	0.48	4136.000	79.923
3	0.72	317.50	6.135
4	0.96	11.000	0.213
5	1.20	0.498	0.010
6	1.44	0.374	0.007
7	1.68	0.233	0.005
8	1.92	ND	0.000
9	2.16	ND	0.000
10	2.40	ND	0.000
11	2.64	ND	0.000
12	2.88	ND	0.000
13	3.12	ND	0.000
14	3.36	ND	0.000
15	3.60	ND	0.000
16	3.84	ND	0.000
17	4.08	ND	0.000
18	4.32	ND	0.000
19	4.56	ND	0.000
20	4.80	ND	0.000

Table : C-12

Substrate : 5 % CH_2O treated W.H.

Effective size : 60-80 mesh.

Synthetic solution (C_0) : 50.18 ppm of $ZnSO_4$

pH : 5.00

Flow rate : 3 ml/min.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C, ppm)	C/C_0
1	0.24	4.1	ND	0.000
2	0.48	4.2	ND	0.000
3	0.72	4.2	ND	0.000
4	0.96	4.3	ND	0.000
5	1.20	4.3	ND	0.000
6	1.44	4.0	ND	0.000
7	1.68	4.1	ND	0.000
8	1.92	4.1	ND	0.000
9	2.16	4.1	ND	0.000
10	2.40	4.1	ND	0.000
11	2.64	4.1	ND	0.000
12	2.88	4.1	ND	0.000
13	3.12	4.0	ND	0.000
14	3.36	4.1	ND	0.000
15	3.60	4.0	ND	0.000
16	3.84	3.9	ND	0.000
17	4.08	3.9	ND	0.000
18	4.32	3.7	ND	0.000
19	4.56	3.7	ND	0.000
20	4.80	3.7	ND	0.000
21	5.04	3.7	ND	0.000
22	5.28	3.7	ND	0.000
23	5.52	3.6	ND	0.000
24	5.76	3.7	ND	0.000
25	6.00	3.7	ND	0.000
26	6.24	3.7	ND	0.000
27	6.48	3.7	ND	0.000
28	6.72	3.7	ND	0.000
29	6.96	3.7	ND	0.000
30	7.20	3.7	0.628	0.013
31	7.44	3.7	2.998	0.060
32	7.68	3.7	12.700	0.253
33	7.92	3.6	18.100	0.361
34	8.16	3.4	21.800	0.434
35	8.40	3.5	25.800	0.514
36	8.64	3.5	26.700	0.532
				cont.

Sample No.	Bed Volume (BV.)	pH	Conc. of effluent (C; ppm)	cont. C/C_o
37	8.88	3.6	31.300	0.624
38	9.12	3 6	33.500	0.668
39	9.36	3.7	34.500	0.688
40	9.60	3.7	40.700	0.811
41	9.84	3.7	48.210	0.961
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	50.18 ppm. of $ZnSO_4$
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C_i, ppm)	C/C_0
1	0.24	1.072	0.021
2	0.48	5516.000	109.924
3	0.72	137.900	2.748
4	0.96	0.795	0.016
5	1.20	0.870	0.017
6	1.44	0.594	0.012
7	1.68	0.470	0.009
8	1.92	0.397	0.008
9	2.16	0.405	0.008
10	2.40	0.420	0.008
11	2.64	0.310	0.006
12	2.88	0.265	0.005
13	3.12	0.222	0.004
14	3.36	0.190	0.004
15	3.60	0.160	0.003
16	3.84	0.149	0.003
17	4.08	0.145	0.003
18	4.32	0.143	0.003
19	4.56	0.159	0.003
20	4.80	0.207	0.004

Table C-13 : Effect of acid treatment for 5 times regeneration

No. of regeneration	Meq/g (ppm)		
	Cu2+	Ni2+	Zn2+
1	1.4021 (222.800)	0.4535 (66.550)	0.4619 (75.500)
2	1.3814 (219.500)	0.4436 (65.100)	0.4576 (74.800)
3	1.4040 (223.100)	0.4577 (67.172)	0.4466 (73.000)
4	1.3757 (218.600)	0.4469 (65.589)	0.4417 (72.200)
5	1.4065 (223.500)	0.4406 (64.665)	72.300 (0.4423)

Table : C-14 (Electroplating wastewater)

Substrate : 5 % CH_2O treated W.H.
Effective size : 60-80 mesh.
Synthetic solution (C_0) : 48.88 ppm of Zn-electroplating wastewater
pH : 5.00
Flow rate : 3 ml/min.

