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APPENDICES

APPENDIX A

Table A.1 Characteristics of wastewater

Parameter	Values	Method of Examination
pH	5.48	pH meter
Conductivity (μs/cm)	32.2	Conductivity meter
Temperature (° C)	29.3	Thermometer
Ni (mg/L)	565.0	ICP-MS
Fe (mg/L)	243.8	ICP-MS
Zn (mg/L)	0.310	ICP-MS
Cu (mg/L)	0.069	ICP-MS

APPENDIX B

Table B.1 Study to nickel adsorption on hydrous ferric oxide (HFO)

Time	Mass of iron	% Ni removal	Ni residue
10	1.03	5.80	6.50
15	1.02	5.80	6.50
20	1.00	5.80	6.50
30	0.98	5.80	6.50
40	1.02	8.21	6.33
50	1.01	8.21	6.33
60	1.04	15.46	5.83
70	1.01	13.04	6.00
80	0.99	13.04	6.00
90	1.00	15.46	5.83
100	1.01	20.29	5.50
110	1.01	27.54	5.00
120	1.02	20.29	5.50
130	1.00	20.29	5.50
140	1.01	17.87	5.67
150	1.00	17.87	5.67
160	1.00	17.87	5.67
170	1.02	15.46	5.83
180	1.01	22.71	5.33
300	0.99	32.37	4.67
420	0.98	39.61	4.17
540	1.00	46.86	3.67
660	1.01	46.86	3.67
900	0.98	63.77	2.50
1020	0.99	68.60	2.17
1140	1.02	63.77	2.50
1260	1.00	61.35	2.67
1380	1.01	68.60	2.17
1500	1.00	66.18	2.33

Remark: Mass of iron is in gram

Time is in minutes

Nickel residue is in mg/L

APPENDIX C

Table C.1 The study to the effect of pH on nickel removal percentage

Time	Nickel removal percentage				
	pH6	pH7	pH8	pH9	pH10
10	3.38	65.22	17.87	3.38	27.54
15	0.00	73.91	22.71	0.97	13.04
20	3.38	65.22	17.87	8.21	32.37
30	8.21	73.91	22.71	10.63	56.52
40	10.63	82.61	32.37	22.71	22.71
50	5.80	76.09	34.78	22.71	10.63
60	0.97	73.91	42.03	29.95	10.63
70	5.80	71.74	44.44	20.29	13.04
80	8.21	78.26	44.44	10.63	58.94
90	15.46	78.26	42.03	22.71	37.20
100	17.87	37.20	42.03	15.46	95.17
110	17.87	34.78	32.37	32.37	51.69
120	25.12	29.95	51.69	27.54	63.77
130	25.12	20.29	44.44	22.71	51.69
140	13.04	37.20	44.44	46.86	46.86
150	15.46	32.37	39.61	34.78	68.60
160	8.21	25.12	39.61	22.71	68.60
170	15.46	51.69	63.77	29.95	80.68
180	5.80	39.61	44.44	27.54	46.86
300	27.54	39.61	63.77	73.43	71.01
420	27.54	39.61	71.01	95.17	92.75
540	49.28	63.77	63.77	71.01	97.58
660	39.61	61.35	54.11	87.92	85.51
900	66.18	66.18	66.18	37.20	42.03
1020	63.77	66.18	66.18	71.01	73.43
1140	46.86	73.43	68.60	97.58	39.61
1260	58.94	63.77	66.18	85.51	90.34
1380	71.01	92.75	68.60	97.58	71.01
1500	80.68	80.68	100.00	87.92	71.01

Remark: Time is in minutes

APPENDIX D

Table D.1 The effect of column height on nickel removal efficiency.

