REFERENCES

Abdul A.S., Gibson T.L. and Rai D.N. 1990. Selection of surfactants for removal of petroleum products from shallow sandy aquifers. Ground Water 28: 920-926.

Abdul A.S., and Gibson T.L. 1992. Laboratory Studies of Surfactant-Enhanced Washing of Polychorinated Biphenyls from Sandy Materials. Environ. Sci. Technology 25, No.4: 665-671.

Agency for Toxic Substances and Disease Registry. 1995. Public Health Statement for Polycyclic Aromatic Hydrocarbons (PAHs) [Online], Available from: http://www.atsdr.cdc.gov/toxprofiles/phs69.html [2002,03,15].

Agency for Toxic Substances and Disease Registry. 1999. CERCLA Priority List of Hazardous Substances [Online], Available from http://www.atsdr.cdc.gov/99list.html [2002, 03,16].

American Public Health Association, Water Environment Federation, and American Water Works Association. 1998. Standard Methods for the Examination of Water and Wastewater. 20th ed. Washington, DC: American Public Health Association, pp. 6-59 to 6-84.

Battke, J., and Lieprlt, G. 2000. Application of Pressurized Reactors and Surfactants for Soil Bound PAH Bioremediation [Online], Available from http://www.ihi-zittau.de/uvt/projekte/EinsatzDruckbioreaktoren.html [2001,08,20],

Bedient, P.B., Rifai, H.S., and Newell, C.J. 1994. Ground Water Contamination, Transport and Remediation. Englewood Cliffs, New Jersey: PTR Prentice Hall.

Bhandari, A., Novak, J.T. and Dove, D.C. 2000. Effect of soil washing on petroleum-hydrocarbon distribution on sand surfaces. J. of Hazardous Substance Research 2: 7-1 to 7-7.

Candida, C.W., and Jeffrey, H.H. 1992. Surfactants and Subsurface Remediation. Environmental Sci. Technology 26: 2324-2330.

Chun, C.L., Lee, Jung-Ju, and Park, J.-W. 2002. Solubilization of PAH mixtures by three different anionic surfactants. Environmental Pollution 118, Issue 3: 307-313.

Committee on Ground Water Cleanup Alternatives, Water Science and Technology Broad. Broad on Radioactive Waste Management and Commission on Geosciences, Environment, and Resources. 1994. Alternatives for ground Water Cleanup. Washington, D.C.: National Academy Press.

Conte, P., Zena, A., Pilidis, G., and Piccolo, A. 2001. Increased retention of polycyclic aromatic hydrocarbons in soils induced by soil treatment with humic substances, Environmental Pollution 112, Issue 1: 27-31.

Ellis, W.D., Payne, J.R., and Mcnabb, G.D. 1985. Treatment of Contaminated Soil with Aqueous Surfactants. U.S. EPA Report No. 600/2-85/129. Hazardous Waste Engineering Research Laboratory. New Jersy: U.S.EPA. Edison.

Environmental Protection Agency. 1997. National Primary Drinking Water Regulations Consumer Factsheet on: BENZO(A)PYRENE [Online], Available from: http://www.epa.gov/safewater/dwh/c-soc/benzopyr.html [2001,09,25].

Environmental Protection Agency. 2000. Revised Draft PBT National Action Plan For Benzo(a)pyrene (B(a)P) for Preliminary Stakeholder Review, Prepared for The USEPA Persistent, Bioaccumulative and Toxic Pollutants (PBT) B(a)P Workgroup.

For a Safer and Cleaner World: BIO NONEX for Safety. [Online], Available from: http://www.oljetekniksunesall.se/page3.html [2001,09,11].

Grasso, D., Subramaniam, K., Pignatello, J.J., Yang, Y., and Ratte, D. 2001. Micellar desorption of polynuclear aromatic hydrocarbons from contaminated soil. Colloids and Surfaces 194: 65–74.

Gregg, S.J., and Sing, K.S. 1982. Adsorption, Surface Area and Porosity. 2nd edition, London: Academic Press.

Grimberg, S.J., Aitken, M.D., and Stringfellow, W.T. 1994. The influence of a surfactant on the rate of phenanthrene mass transfer into water. Water Science and Technology 30, No 7: 23–30.