Sample No.	Bed Volume (B.V.)	pH	Conc. of effluent (C; ppm)	C/C_0
1	0.24	4.4	ND	0.000
2	0.48	4.3	ND	0.000
3	0.72	4.4	ND	0.000
4	0.96	4.4	ND	0.000
5	1.20	4.4	ND	0.000
6	1.44	4.3	ND	0.000
7	1.68	4.4	ND	0.000
8	1.92	4.4	ND	0.000
9	2.16	4.4	ND	0.000
10	2.40	4.3	ND	0.000
11	2.64	4.2	ND	0.000
12	2.88	4.3	ND	0.000
13	3.12	4.4	ND	0.000
14	3.36	4.4	ND	0.000
15	3.60	4.3	ND	0.000
16	3.84	4.3	ND	0.000
17	4.08	4.2	ND	0.000
18	4.32	4.1	ND	0.000
19	4.56	4.1	ND	0.000
20	4.80	4.1	ND	0.000
21	5.04	4.1	ND	0.000
22	5.28	4.0	ND	0.000
23	5.52	4.1	ND	0.000
24	5.76	4.0	0.537	0.011
25	6.00	4.0	2.281	0.047
26	6.24	4.0	17.28	0.354
27	6.48	4.1	18.76	0.384
28	6.72	4.1	28.40	0.581
29	6.96	4.1	27.21	0.557
30	7.20	4.2	34.96	0.715
31	7.44	4.2	38.05	0.778
32	7.68	4.2	37.68	0.771
33	7.92	4.2	42.97	0.879
34	8.16	4.1	43.86	0.897
35	8.40	4.2	48.71	0.997
36	8.64	4.2	43.53	0.891
37	8.88	4.2	46.56	0.953
				end

Regeneration

Substrate	:	5 % CH_2O treated W.H.
Effective size	:	60-80 mesh.
Synthetic solution (C_0)	:	48.88 ppm. of Zn-electroplating wastewater
pH	:	5.00
Flow rate	:	10 ml/min.

Sample No.	Bed Volume (BV.)	Conc. of effluent (C_i, ppm)	C/C_0
1	0.24	0.062	0.001
2	0.48	1.279	0.026
3	0.72	6836.000	139.853
4	0.96	219.600	4.493
5	1.20	24.100	0.493
6	1.44	1.692	0.035
7	1.68	1.039	0.021
8	1.92	0.898	0.018
9	2.16	0.799	0.016
10	2.40	0.684	0.014
11	2.64	1.006	0.021
12	2.88	0.709	0.015
13	3.12	0.405	0.008
14	3.36	0.317	0 001
15	3.60	0.275	0.006
16	3.84	0.246	0.005
17	4.08	0.195	0.004
18	4.32	0.198	0.004
19	4.56	0.178	0.004
20	4.80	0170	0.003

APPENDIX D

Table D-1 : Analysis of varian-one way classification for water hyacinth treatment with acidic formaldehyde solution

Metal ions	Concentration	F. Ratio	F. Prob	Suitable % of formaldehyde
Cu^{2+}	23.6	1763.7982	0.0000	20
	47.1	2.8889	0.0478	20
	70.7	64.8216	0.0000	5
	94.2	27.3061	0.0000	37
Ni^{2+}	23.6	434.4762	0.0000	20
	47.2	2473.1111	0.0000	10
	70.7	401.2963	0.0000	10
	94.3	918.1111	0.0000	20
Zn^{2+}	24.3	556.5714	0.0000	37
	48.5	565.2157	0.0000	10
	72.8	434.8361	0.0000	20
	97.0	1009.7869	0.0000	20

Table D-2a : Effect of synthetic concentrations and percent of formaldehyde used by 2-ways ANOVA for Cu^{2+} ions

