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APPENDIX

APPENDIX

Column experimental results

Table A-1 Conditions (I)

Parameters	Values
Bed height	25 cm
Flow rate	6 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Up-flow

Table A-2 Sample results of conditions (I)

Time (min)	Porevolume (ml)	pH	zinc (mg/l)	Ca (mg/l)	Ce/Co
0	0.00	5.07	0.00	-	0.00
60	8.69	7.81	0.00	40.09	0.00
90	13.04	8.00	0.00	41.70	0.00
100	14.49	7.83	0.06	41.48	0.00
110	15.94	6.56	1.42	41.46	0.02
120	17.39	7.13	7.60	35.41	0.13
130	18.84	6.91	10.05	34.27	0.17
140	20.29	6.66	19.90	29.46	0.33
150	21.73	6.73	24.65	25.12	0.41
160	23.18	6.58	28.98	23.58	0.48
170	24.63	6.64	33.97	20.08	0.56
180	26.08	6.76	37.62	19.09	0.62
190	27.53	6.69	38.02	17.95	0.63
200	28.98	6.65	40.32	16.41	0.67
210	30.43	6.63	41.98	15.60	0.70
220	31.88	5.87	42.79	14.57	0.71
230	33.33	6.15	41.14	13.30	0.68
240	35.07	5.73	41.45	12.44	0.69
300	43.47	6.16	46.59	10.57	0.77
360	52.16	6.46	48.16	9.57	0.80
420	60.86	6.46	51.70	8.79	0.86
480	69.55	6.42	50.11	7.94	0.83
540	78.25	5.56	52.62	7.60	0.87
600	86.94	6.25	52.24	7.04	0.87

Table A-3 Conditions (II)

Parameters	Values
Bed height	21.5 cm
Flow rate	6 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Up-flow

Table A-4 Sample results of condition (II)

Time (min)	Porevolume (ml)	pH	Ce/Co	Zinc (mg/l)	Ca (mg/l)
0	0.00	5.07	0.00	0.00	-
60	10.28	7.69	0.00	0.00	41.07
90	15.42	7.98	0.00	0.00	42.26
100	17.13	7.74	0.00	0.00	41.42
110	18.85	6.14	0.08	4.61	38.20
120	20.56	7.07	0.07	4.11	38.32
130	22.27	6.96	0.18	11.08	34.65
140	23.99	6.75	0.35	21.02	27.61
150	25.70	6.73	0.43	25.82	25.38
160	27.41	6.67	0.52	31.60	21.88
170	29.13	6.66	0.60	35.85	18.46
180	30.84	6.77	0.66	40.02	16.34
190	32.55	6.83	0.68	40.10	15.22
200	34.27	6.58	0.72	43.56	14.54
210	35.98	6.6	0.74	44.36	13.87
220	37.69	5.58	0.77	46.09	13.10
230	39.41	6.09	0.77	46.40	12.54
240	41.12	5.57	0.79	47.31	12.19
300	51.40	6.12	0.83	50.22	10.17
360	61.68	6.46	0.86	51.77	9.28
420	71.96	6.47	0.87	52.47	8.43
480	82.24	6.32	0.90	53.92	7.94
540	92.52	5.50	0.90	54.10	7.66
600	102.80	6.16	0.89	53.74	7.06

Table A-5 Conditions (III)

Parameters	Values
Bed height	18 cm
Flow rate	6 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Up-flow

Table A-6 Sample results of condition (III)