Hashim, M.A., and Gupta, B.S. 1998. The Application of Colloidal Gas Aphron in the Recovery of Fine cellulose Fibers from Paper Mill Wastewater. Bioresource Technology 64: 199-204.

Hashim, M.A., Dey. A., Hasan, S., and Gupta, B.S. 1999. Mass transfer correlation in floatation of plam oil by colloidal gas aphrons. Bioprocess Engineering 21: 401-404.

Hayes, T.D. 2001. Foam transports process for in-situ remediation of contaminated soils. U.S. Pat. No. 6,210,955 [Online], available from: http://www.uspto.gov [2001,08,21].

Kammeraad, N. 1997. Method for soil remediation. U.S. Pat. No. 5,634,983 [Online], available from: http://www.uspto.gov [2001,08,21].

Kommalapati, R.R., Valsaraj. K.T., Constant, W.D., and Roy, D. 1998. Soil Flushing using Colloidal Gas Aphron Suspensions Generated from a Plant-Based surfactant. Journal of Hazardous Materials 60: 73-87.

LaGrega, M.D., Buckingham, P.L., and Evans J.C. 2001. Hazardous Waste Management. 2nd ed. Singapore: McGraw-Hill.

Lange, K.R. 1999. Surfactants: A Practical Handbook. Cincinnati: Hanser Publishers, Munich, Hanser Gardner Publications, Inc.

Lui, Z., Laha, S., Luthy, R.G. 1991. Surfactant Solubilization of Polycyclic Aromatic Hydrocarbon in Soil Water Suspension. Water Science Technology 23: 475-485.

Martin J.S. 1987. Nonionic Surfactants Physical Chemistry. Surfactant Science Series Volume 23. New York: Marcael Dekker, Inc.

Panida Thamsatitman. 1995. Surfactant Adsorption and soil decontamination using model soils. Part I: Negatively charged soil Model. Master's Thesis, Deppartment of Petrochemical Technology, Chulalongkorn University.

Ross, D.D. 1999. Bioremediation of sediments contaminated by Polynuclear Aromatic Hydrocarbons. [Online], Available from: http://www.iisgcp.org/research/wq/wqr3.html [2001,09,08].

Roy, D., Valsaraj, K.T., Constant, W.D., and Darij, M. 1994. Removal of hazardous oily waste from a soil matrix using surfactants and colloidal gas aphron suspensions under different flow conditions. J. of Hazardous Materials 38: 127-144.

Roy, D., Kommalapati, R.R., Valsaraj, K.T., and Constant, W.D. 1995. Soil Flushing of Residue Transmission Fluid: Application of Colloidal Gas Aghron Suspensions and Conventional Surfactant Solutions. Water Research 29: 589-595.

Roy, D., Kommalapati, R.R., Mandava, S.S., Valsaraj, K.T., and Constant, W.D. 1997. Soil Flushing Potential of a Natural Surfactant Environmental Science Technology 31: 670-675.

Sebba, F. 1987. Foams and Biliquid Foams – Aphrons. Chichester: John Wiley and Sons.

Shiau, B.-J., Sabatini, D.A., and Harwell, J.H. 1994. Solubilization and Microemulsification of Chlorinated Solvents Using Direct Food Additive (Edible) Surfactants. Ground Water 32, No. 4: 561-569.

Sun, X. and Puri, R.K. 2001. Surfactant-Enhanced Solubility and Mobility of Polycyclic Aromatic Hydrocarbons in Soil. in Conference on Hazardous Waste Research Building Partnerships for Innovative Technologies [Online], Available from: http://www.engg.ksu.edu/HSRC/97Proceed/Remediation4/surfactant.html [2002,02,12].

Tadros, Th.F. 1984. Surfactants. 2nd ed. London: Academic Press, Inc.

The Occupational Safety and Health Administration (OSHA). 1994. Federal Registers Indoor Air Quality 59:15968-16039 [Online], Available from: http://www.osha.gov [2001,07,26].

The Westford Chemical Corporation. 1997. BioSolve for enhanced, accellerated, in-situ remediation of hydrocarbon based contamination. [Online], Available from: http://www.biosolve.com/bio2.html [2001,08,09].