Source of variation	Sum of squares	DF	Mean square	F	Sig of F
Main effects	40.561	9	4.507	205.668	0.000
Conc. of Cu^{2+}	30.226	3	10.075	459.789	0.000
% of CH_2O	10.335	6	1.723	78.608	0.000
2-way interactions		18	0.332	15.153	0.000
Explained		27	1.724	78.658	0.000
Residual		56	0.022		
Total		83	0.575		

Table D-2b : Effect of synthetic concentrations and percent of formaldehyde used by 2-ways ANOVA for Ni^{2+} ions

Source of variation	Sum of squares	DF	Mean square	F	Sig of F
Main effects	28.536	9	3.171	11630.539	0.000
Conc. of Ni^{2+}	22.494	3	7.498	27504.105	0.000
% of CH_2O	6.042	6	1.007	3693.755	0.000
2-way interactions	0.887	18	0.049	180.853	0.000
Explained	29.424	27	1.090	3997.415	0.000
Residual	0.015	56	0.000		
Total	29.439	83	0.355		

Table D-2c : Effect of synthetic concentrations and percent of formaldehyde used by 2-ways ANOVA for Zn^{2+} ions

Source of variation	Sum of squares	DF	Mean square	F	Sig of F
Main effects	39.009	9	4.334	14390.684	0.000
Conc. of Zn^{2+}	34.562	3	11.521	38250.955	0.000
% of CH_2O	4.447	6	0.741	2460.5483	0.000
2-way interactions	0.171	18	0.010	1.573	0.000
Explained	39.180	27	1.451	4817.943	0.000
Residual	0.017	56	0.000		
Total	39.197	83	0.472		

Note : ONE-way and two-ways ANOVA statistical results processed by SPSS for windows release 6.0 (Copyright SPSS inc., 1989-1993 All rights reserved)

Table D-3a : Correlation coefficient analysis by Pearson product-moment method for Cu^{2+} removal.

x	y	xy	x^2	y^2
5	141.14	705.7	25	19920.50
10	85.26	852.6	100	7269.27
20	34.66	693.2	400	1201.32
50	12.48	624	2500	155.75
85	273.54	2875.50	3025	28546.84

$$r = \frac{\Sigma xy - \bar{x}\Sigma y}{(\Sigma x^2 - \bar{x}\Sigma x)\,(\Sigma y^2 - y\Sigma y)^{1/2}}$$

$$r = \frac{2875.50 - [(21.25 \times 273.54)]}{[\,[(3025 - 21.25(85)] \times [(28546.84 - [(68.39(273.54)]\,]^{1/2}}$$

$$r = -0.85$$

Table D-3b : Correlation coefficient analysis by Pearson product-moment method for Ni^{2+} removal.

x	y	xy	x^2	y^2
5	83.38	41.69	25	6952.22
10	45.90	459.00	100	2106.81
20	22.23	444.60	400	494.17
50	7.20	360.00	2500	51.84
85	158.71	1305.29	3025	9605.04

$$r = \frac{1305.29 - [(21.25 \times 158.71)]}{[\,[(3025 - 21.25(85) \times [(9605.04 - [(39.68 \times 158.71)]\,]^{1/2}}$$

$$r = -1.03$$

Table D-3c : Correlation coefficient analysis by Pearson product-moment method for Zn^{2+} removal.

x	y	xy	x^2	y^2
5	118.47	592.35	25	14035.14
10	49.23	492.30	100	2423.59
20	29.42	588.40	400	865.54
50	9.84	492.00	2500	96.83
85	206.96	2165.05	3025	17421.06

$$\mathbf{r} = \frac{2165.05 - [(21.25 \times 206.96)]}{[\,[(3025 - 21.25(85) \times [(17421.10 - [(68.39 \times 273.54)]\,]^{1/2}}$$