Time (min)	Porevolume (ml)	pH	Zinc (mg/l)	Ce/Co	Ca (mg/l)
0	0.00	4.77	0.00	0.00	-
20	4.09	7.23	0.00	0.00	45.30
30	6.14	6.91	0.00	0.00	38.94
60	12.28	7.61	0.00	0.00	39.70
70	14.32	7.28	1.22	0.02	39.31
80	16.37	7.04	4.36	0.08	37.20
90	18.42	6.94	9.50	0.16	33.85
100	20.46	6.76	20.41	0.35	27.58
110	22.51	6.6	26.97	0.47	24.11
120	24.56	6.64	30.48	0.53	22.24
130	26.60	6.58	36.68	0.64	18.49
140	28.65	6.78	41.76	0.72	15.28
150	30.70	6.63	44.68	0.77	13.79
160	32.74	6.63	45.92	0.80	12.82
170	34.79	6.79	48.11	0.83	11.74
180	36.83	6.82	48.88	0.85	10.88
190	38.88	6.56	50.14	0.87	10.40
200	40.93	6.49	51.01	0.88	9.99
210	42.97	5.91	51.65	0.90	9.71
220	45.02	5.94	52.10	0.90	9.42
230	47.07	5.95	52.40	0.91	9.20
240	49.11	5.95	52.61	0.91	8.68
300	61.39	5.93	54.50	0.95	7.54
360	73.67	5.54	55.20	0.96	6.83
540	110.50	5.66	55.42	0.96	5.58
600	122.78	5.60	56.44	0.98	5.01

Table A-7 Conditions (IV)

Parameters	Values
Bed height	14.5 cm
Flow rate	6 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Up-flow

Table A-8 Sample results of condition (IV)

Time (min)	Porevolume (ml)	pH	Ce/Co	Zinc (mg/l)	Ca (mg/l)
0	0.00	5.04	0.00	62.84	0.00
20	5.08	7.05	0.00	0.00	36.43
30	7.62	7.24	0.00	0.16	35.26
40	10.16	7.15	0.08	5.01	35.07
50	12.70	6.85	0.12	7.53	31.73
60	15.24	6.79	0.27	17.09	28.51
70	17.78	6.73	0.37	23.08	26.06
80	20.32	6.20	0.45	28.05	22.73
90	22.86	6.23	0.56	35.18	19.63
100	25.40	6.22	0.71	44.83	16.87
110	27.94	6.05	0.76	47.55	14.04
120	30.48	6.11	0.80	50.01	12.57
130	33.02	6.05	0.88	55.08	11.36
140	35.56	6.04	0.83	52.26	10.66
150	38.10	6.10	0.89	55.91	10.21
170	43.18	5.97	0.89	55.77	9.41
230	58.43	5.93	0.92	57.94	8.15
300	76.21	6.06	0.97	60.85	7.21

Table A-9 Condition (V)

Parameters	Values
Bed height	25 cm
Flow rate	11 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Up-flow

Table A-10 Sample results of condition (V)

Time (min)	Porevolume (ml)	Ce/Co	pH	Zinc (mg/l)	Ca (mg/l)
0	0.00	0.00	5.02	0.00	-
20	5.31	0.00	8.13	0.00	-
30	7.97	0.00	8.14	0.00	38.02
40	10.63	0.00	8.00	0.00	37.98
50	13.29	0.03	7.54	1.65	36.34
60	15.94	0.17	6.99	9.87	32.31
70	18.60	0.37	6.78	21.23	26.62
80	21.26	0.55	6.68	31.50	19.59
90	23.91	0.70	6.64	39.83	15.15
100	26.57	0.78	6.53	44.29	12.79
110	29.23	0.82	6.73	46.83	10.75
120	31.88	0.84	6.73	48.12	9.98
130	34.54	0.87	6.67	49.64	9.21
140	37.20	0.88	6.82	50.23	8.66
160	42.51	0.90	6.68	51.61	8.41
170	45.17	0.88	6.98	50.51	7.60
190	50.48	0.93	6.86	52.89	7.06
200	53.14	0.92	6.86	52.36	6.75
210	55.80	0.93	6.77	52.95	6.54
220	58.45	0.93	6.71	53.22	6.35
240	63.77	0.94	6.95	53.61	6.29
300	79.71	0.96	6.58	54.92	5.63
360	95.65	0.97	6.61	55.20	4.96
420	111.59	0.96	6.49	54.88	5.21
480	127.54	0.99	6.38	56.64	7.50
540	143.48	1.00	-	56.86	7.83
600	159.42	1.00	-	56.93	7.45

Table A-11 Condition (VI)

Parameters	Values
Bed height	25 cm
Flow rate	15 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Up-flow

