REFERENCES

Al-Ekabi H. (1998). Abstracts of the 1998 Pan-American Workshop on Commercialization of Advanced Oxidation Technologies, London, Ontario, Canada: 27±30.

Ao, C.H., Lee, S.C., and Yu, J.C. 2003. Photocatalyst TiO_2 supported on glass fiber for indoor air purification: effect of NO on the photodegradation of CO and NO_2. Journal of Photochemistry and Photobiology A: Chemistry 156: 171-177.

APHA, AWWA, WPCF. Standard methods for the examination of water and wastewater. 20th edition. 1998.

Arabatzis, I. M., Antonaraki, S., Stergiopoulos, T., Hiskia, A., Papaconstantinou, E., Bernard, M. C., and Falaras, P. (2002). Preparation, characterization and photocatalytic activity of namocrystalline thin film TiO_2 catalysts towards 3,5-dichlorophenol degradation. Journal of Photochemistry and Photobiology A: Chemistry. 149: 237-245.

Benoit, D.A. (1976). Toxic Effects of Hexavalent Chromium on Brook Trout and Rainbow. Water Research. Vol. 10: 497-500.

Brinker, C.J., and Scherer, G.W. (1990). Sol-gel science: The physics and chemistry of sol-gel processing. Boston: Academic Press.

Chen, J., Truesdail, S., Lu, F., Zhan, G., Belvin, C., Koopman, B., Farrah, S., and Shah, D. (1998). Long-term evaluation of aluminum hydroxide-coated sand for removal of bacteria from wastewater. Water Research. 32(7): 2171–2179.

Chenthamarakshan, C. R., and Rajeshwar, K. (2000). Heterogeneous Photocatalytic Reduction of Cr(VI) in UV-Irradiated Titania Suspensions: Effect of Protons, Ammonium Ions, and Other Interfacial Aspects. Langmuir. 16(6): 2715-2721.

Choi1, H., Stathatos, E., and Dionysios D.D. (1995). Preparation of Nanostructured TiO_2 Photocatalytic Films and Membranes Using Sol-Gel Methods Modified with Surfactants Table 1. Properties of TiO_2/Al_2O_3 composite membranes. Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, USA, OH 45221-0071.

Daramuang, K. (2004). Recycle of Chromium from Titanium Dioxide Power Using Acid/Alkali Treatment Method. Master's Thesis, Department of Environmental Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

De Heredia, J. B., Torregrosa, J., Dominguez, J. R., and Peres, J. A. (2001). Oxidation of p-hydroxybenzoic acid by UV radiation and by TiO_2/UV radiation: comparison and modeling of reaction kinetic. Journal of Hazardous Materials. B83: 255-264.

Ding, Z., Hu, X., Yue, P. L., Lu, G. Q., and Greenfield, P. F. (2001). Synthesis of anatase TiO_2 supported on porous solids by chemical vapor deposition. Catalysis Today. 68: 173-182.

Dionysiou D.D., Balasubramanian G., Suidan M. T., Amid P.K., Baudin, I. and Laine, J.M. (1999). Rotating disk photocatalytic reactor: development, characterization, and evaluation for the destruction of organic pollutants in water. Water Reseach. 34 : 2927-2940.

Dionysiou D.D., Balasubramanian G., Suidan M. T., Baudin I. and Laine, J.M. (2002). Oxidation of organic contaminants in a rotating disk photocatalytic reactor: reaction kinetics in the liquid phase and the role of mass transfer based on the dimensionless. Reaction Engineering for Pollution Prevention, eds M. Abraham and R. P. Hesheth. Elsevier, Amsterdam, the Nether-lands: 2927-2938

Douglas, A., Gotic, M.M., Ivanda, M., Popovic,S., Turkovic, A., Trojko, R., Sekulic, A., and Furic, K.(2001). Chemical and microstructural properties of TiO_2 synthesized by sol-gel process.