$$\mathbf{r} = -0.78$$

APPENDIX E

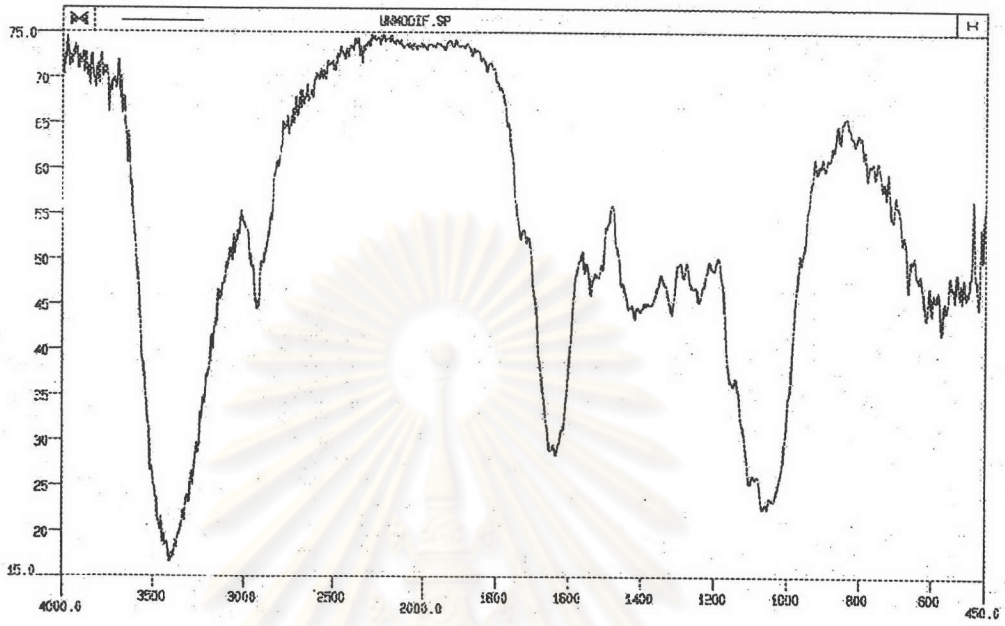

Figure E-1 : Infrared spectrum of unmodified water hyacinth sample

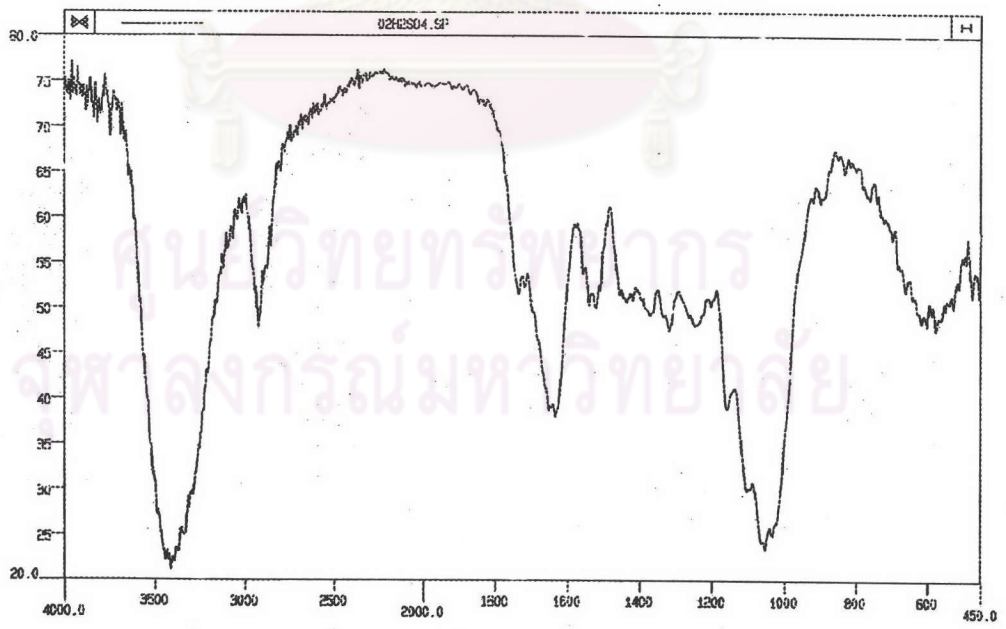

Figure E-2 : Infrared spectrum of 0.2 N H_2SO_4 treated water hyacinth sample