Time	Inf.	Eff.C1	Eff.C2	Eff.C3	%Eff.C1	%Eff.C2	%Eff.C3
1	10.20	0.00	0.00	0.00	100.00	100.00	100.00
2	9.56	0.00	0.00	0.00	100.00	100.00	100.00
3	11.02	0.11	0.00	0.00	98.88	100.00	100.00
4	10.50	0.00	0.00	0.00	100.00	100.00	100.00
5	10.00	0.00	0.00	0.00	100.00	100.00	100.00
6	9.98	1.00	0.90	0.36	90.00	91.00	96.38
7	9.68	1.39	1.19	0.89	86.13	88.13	91.13
8	10.50	1.79	1.36	1.88	82.13	86.38	81.25
9	11.00	2.00	1.48	1.16	80.00	85.25	88.38
10	12.00	2.80	1.31	0.75	72.00	86.88	92.50
11	9.88	1.41	0.89	1.14	85.88	91.13	88.63
12	10.31	1.14	0.83	0.76	88.63	91.75	92.38
13	10.40	1.16	0.89	0.84	88.38	91.13	91.63
14	10.01	2.04	1.19	1.75	79.63	88.13	82.50
15	10.33	1.30	0.93	0.95	87.00	90.75	90.50
16	10.12	1.75	0.76	1.50	82.50	92.38	85.00
17	10.47	1.84	0.84	1.89	81.63	91.63	81.13
18	9.96	2.96	0.93	1.54	79.38	90.75	84.63
19	10.25	1.68	0.91	0.96	83.25	90.88	90.38
20	10.40	1.48	1.28	0.85	85.25	87.25	91.50
21	10.20	1.63	0.78	2.64	83.75	92.25	75.63
22	10.80	2.95	0.69	1.38	75.50	93.13	86.25
23	9.80	1.09	1.01	1.14	89.13	89.88	88.63
24	9.96	1.13	1.33	1.11	88.75	86.75	88.88
25	10.20	2.99	3.36	1.06	74.13	84.38	89.38
26	10.70	1.58	1.45	1.89	84.25	85.50	81.13
27	10.86	1.49	1.14	1.53	85.13	88.63	84.75
28	10.00	1.03	1.06	2.40	89.75	89.38	76.00
29	10.23	3.95	1.44	2.63	60.50	85.63	73.75
31	10.46	2.08	2.00	1.88	79.25	65.88	81.25
33	9.82	1.04	1.16	3.23	89.63	88.38	67.75
35	9.65	1.95	2.23	1.66	80.50	77.75	83.38
36	10.47	2.00	1.79	2.08	80.00	82.13	79.25
38	10.00	1.95	1.53	1.04	80.50	84.75	89.63

Table D.1 The effect of column height on nickel removal efficiency (Cont.).

Time	Inf.	Eff.C1	Eff.C2	Eff.C3	%Eff.C1	%Eff.C2	%Eff.C3
40	10.23	2.69	2.11	1.73	73.13	78.88	82.75
42	9.55	3.24	2.08	1.79	67.63	79.25	82.13
44	10.65	4.23	2.55	2.34	57.75	74.50	76.63
46	9.82	2.69	2.78	1.66	73.13	72.25	83.38
48	10.63	3.39	2.73	2.79	66.13	72.75	72.13
50	10.40	2.79	2.39	2.43	72.13	76.13	75.75
52	10.20	1.61	2.33	2.19	83.88	76.75	78.13
54	10.11	3.86	2.55	2.45	61.38	74.50	75.50
56	10.05	2.60	4.08	1.96	74.00	59.25	80.38
58	10.14	4.20	5.34	Clogging			
60		Clogging	Clogging				
Avg.	10.26						

Remark : Inf. is influent nickel concentration 10 mg/L.

Eff. C1, C2 and C3 are effluents from the column height 30 cm. with 3 columns in series, 40 cm. with 3 columns in series, and 50 cm. with 3 columns in series, respectively.

Inf. and Eff. are in mg/L nickel.

Time is in days.