Wilson, D.J., and Clarke, A.N. 1994. Soil Surfactant Flushing/Washing, in Hazardous Waste Site Soil Remediation, Theory and Application of Innovative Technologies. New York: Marcell Dekker, Inc.: 413-550.

Yeom, I.-T., Ghosh, M.M., Cox, C.D., and Ahn, K.-H. 1996. Dissolution of polycyclic aromatic hydrocarbons from weathered contaminated soil. Water Science and Technology 34, Issues 7-8: 335-342.

Yeom, I.-T., and Ghosh, M.M. 1998. Mass transfer limitation in PAH-contaminated soil remediation. Water Science and Technology 37, Issue 8: 111-118.

APPENDIX

Appendix

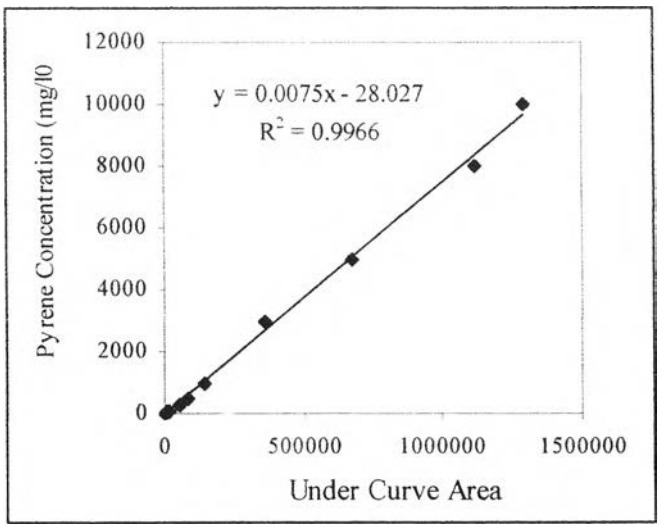

Figure A 1 Standard curve for pyrene in toluene solution

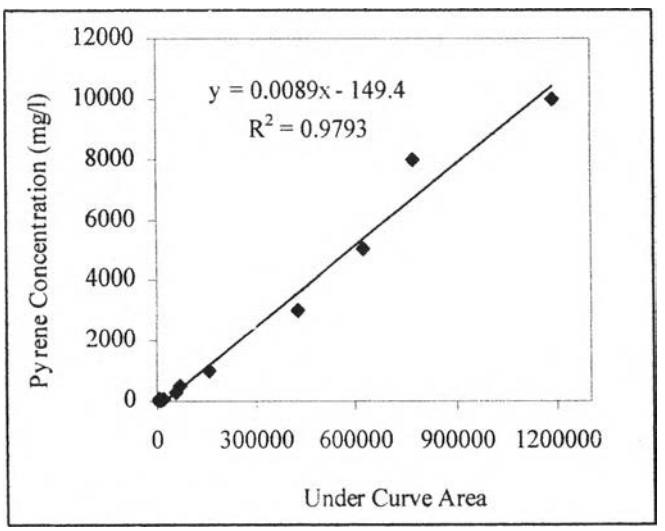

Figure A 2 Standard curve for pyrene in the presence of BioSolve

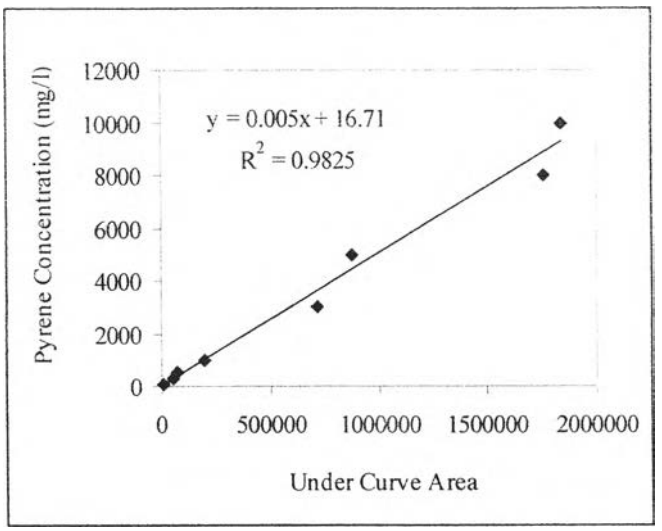

Figure A 3 Standard curve for pyrene in the presence of BioSolve

Table A 1 Influence of pumice size and initial pyrene concentration on the pyrene adsorption and pyrene removal efficiency by toluene extraction in batch experiments.