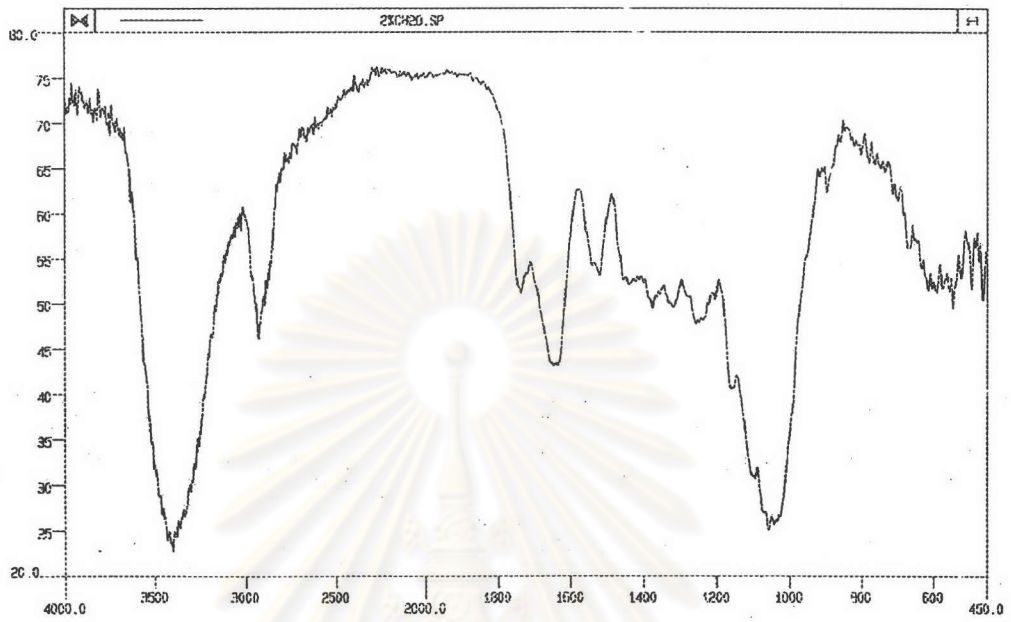

Figure E-3 : Infrared spectrum of 2 % formaldehyde treated water hyacinth sample

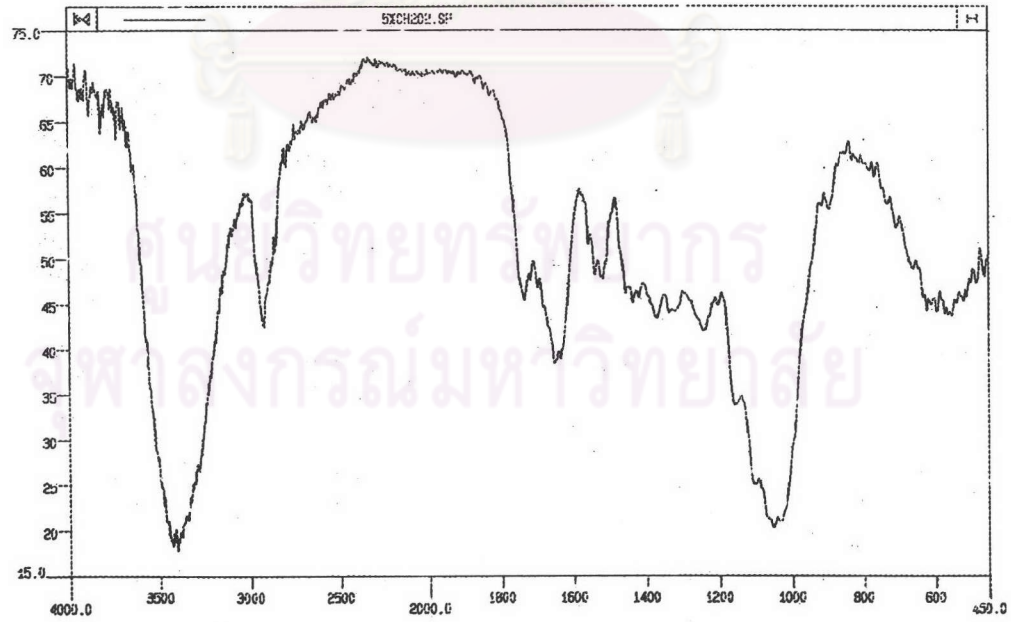

Figure E-4 : Infrared spectrum of 5 % formaldehyde treated water hyacinth sample