Table D.2 The statistic analysis for the effect of column height on nickel removal efficiency

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
H30CM	.110	19	.200*	.931	19	.235
H40CM	.219	19	.017	.919	19	.119
H50CM	.194	19	.057	.918	19	.110

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Test of Homogeneity of Variances

REMOVALH

Levene Statistic	df1	df2	Sig.
2.735	2	54	.074

ANOVA

REMOVALH

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		417.088	2	208.544	11.677	.000
	Linear Term	Contrast	166.909	1	166.909	9.346	.003
		Deviation	250.179	1	250.179	14.009	.000
Within Groups			964.372	54	17.859		
Total			1381.460	56			

Multiple Comparisons

Dependent Variable: REMOVALH

LSD

(I) HIGHT	(J) HIGHT	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
30	40	-6.5400*	1.3711	.000	-9.2889	-3.7911
	50	-4.1916*	1.3711	.003	-6.9404	-1.4427
40	30	6.5400*	1.3711	.000	3.7911	9.2889
	50	2.3484	1.3711	.092	-.4004	5.0973
50	30	4.1916*	1.3711	.003	1.4427	6.9404
	40	-2.3484	1.3711	.092	-5.0973	.4004

*. The mean difference is significant at the .05 level.

APPENDIX E

Table E.1 The effect of influent flow rate on nickel removal efficiency

Flow rate Time	Inf. pH	Nickel residual (mg/L)			% Nickel removal (mg/L)		
		Eff. FR 1	Eff. FR 2	Eff. FR 3	Eff. FR 1	Eff. FR 2	Eff. FR 3
1	7.00	0.12	0.00	0.44	98.75	100.00	95.48
3	7.01	0.31	0.00	0.50	96.92	100.00	95.07
5	7.02	0.12	0.00	0.65	98.92	100.00	94.21
7	7.00	0.13	1.19	1.56	98.70	88.33	84.70
9	6.99	0.08	1.48	1.87	99.14	84.90	80.92
11	7.01	0.68	0.89	1.65	92.84	90.63	82.63
13	7.00	0.98	0.89	1.40	91.83	92.58	88.33
15	7.00	0.70	0.93	1.35	93.00	90.70	86.50
17	6.99	0.46	0.84	1.68	95.49	91.76	83.53
19	7.01	0.82	0.91	2.01	92.34	91.50	81.21
21	7.02	0.73	0.78	2.32	93.12	92.65	78.13
23	7.00	0.88	1.01	1.98	92.28	91.14	82.63
25	7.00	1.80	1.10	2.45	83.33	89.81	77.31
27	6.99	1.20	1.14	1.77	88.57	89.14	83.14
29	7.01	1.30	1.14	2.86	88.01	89.48	73.62
31	7.00	1.65	2.00	2.63	83.50	80.00	73.70
33	7.02	1.70	1.16	1.97	82.83	88.28	80.10
35	7.00	1.75	2.23	2.50	82.27	77.41	74.67
37	7.01	1.60	1.79	2.80	83.84	81.92	71.72
39	7.01	1.70	1.53	2.70	83.33	85.00	73.53
41	7.00	1.90	2.11	3.01	82.24	80.28	71.87
43	7.00	2.00	2.08	3.45	81.11	80.36	67.42
45	7.00	2.50	2.55	3.62	75.25	74.75	64.16
47	6.99	2.65	2.78	3.90	74.10	72.83	61.88
49	7.02	2.70	2.73	4.06	72.53	72.23	58.70
51	7.00	2.53	2.39	4.00	74.95	76.34	60.40
53	7.00	2.30	2.33	3.94	76.84	76.54	60.32
55	6.99	2.45	2.55	4.23	75.62	74.63	57.91
57	7.00	3.00	4.08	4.60	70.30	59.60	54.46

Remark: Inf. is influent nickel concentration 10 mg/L.

Eff. FR 1, FR 2 and FR 3 are effluents from influent flow rate 5 L/day, 10 L/day and 15 L/day respectively.

Inf. and Eff. is in mg/L Nickel.

Time is in days.