Table A-12 Sample results of condition (VI)

Time (min)	Porevolume (ml)	pH	Ce/Co	Zinc (mg/l)	Ca (mg/l)
0	0.00	5.02	0.00	0.00	-
30	10.87	8.13	0.00	0.00	37.68
40	14.49	7.79	0.03	1.48	36.80
50	18.12	6.97	0.26	14.86	28.30
60	21.74	6.68	0.59	33.71	18.02
70	25.36	6.63	0.75	42.93	13.14
80	28.99	6.60	0.83	47.45	10.61
90	32.61	6.51	0.86	49.20	9.54
100	36.23	6.45	0.88	50.30	8.42
110	39.86	6.68	0.90	51.65	7.46
120	43.48	6.69	0.91	51.74	6.98
130	47.10	6.74	0.92	52.46	6.67
140	50.72	6.79	0.93	53.14	6.30
160	57.97	6.68	0.94	53.85	6.01
170	61.59	6.96	0.97	55.17	5.71
190	68.84	6.88	0.95	54.30	5.16
200	72.46	6.84	0.96	54.64	5.06
210	76.09	6.79	0.96	54.60	5.03
220	79.71	6.70	0.96	54.55	4.90
240	86.96	6.91	0.97	55.48	4.73
300	108.70	6.66	0.96	54.70	3.63
360	130.43	6.60	0.99	56.47	3.73
420	152.17	6.47	0.98	56.23	3.68
480	173.91	6.42	0.99	56.50	3.26
540	195.65	6.07	0.97	55.32	2.82
600	217.39	-	1.00	56.97	2.80

Table A-13 Condition (VII)

Parameters	Values
Bed height	25 cm
Flow rate	6 ml/min
Initial concentration	30 mg/l
pH	5
Column operation mode	Up-flow

Table A-14 Sample results of condition (VII)

Time (min)	porevolume (ml)	pH	Ce/Co	Zinc (mg/l)	Ca (mg/l)
0	0.00	4.97	0.00	0.00	-
20	3.43	7.57	0.00	0.00	20.75
30	5.14	7.69	0.00	0.00	20.03
40	6.85	8.43	0.00	0.00	19.53
50	8.57	8.37	0.00	0.00	19.73
60	10.28	8.48	0.00	0.00	20.00
140	23.99	7.94	0.00	0.00	20.31
150	25.70	7.86	0.01	0.28	19.91
160	27.41	7.66	0.04	1.38	19.50
170	29.13	7.53	0.08	2.71	18.74
180	30.84	7.41	0.12	3.96	18.24
190	32.55	7.36	0.16	5.44	17.63
200	34.27	7.32	0.20	6.54	17.03
210	35.98	7.26	0.23	7.72	16.41
220	37.69	7.22	0.26	8.82	16.06
230	39.41	7.19	0.30	9.92	15.65
240	41.12	7.15	0.32	10.79	15.10
300	51.40	6.80	0.46	15.43	12.05
360	61.68	6.71	0.63	20.88	9.13
420	71.96	6.53	0.72	23.86	7.31
480	82.24	6.57	0.75	25.13	6.35
540	92.52	6.61	0.77	25.72	5.88
600	102.80	6.39	0.80	26.68	5.13

Table A-15 Condition (VIII)

Parameters	Values
Bed height	21.5 cm
Flow rate	6 ml/min
Initial concentration	60 mg/l
pH	3
Column operation mode	Up-flow

Table A-16 Sample results of condition (VIII)