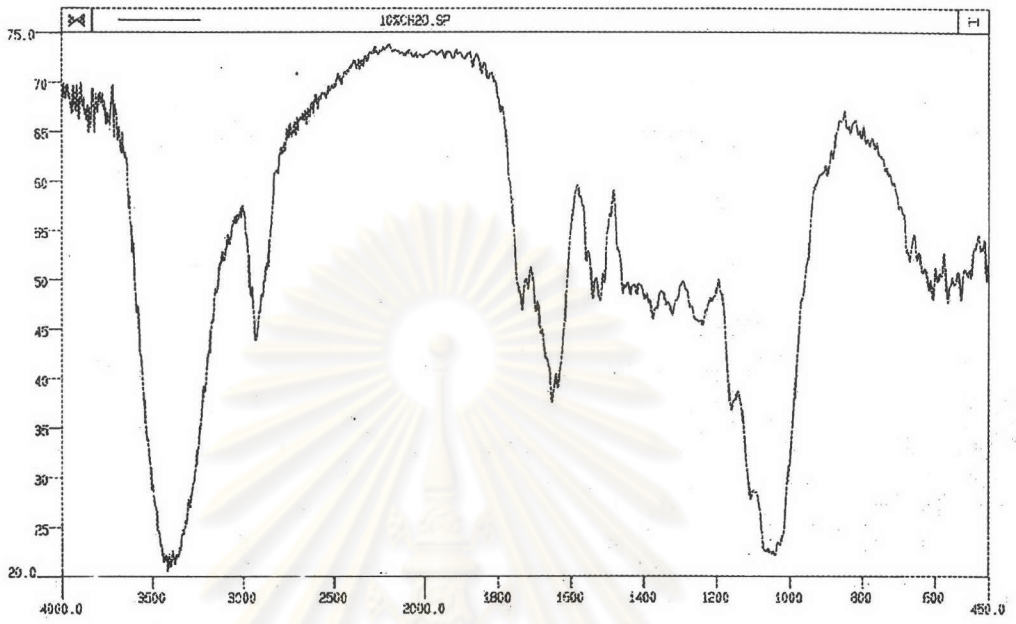

Figure E-5 : Infrared spectrum of 10 % formaldehyde treated water hyacinth sample

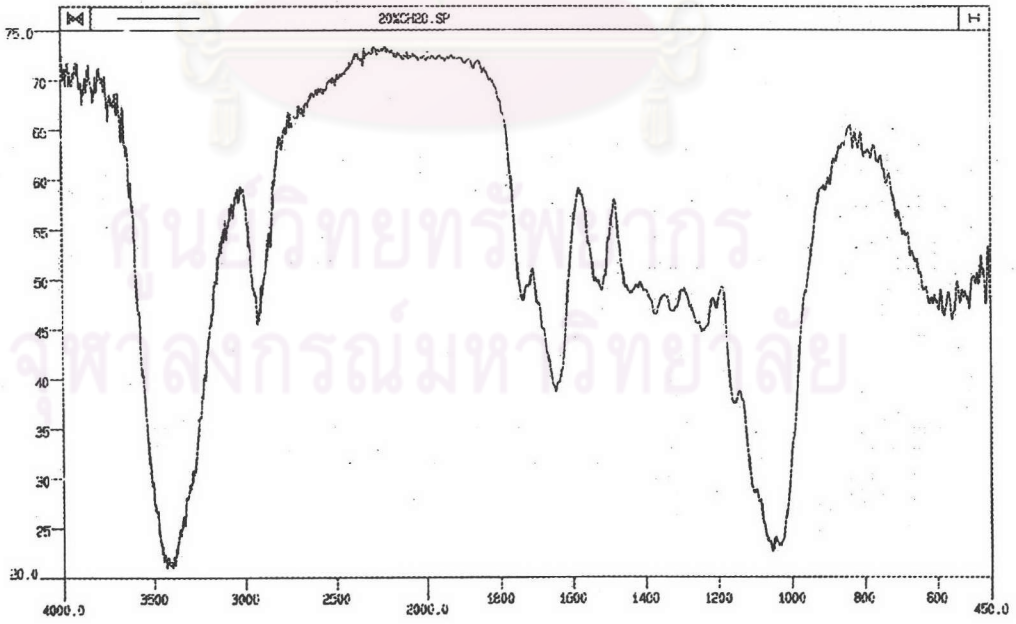

Figure E-6 : Infrared spectrum of 20 % formaldehyde treated water hyacinth sample