Epling, G. A., and Lin, C. (2002). Investigation of retardation effects on the titanium dioxide photodegradation system. Chemosphere. 46: 937-944.

Fretwell, R. and Douglas, P. (2001). An Active, Robust and Transparent Nanocrystalline Anatase TiO_2 Thin Film Preparation, Characterization and The Kinetics of Photodegradation of Model Pollutants. Journal of Photochemistry and Photobiology A : Chemistry. 143: 229-240.

Fujishima, A., Hashimoto, K. and Watanabe, T. (1999). TiO_2 Photocatalysis: Fundamental and Application, Tokyo: 158

Goeringer, S., Chenthamarakshan, C.R., and Rajeshwar, K. 2001. Synergistic photocatalysis mediated by TiO_2: mutual rate enhancement in the photoreduction of Cu(VI) and Cu(II) in aqueous media. Electrochemistry Communications 3: 290-292.

Guillard, C., Beaugiraud, B., Dutriez, C., Herrmann, J.M., Jaffrezic, H., Renault, N.J. and Lacroix, M. (2002). Physicochemical Properties and Photocatalytic Activities of TiO_2-Film Prepared by Sol-Gel Methods. Applied Catalysis B : Environmental. 39: 331-342.

Herrmann, J.M. (1999). Heterogeneous photocatalysis: fundamentals and applications to the removal of various types of aqueous pollutants. Catalysis Today. 53: 115-129.

Herrmann, J.-M., Gul, C.H. and Pichat, P. (1993). Heterogeneous Photocatalysis : an Emerging Technology for Water Treatment. Catalysis Today 17: 7-20.

Hilmi, A., Luong, J.H.T., and Nguyen A-L. 1999. Utilization of TiO_2 deposited on glass plates for removal of metals from aqueous wastes. Chemosphere 38: 865-874.

Jacoby W. A., Maness P. C., Wolfrum E. J., Blake D. M.and Fennell J. A. (1998) Mineralization of bacterial cell mass on a photocatalytic surface in air. Environ. Sci. Technol. 32: 2650±2653.

Jirapattarasakul, S. (2004). Titanium Dioxide Thin Film preparation using Diethanolamile in sol-gel process for chromium hexavalence (VI) removal for wastewater. Master's Thesis, Department of Environmental Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

Klein, L.C. (1991). Sol-gel coating. In Vossen, J.L., and Kern, W. I (eds.), Thin film processes II, Boston: Academic Press.

Klein, L.C. (1997). Sol gel formation and deposition. In Goldstein, A.N. (ed.), Handbook of Nanophase materials, New York: Marcel Dekker.

Ku, Y. and Jung, I.L. (2001). Photocatalytic Reduction of Cr(VI) in Aqueous Solutions by UV Irradiation with The Presence of Titanium Dioxide. Water Research. 35: 135-146.

Lin, W.Y., Wei, C. and Rojeshwar, K. (1993). Photocatalytic reduction and immobilization of hexavalent chromium at titanium dioxide in aqueous basic media. Journal of Electrochemical Society. 140, 9 : 2477-2482

Ling, C.M., Mohamed, A.R., and Bhatia, S. (2004). Performance of photocatalytic reactors using immobilized TiO_2 film for the degradation of phenol and methylene blue dye present in water stream. Journal of Chemosphere. 57: 547-554

Linsebigler, A. L., Lu, G., and Yates, J. T. (1995). Photocatalysis on TiO_2 Surfaces: Principles, Mechanisms, and Selected Results. Chemical Reviews. 95(3): 735-758.

Liqiang, J., Xiaojun, S., Weimin, C., Zili, X. and Yaoguo, D. (2003). The Preparation and Characterization of Nanoparticle TiO_2/Ti Films and Their Photocaalytic Activity. Journal of Physics and Chemistry of Solids. 64: 615-623.

Litter, M.I. (1999). Heterogeneous Photocatalysis Transition Metal Ions in Photocatalytic System. Applied Catalysis B : Environmental. 23: 89-114.