Table E.2 The statistic analysis for the effect of influent flow rate on nickel removal efficiency

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
INF5L_D	.173	10	.200*	.937	10	.495
INF10L_D	.229	10	.145	.845	10	.056
INF15L_D	.125	10	.200*	.963	10	.789

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Test of Homogeneity of Variances

REMOVALF

Levene Statistic	df1	df2	Sig.
1.536	2	26	.234

ANOVA

REMOVALF

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		550.553	2	275.277	21.261	.000
	Linear Term	Unweighted	485.174	1	485.174	37.473	.000
		Weighted	473.759	1	473.759	36.591	.000
		Deviation	76.795	1	76.795	5.931	.022
Within Groups			336.633	26	12.947		
Total			887.187	28			

Multiple Comparisons

Dependent Variable: REMOVALF

LSD

(I) FLOWRATE	(J) FLOWRATE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
5	10	1.6350	1.6092	.319	-1.6727	4.9427
	15	10.1206*	1.6533	.000	6.7222	13.5189
10	5	-1.6350	1.6092	.319	-4.9427	1.6727
	15	8.4856*	1.6533	.000	5.0872	11.8839
15	5	-10.1206*	1.6533	.000	-13.5189	-6.7222
	10	-8.4856*	1.6533	.000	-11.8839	-5.0872

*. The mean difference is significant at the .05 level.

APPENDIX F

Table F.1 The effect of nickel concentration on column performance.

Time	Nickel Removal					
	Inf L1	Eff L1	Inf L2	Eff L2	Inf L3	Eff L3
1	21.02	92.51	50.21	71.48	100.45	53.37
3	20.14	90.19	49.83	79.69	102.25	62.06
5	20.45	93.60	50.33	84.99	100.31	58.42
7	20.23	82.34	50.75	70.65	100.65	52.45
9	20.14	81.51	49.98	59.24	102.35	45.85
11	21.22	77.69	50.75	56.32	99.86	38.95
13	22.35	74.56	51.22	52.86	100.21	25.78
15	20.04	53.58	51.35	35.81	100.35	24.65
17	20.56	42.65	52.45	28.56	100.48	25.84
19	21.42	44.15	52.56	22.78	99.83	19.87
21	22.14	41.25	51.44	21.77	102.00	16.21
23	22.26	43.85	53.02	23.58	100.21	20.27
25	22.81	45.26	49.98	20.45	100.06	18.25
27	20.86	43.89	49.87	18.20	99.87	10.79
29	20.21	39.12	51.20	15.20	101.05	8.26
31	20.70	32.54	53.44	11.11	103.04	8.59
33	19.37	24.12	48.86	18.32	101.21	8.46
35	21.04	27.21	50.13	19.21	99.87	9.28
37	23.00	15.24	51.78	5.36	99.98	clogging
39	21.70	12.33	52.34	4.28		
41	19.68	8.58	48.79	3.01		
43	22.64	7.24	50.12	8.38		
45	22.70	5.36	50.35	7.25		
47	21.06	10.38	49.88	1.25		
49	20.15	9.29	48.92	1.43		
51	20.46	8.72	51.75	4.72		
53	19.22	10.50	52.37	1.46		
55	19.97	3.52	48.99	clogging		
57	22.04	2.45				
59	21.08	2.81				
61	19.68	3.56				

Remark: Inf L1, L2. and L3 are influent nickel concentration are 20 mg/L.50 mg/L and100 mg/L respectively.

Eff L1, L2. and L3 are nickel removal percentage of influent nickel concentration are 20 mg/L.50 mg/L and100 mg/L respectively

Time is in days

APPENDIX G

Notification of the Ministry of Science, Technology and Environment No.3 B.E. 2539 (1996), dated 3 January B.E. 2539 (1996), on effluent standards from factories and Industrial estates.

Table G.1 Effluent standards from factories and Industrial estates.