Pumice Size	4.0-4.75 mm		4.75-6.3 mm		6.3-8.0 mm	
Initail pyrene conc. (ppm)	Pyrene adsorbed (mg/kg)	Pyrene Removal (mg/kg)	Pyrene adsorbed (mg/kg)	Pyrene Removal (mg/kg)	Pyrene adsorbed (mg/kg)	Pyrene Removal (mg/kg)
1000	646.85	99.13	506.38	44.50	485.03	28.29
4000	2490.42	621.86	1849.05	391.96	1753.56	256.13
7000	3488.54	2164.73	2993.55	1825.13	2556.40	1473.39
10000	4647.49	3575.18	4073.57	2891.32	3545.86	2335.26

Table A 2 Pyrene removal (mg pyrene/ kg pumice): Influence of initial pyrene concentration and concentration of BioNonex solutions on pumice removal

Initial Pyrene conc. (ppm)	BioNonex-1% pyrene (mg/kg)	BioNonex-3% pyrene (mg/kg)	BioNonex-5% pyrene (mg/kg)	BioNonex-7% pyrene (mg/kg)	BioNonex-10% pyrene (mg/kg)
1000	184.40	221.38	285.31	420.64	513.21
4000	322.33	517.46	725.34	854.36	1239.99
7000	353.97	725.36	1611.56	1857.38	2516.19
10000	422.62	1321.74	2551.28	3078.78	3477.13

Table A 3 Pyrene removal (mg pyrene/ kg pumice): Influence of initial pyrene concentration and concentration of BioSolve solutions on pumice removal

Initial Pyrene conc. (ppm)	BioSolve-1% pyrene (mg/kg)	BioSolve-3% pyrene (mg/kg)	BioSolve-5% pyrene (mg/kg)	BioSolve-7% pyrene (mg/kg)	BioSolve-10% pyrene (mg/kg)
1000	47.17	65.23	92.65	102.06	194.39
4000	186.72	327.45	539.82	624.71	688.61
7000	281.04	1009.61	1636.94	1845.21	1930.58
10000	284.45	1232.48	1840.53	2344.26	2479.01

Table A 4 Effect of types and surfactant concentrations on percentage of pyrene removal using initial pyrene contamination at 1300 mg pyrene/kg pumice.

Surfactant	BioNox	Biosolve
Conc (%)	pyrene removal (%)	pyrene removal (%)
1	27.26	11.05
3	36.57	15.24
5	51.52	23.63
7	69.97	45.38
10	75.53	52.60

Table A 5 Influence of contact time on pyrene removal by surfactant solution and water flood.

time	Bionox5%	Biosolve5%	Water
(hr)	% pyrene removal	% pyrene removal	% pyrene removal
0.25	24.12	0.33	0
0.5	40.24	1.01	1.2
1	48.64	4.43	2
2	52.70	6.55	3
3	55.33	9.63	4
5	59.08	11.28	5
7	60.89	14.33	5.5
10	66.39	16.43	6
15	72.42	21.01	7
20	76.47	24.14	7.7
24	76.88	24.75	8

Table A 6 Stability of CGA: The height of the clear liquid interface below the dispersion of CGA was measured with time to determine half life of CGA bubbles generated from 3% and 7% BioNonex solutions.

Time (min)	Volume of 3% BioNonex Solution	Time (min)	Volume of 7% BioNonex Solution
0	0	0	0
4	200	5.42	170
6.75	300	6.8	200
9.22	400	9.63	300
12	500	11	350
15.58	600	12.72	400
20	680	15.7	500
22	695	16.73	540
22.9	700	18.37	580
24.57	700	19.33	600
		21.67	642
		24.27	662
		25.67	670
		27.28	673
		28.62	680

Table A 7 Typical results showing the variation between the duplicate runs of BioNonex-3% solution in the column experiment.