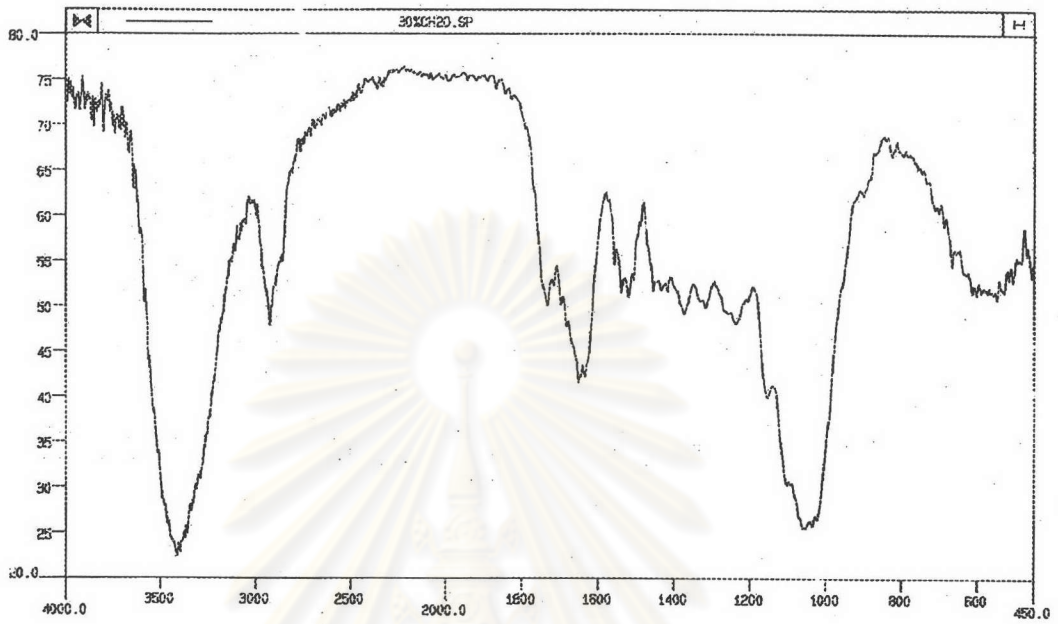

Figure E-7 : Infrared spectrum of 30 % formaldehyde treated water hyacinth sample

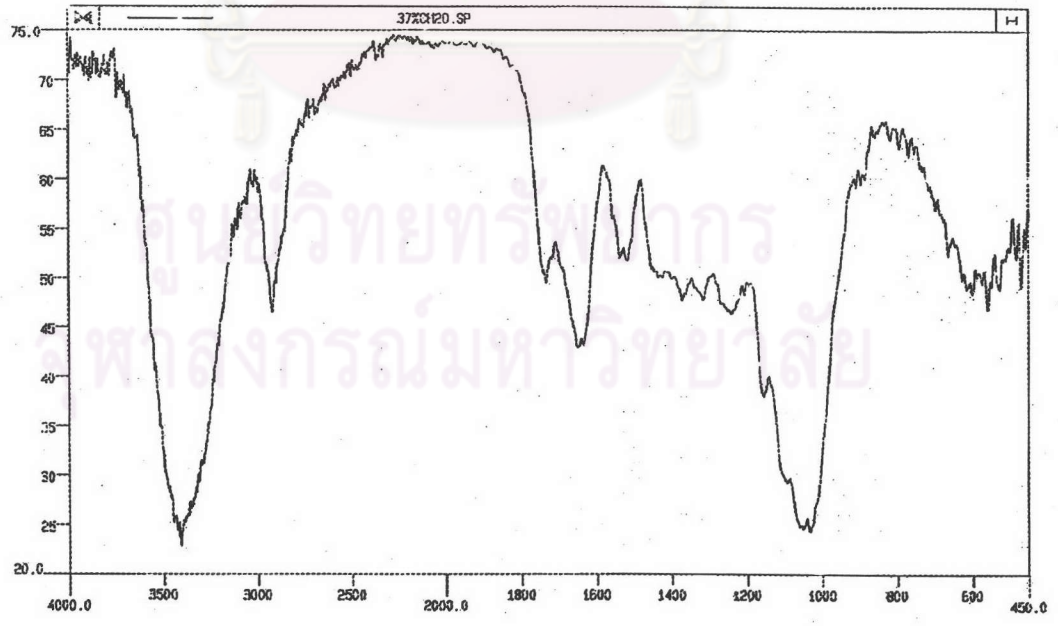

Figure E-8 : Infrared spectrum of 37 % formaldehyde treated water hyacinth sample