1.	PH Value	5.5-9.0	pH Meter
2.	Total Dissolved Solids (TDS)	factory but, not exceeding 5,000 mg/l	Evaporated at 103 °C - 108 °C for 1 hour
		Not more than 5,000 mg/i exceed TDS of receiving water having salinity of more than 2,000 mg/l or TDS of sea If discharge to sea	Glass fiber filter disc
3.	Suspended Solids (SS)	Not more than 50 mg/l depending on receiving water or type of factory, but not exceeding 150 mg/l	
4.	Temperature	Not more than 40 °C	Thermometer
5.	Colour and Odour	Not objectionable	-
6.	Sulfide (as H_2S)	Not more than 1.0 mg/l	Titrate
7.	Cyanide (as HCN)	Not more than 0.2 mg/l	Distillation, followed by Pyridine- Barblturic Add Method
8.	Fats oil and Grease (FOG)	Not more than 5 mg/l depending on receiving water or type ot factory. but not exceedimg 15 mg/l	Extract by solvents
9.	Formaldehyde	Not more than 1.0 mg/l	Spectrophotometry
10.	Phenols	Not more than 1-0 mg/l	Distillation, followed by 4 - Aminoantipyrine Method

Table G.1 Effluent standards from factories and Industrial estates. (Cont.)

11.	Free Chlorine	Not more than 1-0 mg/l	Iodometric Method
12.	Pesticides	Not detectable	Gas - Chromatography
13.	Biochemical Oxygen Demand (BOD)	Not more than 20 mg/l depending on receiving water or type of factory. but not exceeding 60 mg/l	Azide modification at 20 °C for 5 days
14.	Total Kjeldahl Nitrogen CTKN)	Not more than 100 mg/l depending on receiving water or type of factory, but not exceeding 200 mg/l	Kjeldahl
15.	Chemical Oxygen Demand (COD)	Not more than 120 ma/l depending on waiving water or type of factory but not exceeding 400 ma/l	Potassium dichromate digestion
16.	Heavy Metals		
	1. Zinc(Zn)	Not more than 5.0 mg/l	Atomic absorption spectrophotometry using Direct Aspiration Method or Plasma Emission Spectroscopy with Inductively Coupled Plasma (ICP) Method
	2. Chromium Hexaualent (Cr^{6+})	Not more than 0.2& mg/l	
	3. Chromium Trivalent (Cr^{3+})	Not more than 0.75 mg/l	
	4. Copper (Cu)	Not more than 2.0 mg/l	
	5. Cadmium (Cd)	Not more than 0.03 ma/l	
	6. Barium (Ba)	Not more than 1.0 mg/l	
	7. Lead (Pb)	Not more than 0.2 mg/l	
	8. Nickel (Ni)	Not more than 1.0 mg/l	
	9. Manganese (Mn)	Not more than 5-0 mg/l	

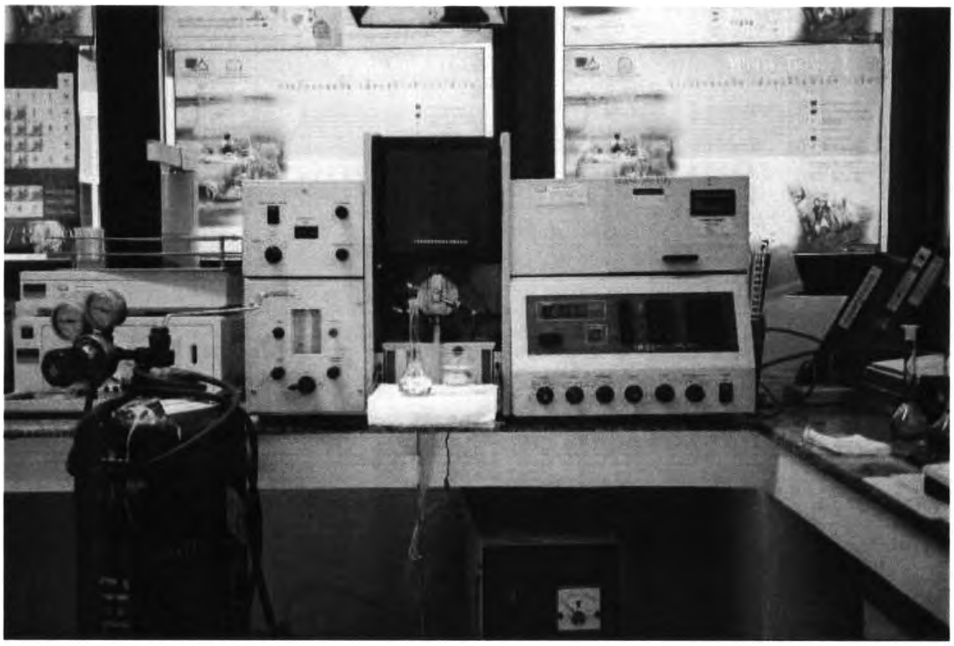
Table G.1 Effluent standards from factories and Industrial estates. (Cont.)