Matthews, R.W. 1987. Photooxidation of organic impurities in water using thin films of titanium dioxide. The Journal of Physical Chemistry. 91: 3328-3333.

Mohapatra, P., Samantaray, S.K., and Parida, K. (2005). Photocatalytic reduction of hexavalent chromium in aqueous solution over sulphate modified titania. Journal of Photochemistry and Photobiology A: Chemistry. 170: 189–194.

Noel A.H., Lawrence, R.W., and Hardacre, C. (2001). Use of a batch rotating photocatalytic contactor for the degradation of organic pollutants in wastewater. Journal of Applied Catalysis B: Environmental. 30: 49-60.

Ollis, D. F. (2000). Photocatalytic purification and remediation of contaminated air and water. Chemistry. 3: 405-411.

Pelizzetti, E. and Minero, C. (1993). Mechanism of the photooxidative degradation of organic pollutants over TiO2 particles. Electrochim. Acta 38: 47-55.

Pecchi, G., Reyes, P., Sanhueza, P., and Villaseñor, J. 2001. Photocatalytic degradation of pentachlorophenol on TiO_2 sol-gel catalyst. Chemosphere 43: 141-146.

Photocatalysis . Available from: http://dev.nsta.org/evwebs/1952/photocatalysis.htm. [31/10/05]

Pongpom, S. (2004). Preparation of Titanuimdioxide Thin Film on Glass Plate Using Sol-Gel Technique for Photocatalytic Reduction of Chromium (VI). Master's Thesis, National Research Center for Environmental and Hazardous Waste Management, Chulalongkorn University, Bangkok, Thailand

Poulios, I., Makri, D., and Prohaska, X.(1999). Photocatalytic treatment of olive milling wastewater: Oxidation of protocatechic acid. Global Nest: the Int. J. 1, 1: 55-62.

Rai, D., Sass, B.M. and Moore, D.A. (1987). Chromium(III) Hydrolysis Constants and Solubility of Chormium(III) Hydroxide. Inorganic. Vol. 26 No. 3: 345-349.

Rookpun, C., Baingern, P., and Tanamongkolsawas, K. (2003). Preparation of thin film TiO_2 by Sol-Gel method using Ethanol as solvent. B. Eng. Project. Department of Environmental Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

Schrank, S.G., Jose, H.J. and Moreira, R.F.P.M. (2002). Simultaneous Photocatalytic Cr(VI) Reduction and Dye Oxidation in a TiO_2 Slurry Reactor. Journal of photochemistry and photobiology A : Chemistry. 147.

Shinskey, F.G. (1973). pH and Iron Control in Process and Water Stream, John Wiley & Son, New York, p. 259.

Sobczynski, A., Duczmal, L., and Zmudzinski, W. (2004). Phenol destruction by photocatalysis on TiO_2: an attempt to solve the reaction mechanism. Journal of Molecular Catalysis A: Chemical 213: 225-230.

Takahashi, M., Tsukigi, K., Uchino, T., and Yoko, T.(2001). Enchanced photocurrent in thin film TiO_2 electrodes prepared by sol-gel method. : 231-236

Tuprakay, S., and Liengcharernsit, W. (2005). Lifetime and regeneration of immobilized titania for photocatalyticremoval of aqueous hexavalent chromium. Journal of Hazardous Materials. B124: 53-58

Vicente, G.S., Morales, A., and Gutierrez, M.T. 2001. Preparation and characterization of sol-gel TiO_2 antireflective coating for silicon. Thin Solid Films 391: 133-137.

Watcharenwong, A. (2003). Removal of Chromium (VI) from synthetic wastewater using powdered TiO_2 in photocatalysis process. Master's Thesis, Department of Environmental Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

Weng, C. H., Wang, J. H., and Huang, C. P. (1997). Adsorption of Cr(VI) onto TiO_2 from dilute aqueous solutions. Water Science and Technology. 35(7): 55-62.