APPENDIX F

Complexometric method

1. Determination of copper using Eriochrome Black T as indicator (Back-titration).

Treat the solution containing ≤ 20 mg Cu (II) in *ca.* 100 ml with buffer solution (pH=10) in a dropwise until the light blue precipitate first formed dissolves to form a clear blue solution. Add an excess of 0.005 M-EDTA solution (25-50 ml) and add a few drops of Eriochrom Black T indicator. Titrate the excess of EDTA with standard 0.005 M-zinc sulphate solution until the colour changes from blue to wine red.

Remarks : It should be noted that if the cocentration of Cu2+ is too high, the intense blue colour of the copper (II) ammine complex masks the colour change at the end point.

2. Determination of nickel and zinc using Eriochrome Black T as indicator (Back-titration).

Pipette 100 ml of samples into a conical flask. Add 4 ml of the buffer solution (pH=10) and add an excess of 0.005 M-EDTA solution (25-50 ml). Add a few drops of Eriochrome Black T indicator. Titrate the excess of EDTA with standard 0.005 M-zinc sulphate solution until the colour changes from blue to wine red.

Calculation

$$\text{mg B} = [(ml_A N_A) - (ml_C N_C)] \times (\text{eq.wt. B})$$

A = 0.005 M of EDTA

B = Heavy metals

C = 0.005 M of standard $ZnSO_4$

APPENDIX G

Glossary of ion exchange terms

The following terms are useful definitions associated with ion exchange technology. Many of terms will be encounterd in the experiment sections of this thesis. The reader will also find many of these definitions useful when reading ion exchange publications.

Adsorption : The removal of materials from solution by physical attraction without the exchange of ionic species.

Adsorption Isotherm : A graph showing the amount of material absorbed as a function of the equilibrium concentration at a fixed temperature per unit weight of ion exchange material.

Bed Volume : The volume of ion exchange material of specified ionic form contained in a column or operating unit, usually measured as the backwashed and drained volume, and expressed as cubic feet or cubic meter.

Breakthrough : That volume of effluent where the concentration of the exchanging ion in the effluent reaches a predetermined limit. This point is usually the pratical end of the exhaustion cycle and the beginning of the regeneration cycle.

Capacity : The number of equivalents of exchangeable ion per unit volume, unit wet weight, or dry weight of an ion exchange material in a standard ionic form.

Column Operation : The most common method of employing ion exchange materials, in which the liquid to be treated passes through a fixed bed of ion exchange resin.

Cross-linking : Binding of the linear polymer chains in the matrix of an ion exchange material with an agent which produces a three-dimensional insoluble product.

Degradation : The physical or chemical reduction of ion exchange properties due to type of service, solution concentration used, heat, or aggressive operating conditions. Some effects are capacity loss, particel size reduction, excessive swelling, or any combination or the above.

Exhaustion : The step in an ion exchange cycle in which the undesirable ions are removed from the process liquid. When the supply of desirable ions on the resin exchange sites is almost fully depleted, the ion exchange material is said to be exhausted.

ppm : Unit of concentration, parts per million equal to 1 mg/L.

Regeneration : The displacement from the ion exchange material of the ions removed during the service run. Performed by passing the regenerant through the bed.

Strong Acid Cation Exchanger : A cation exchange material with an active group capable of splitting neutral salts to form their corresponding free acids.

Total Capacity : The ultimate ion exchange capacity of any exchange material.

BIOGRAPHY

Pitee Krasinsri was born on August 15, 1972. He received a Bechelor of Science (Analytical Chemistry) in 1994 from Faculty of Agricultural Engineering and Technology, Rajamangala Institute of Technology. After that, he entered a master degree program at the Inter-department of Environmental Science, Graduate School of Chulalongkorn University.