Time (hr)	Run 1	Run 2	Average Results
0.2	0.62	1.02	0.822
0.5	2.36	3.56	2.963
1	6.84	8.04	7.436
1.5	12.33	13.53	12.928
2	19.09	19.89	19.490
3	25.36	26.36	25.864
4	29.96	31.56	30.757
5	33.57	34.77	34.168
6	35.92	37.12	36.516
7	37.67	38.87	38.268
8	39.33	39.73	39.527
9	40.06	41.26	40.659
10	40.94	42.44	41.690
11	42.02	43.22	42.619
12	42.40	44.40	43.397
13	43.46	44.66	44.060
14	44.07	45.27	44.673
15	44.21	46.21	45.210
16	45.50	45.90	45.696
17	45.19	46.99	46.094
18	46.13	46.73	46.428
19	46.11	47.31	46.712
20	46.57	47.37	46.970

Table A 8 Pyrene removal in column operation with different flushing media at pyrene contamination level of 1300 mg pyrene/ kg pumice.

time (hr)	3% solution %pyrene removal	3% aphron %pyrene removal	7%solution %pyrene removal	7% aphron %pyrene removal	Water %pyrene removal
0.2	0.82	4.48	2.59	7.46	0.21
0.5	2.96	10.01	8.26	15.49	0.84
1	7.44	16.87	14.62	23.93	1.23
1.5	12.93	24.05	22.06	32.27	2.56
2	19.49	30.78	29.44	40.38	3.5
3	25.86	36.05	39.24	48.10	4.95
4	30.76	40.17	45.17	54.62	5.18
5	34.17	43.10	48.07	59.13	6.82
6	36.52	45.05	52.10	62.76	7.45
7	38.27	46.59	54.69	65.73	8.56
8	39.53	47.96	56.90	67.88	9.02
9	40.66	49.25	58.92	69.65	9.26
10	41.69	50.36	60.49	71.20	9.52
11	42.62	51.28	61.94	72.59	9.56
12	43.40	52.00	63.16	73.76	9.85
13	44.06	52.69	64.21	74.67	10.08
14	44.67	53.30	65.09	75.52	10.23
15	45.21	53.89	65.83	76.33	10.56
16	45.70	54.39	66.46	77.03	10.67
17	46.09	54.72	67.00	77.65	10.78
18	46.43	55.02	67.51	78.13	10.85
19	46.71	55.24	67.91	78.46	11.07
20	46.97	55.42	68.23	78.70	11.08

Table A 9 Pyrene removal in column operation with different flushing media at pyrene contamination level of 12000 mg pyrene/ kg pumice.

time (hr)	3% solution pyrene removal, %	3%aphron pyrene removal, %	7%solution pyrene removal, %	7%aphron pyrene removal, %	Water pyrene removal, %
0.2	0.49	0.72	1.21	1.46	0.21
0.5	1.66	2.33	5.23	7.49	0.84
1	3.81	4.98	9.23	12.93	1.23
1.5	6.17	7.73	12.74	20.27	1.56
2	8.52	10.48	16.58	25.38	2.50
3	12.53	15.44	24.24	32.12	3.95
4	16.21	19.79	30.25	34.56	4.18
5	19.53	23.27	33.56	36.85	4.52
6	22.39	26.00	35.08	39.12	5.02
7	24.49	27.91	35.84	41.53	6.12
8	25.91	29.30	36.67	42.35	6.65
9	26.93	31.06	36.92	43.27	6.62
10	27.58	31.49	37.51	44.12	6.85
11	27.89	32.23	38.08	45.68	6.98
12	28.06	32.87	39.23	46.23	7.06
13	28.22	33.25	39.86	47.85	7.11
14	28.35	33.89	40.59	48.56	7.23
15	28.46	33.97	41.82	49.07	7.34
16	28.53	34.23	42.27	50.12	7.36
17	28.58	34.52	42.52	50.89	7.38
18	28.62	35.08	42.85	51.23	7.40
19	28.65	35.56	43.05	51.88	7.41
20	28.67	36.18	43.23	52.65	7.45

Table A 10 Concentration of pyrene in the effluents of soil flushing in column at the pyrene contamination level of 1300 mg pyrene/kg pumice using different media.