Time (min)	Porevolume (ml)	pH	Ce/Co	Zinc (mg/l)	Ca (mg/l)
0	0.00	3.05	0.00	0.00	-
20	3.43	7.01	0.00	0.00	63.13
30	5.14	7.61	0.00	0.00	65.03
40	6.85	7.70	0.00	0.00	66.29
50	8.57	7.87	0.00	0.00	67.16
60	10.28	7.61	0.00	0.00	66.77
70	11.99	7.16	0.09	6.12	66.88
80	13.71	6.95	0.34	22.03	57.42
90	15.42	6.82	0.58	38.29	46.49
100	17.13	6.82	0.78	51.23	37.50
110	18.85	6.84	0.87	57.19	33.52
120	20.56	6.80	0.92	60.24	30.42
130	22.27	6.84	0.95	62.50	29.15
140	23.99	6.85	0.99	64.86	28.54
150	25.70	6.82	0.99	65.04	28.25
160	27.41	6.80	1.00	65.72	27.28
170	29.13	6.77	1.01	66.18	26.72
180	30.84	6.70	1.02	66.79	26.37
190	32.55	6.71	1.01	66.13	25.93
200	34.27	6.71	1.01	66.38	25.46
210	35.98	6.70	1.01	66.15	25.33
220	37.69	6.69	1.01	66.31	25.22
240	41.12	6.64	1.01	66.98	24.74

Table A-17 Condition (IX)

Parameters	Values
Bed height	21.5 cm
Flow rate	6 ml/min
Initial concentration	60 mg/l
pH	5
Column operation mode	Down-flow

Table A-18 Sample results of condition (IX)

Time (min)	Porevolume (ml)	pH	Ce/Co	Zinc (mg/l)	Ca (mg/l)
0	0.00	5.20	0.00	0.00	-
20	3.43	6.85	0.00	0.00	37.97
30	5.14	7.52	0.00	0.00	36.54
40	6.85	8.13	0.00	0.00	37.35
50	8.57	7.79	0.00	0.00	36.90
60	10.28	7.36	0.01	0.52	38.15
70	11.99	7.57	0.04	2.29	36.14
80	13.71	7.45	0.12	7.73	34.83
90	15.42	7.25	0.23	14.29	31.69
100	17.13	7.45	0.35	22.29	28.67
110	18.85	7.52	0.43	26.91	26.18
120	20.56	7.30	0.51	31.99	22.00
130	22.27	7.18	0.59	37.27	19.86
140	23.99	7.21	0.65	41.01	18.00
150	25.70	7.06	0.67	42.16	16.73
160	27.41	7.22	0.72	45.32	15.74
170	29.13	7.04	0.73	46.16	14.79
180	30.84	7.08	0.77	48.20	14.36
190	32.55	7.00	0.78	49.28	13.37
200	34.27	7.02	0.77	48.43	12.35
210	35.98	7.48	0.80	50.23	12.43
220	37.69	7.05	0.83	52.39	12.61
230	39.41	6.95	0.85	53.51	10.97
240	41.12	6.99	0.89	55.74	11.04
360	61.68	7.17	0.89	55.67	8.94
420	71.96	-	0.95	59.82	11.12
480	82.24	-	0.97	60.69	9.04
540	92.52	-	0.96	60.57	8.86
600	102.80	-	0.98	61.34	8.84

Table A-19 Condition (X)

Parameters	Values
Bed height	21.5 cm
Flow rate	6 ml/min
Initial concentration	0 mg/l
pH	5
Column operation mode	Up-flow

Table A-20 Sample results of condition (X)

Time (min)	Porevolume (ml)	pH	Zinc (mg/l)	Ca (mg/l)
0	0.00	5.08	0	-
20	3.43	7.52	0	29.03
30	5.14	8.35	0	9.92
40	6.85	8.51	0	6.91
50	8.57	8.32	0	7.31
60	10.28	8.44	0	7.11
70	11.99	8.21	0	7.24
140	23.99	7.67	0	7.58
180	30.84	7.68	0	7.89
420	71.96	8.58	0	7.85
600	102.80	-	0	7.82

BIOGRAPHY

Ms. Tarinee Leepulsap was born on December 15, 1981 in Bangkok, Thailand. She obtained her B.Sc.Degree in Environmental Technology from the Faculty of Environmental and Resource Studies of Mahidol University in 2003. She pursued her master's degree studies at the International Postgraduate Programs in Environmental Management, Inter-Department of Environmental Management, Chulalongkorn University, Bangkok, Thailand in May 2004. She finished her Master's of Science Degree in Environmental Management in May 2006.