Westerterp K. R., Van Swaaij W. P. M. and Beenackers, A. A. C. M. (1984). Chemical Reactor Design and Operation, 2nd ed.: 177±179.

Yu, G., Zhu, W., Yang, Z., and Li, Z. (1998). Semiconductor Photocatalytic Oxidation of H-acid Aqueous Solution. Chemosshere. 36(12): 2673-2681.

Yu, J., Zhao, X., and Zhao, Q. (2001). Photocatalytic activity of namometer TiO_2 Thin films prepared by the sol-gel method. Materials Chemistry and Physics. 69: 25-29.

Zhang, L., Kanki, T., Sano, N., and Toyoda, A. (2001). Photocatalytic Degradation of organic compound in aqueous solution by a TiO-coated rotating–drum reactor 2 using solar. Journal of Solar Energy. 70, 40: 331-337.

Zhaolin L., and Liang H.(2004). Nano-TiO2-coated polymer electrolyte membranes for direct methanol fuel cells. Institute of Materials Research and Engineering, 3 Research Link, Singapore 117602, Singapore.

Liu Zhaolin and Hong Liang "Self-cleaning Surfaces using Nano-TiO_2 Photocatalytic Coating" INSTITUTE OF MATERIALS RESEARCH AND ENGINEERING. Available from: www.imre.a-star.edu.sg.

APPENDICES

APPENDIX A

Colorimetric method for chromium (VI) analysis

1. Principle

This process measures only hexavalent chromium. It is determined colorimetrically by reaction with diphenylcarbazide in acid solution. The complex red-violet color was produced that can be measured with 540 nm.

2. Special reagents

2.1 Diphenylcarbazide solution: dissolve 250 mg 1,5-diphenylcarbazide in 50 ml of acetone. Then, store diphenylcarbazide solution in a brown bottle. Discard when solution becomes discolored.

2.2 Stock chromium solution: dissolve 1.411 g of $K_2Cr_2O_7$ in double distilled water (DDW) and dilute to 1 l; 1.00 ml = 500.0 μg Cr^{6+}

3. Procedures

(Standard Methods for the examination of water and wastewater, 1998).

3.1 Preparation of calibration curve:

1) Pipet measured volumes of standard chromium solution (500 μg/ml) ranging from 1.00 to 25.0 ml, to give standards for 0.50 to 12.50 mg Cr (VI), into 250 ml volumetric flasks. Then, get standard chromium solution 2 to 50 mg/l or ppm.

2) Take 5 ml of solution to a bigger

3) Add 0.25 ml H_3PO_4

4) Use 0.2 N H_2SO_4 and a pH meter to adjust solution to pH 1.0 ± 0.3

5) Transfer solution to a 100 ml volumetric flask, dilute to 100 ml and mix.

6) Add 2.0 ml diphenycarbazide solution, mix and allow 5 to 10 min for full color development.

8) Transfer an appropriate portion to a 1-cm absorption cell and measure its absorbance at 540 nm. Use distilled water as reference.

9) Correct absorbance reading of sample by subtracting absorbance of a blank carried through the method.

10) Construct a calibration curve by plotting corrected absorbance against micrograms of chromium.

3.2 Sample measurement

1) Take 5 ml of sample in the bigger

2) Add 0.25 ml H_3PO_4

3) Use 0.2 N H_2SO_4 for adjust pH to be 1.0 ±0.3

4) Transfer solution to a 100 ml volumetric flask, dilute to 100 ml and mix.

5) Add 2.0 mL diphenycarbazide solution, mix and allow 5 to 10 min for full color development.

6) Transfer an appropriate portion to a 1-cm absorption cell and measure its absorbance at 540 nm. Use distilled water as reference.

7) Correct absorbance reading of sample by subtracting absorbance of a blank carried through the method.