time (hr)	3% solution pyrene conc. (mg/l)	3% aphron pyrene conc. (mg/l)	7%solution pyrene conc. (mg/l)	7% aphron pyrene conc. (mg/l)
0.2	2.95	10.71	9.22	17.82
0.5	3.84	13.23	10.10	19.20
1	5.35	16.42	11.34	20.16
1.5	6.57	17.17	8.83	19.93
2	7.85	16.09	6.58	19.38
3	3.81	12.60	4.27	18.44
4	2.93	4.92	3.88	7.79
5	2.04	3.51	2.91	5.39
6	1.40	2.33	2.40	4.34
7	1.05	1.84	1.54	3.55
8	0.75	1.64	1.31	2.57
9	0.68	1.53	1.20	2.12
10	0.62	1.34	0.93	1.84
11	0.56	1.10	0.86	1.66
12	0.46	0.86	0.72	1.40
13	0.40	0.83	0.62	1.09
14	0.37	0.72	0.53	1.02
15	0.32	0.71	0.44	0.97
16	0.29	0.59	0.37	0.84
17	0.24	0.40	0.32	0.74
18	0.20	0.37	0.30	0.57
19	0.17	0.26	0.24	0.40
20	0.15	0.22	0.19	0.29

Table A 11 Cumulative removal of pyrene from soil column at different contamination level and using different flushing media

contamination level	1300 mg/kg	1300 mg/kg	12000 mg/kg	12000 mg/kg
Time (hr)	3% solution	3% aphron	3% solution	3% aphron
0.2	2.95	16.06	16.55	24.30
0.5	10.63	35.91	56.39	79.13
1	26.67	60.53	129.45	169.21
1.5	46.37	86.28	209.45	262.39
2	69.91	110.41	289.24	355.81
3	92.78	129.31	425.39	524.21
4	110.33	144.09	550.46	671.99
5	122.57	154.61	663.04	790.02
6	130.99	161.61	760.26	882.70
7	137.28	167.14	831.51	947.59
8	141.79	172.06	879.81	994.98
9	145.85	176.65	914.58	1020.66
10	149.55	180.66	936.54	1035.35
11	152.88	183.96	947.18	1040.55
12	155.67	186.54	952.92	1043.34
13	158.05	189.02	958.30	1043.81
14	160.25	191.19	962.68	1043.81
15	162.18	193.31	966.47	1043.81
16	163.92	195.09	968.90	1043.81
17	165.35	196.28	970.41	1043.81
18	166.55	197.38	971.70	1043.81
19	167.56	198.16	972.67	1043.81
20	168.49	198.81	973.47	1043.81

Table A 12 Organic matter content of the natural soil.

weight of dry soil	W. of soil after burnt at 600oC	W. of organic mater	%organic content
10.0859	9.7855	0.3004	2.98
9.6074	9.3195	0.2879	3.00
Average organic content (%)			2.99

Table A 13 Pyrene removal from pumice and natural soil using BioNonex-3% solution.

]

time (hr)	Real soil			Pumice		
	pyrene loaded (mg/kg)	pyrene removal (mg/kg)	% pyrene removal	pyrene loaded (mg/kg)	pyrene removal (mg/kg)	% pyrene removal
0.25	410.74	76.82	18.70	767.08	213.79	27.87
0.5	410.22	102.85	25.07	793.41	289.71	36.51
1	410.11	127.56	31.10	702.79	303.38	43.17
2	405.27	154.63	38.15	707.00	328.89	46.52
4	404.44	178.08	44.03	759.62	370.56	48.78
8	404.18	201.28	49.80	698.67	361.02	51.67
14	404.46	219.00	54.15	797.07	425.68	53.41
20	414.90	238.90	57.58	767.89	420.13	54.71

BIOGRAPHY

Miss Panitan Jutaporn was born on November 13, 1980, in Hat Yai, Songkla. She received the B.Eng. degree of Environmental Engineering from Faculty of Engineering, Prince of Songkla University in 2001. Then she continued her study for the M.Sc. degree in the Inter-Departmental Program on Environmental Management at the Environmental Research Institute of Chulalongkorn University (ERIC), National Research Center for Environmental and Hazardous Waste Management on May, 2001.