10. Arsenic (As)	**Not more than 0.25 mg/l**	**Atomic absorption Spectrophotometry using Hydride Generation Method or Plasma Emission Spectroscopy with inductively Coupled Plasma (ICP) Method**
11. Selenium (Se)	**Not more than 0.02 mg/l**	
12. Mercury (Hg)	**Not more than 0.005mg/l**	**Atomic Absorption Cold Vapour Technique**

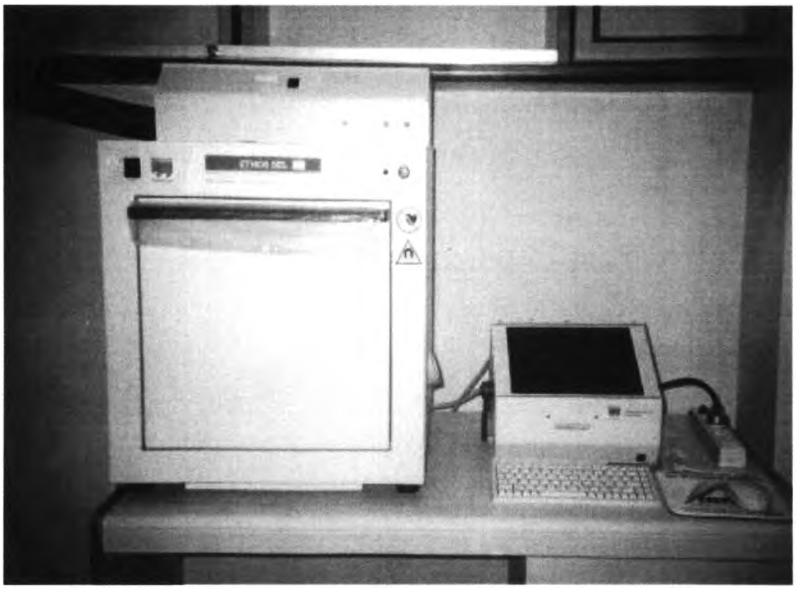
(The Notification was published in the Royal Government Gazette, Vol 113, Part 13 D, dated 13 February B.E, 2539 (1996)).

APPENDIX H

The pictures are accessories in this research.



Atomic Absorption Spectrometer



Microwave Digestion and Extraction System Model ETHOS SEL

BIOGRAPHY

Ms. Buppa Ounsangchan was born on December 29, 1962 in Phayao, a province in the north of Thailand. After she finished high school in Chiang Mai, she then went to continue her study at Khon Kaen University, in the northeastern of Thailand. She graduated from the university with a Bachelor's Degree in Science, majoring in chemistry in 1985. She started working as an environmental officer at the Pollution Control Department (PCD), Ministry of Science, Technology and Environment, Thailand in April 1993. She was encouraged to carry out her further postgraduate study in Environmental Management (International Program)at Chulalongkorn University in May, 2000. And she has completed her programme in October, 2002.