APPENDIX B

Calculations

Example experimental data; Wastewater flow rate 20 ml/s, reaction period time 143 min, reaction time for completely remove is 208 min, volume of wastewater 20 litter and volume capacity of reactor is 10.092 litter.

1. Calculation of contact time, min/cycle

- Contact time $= \frac{10.092 \text{ liter}}{20 \text{ ml/s}} = 8.41 \text{ min}$

2. Calculation of treating cycle, cycle

- Treating cycle $= \frac{143 \text{ min}}{8.41 \text{ min}} = 17$

3. Calculation of Cr (VI) removal percentage, %

- Cr (VI) removal percentage $= \frac{143 \text{ min}}{208 \text{ min}} * 100 = 68.75 \%$

Example experimental data; Rotating speed disc 10 rpm, reaction period time 105 min, reaction time for completely remove is 182 min, volume of wastewater 20 litter and volume capacity of reactor is 10.092 m^3.

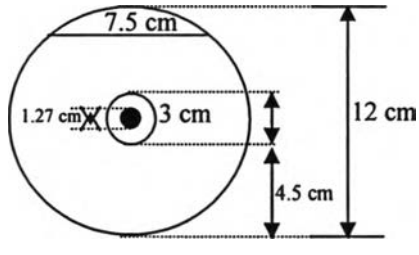
4. Calculation of rotating disc cycle, round

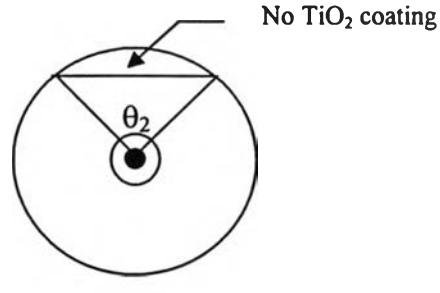
- Total rotating cycle in 105 min = 10 rpm* 105 min = 1050 rounds

5. Calculation of reaction time for one round of rotating disc, min

- Reaction time for one round = $\frac{1}{10 \text{ rpm}}$ = 0.1 min

Example experimental data; Outer diameter of disc plate 12 cm, inner diameter of disc plate is 1.27 cm, wastewater level in the reactor is 5 cm, disc submerge in the wastewater is 4.5 cm, in the reactor has 12 discs plate, amount of TiO_2 is approximate 0.226 mg/cm^2 and the experimental time is 105 min.

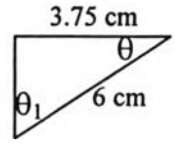




$$\theta = COS^{-1}\left(\frac{3.75}{6}\right) = 51.318$$

$$\theta_1 = 90 - 51.318 = 38.682$$

$$\theta_2 = 38.685 * 2 = 77.364$$



6. Calculation of TiO_2 coating surface area which contract wastewater, m^2

- No TiO_2 coating surface area can calculate by

$$A = \left(\frac{\Pi.r^2.\theta_2}{360}\right) - \left(\frac{1}{2}.r^2 - \sin\theta_2\right)$$

$$A = \left(\frac{\Pi.6^2.(77.364)}{360}\right) - \left(\frac{1}{2}.6^2 - \sin 77.364\right) = 7.281 \text{ cm}^2$$

- All area of disc plate:

$$A = \left(\frac{\Pi.(12)^2}{4}\right) - \left(\frac{\Pi.(1.27)^2}{4}.\right) = 111.83 \text{ cm}^2$$

- Total TiO_2 coating surface area on one side of disc plate

$$A = 111.83 - 7.281 = 104.549 \text{ cm}^2$$

- TiO_2 coating surface area which contract wastewater

$$A = 104.549 - \left(\frac{\prod .3^2}{4} \right) = 97.48 \text{ cm}^2$$

7. Calculation of total TiO_2 coating surface area which contract wastewater in the experimental time, m^2

- If experimental time is 105 min, TiO_2 coating surface area which contract wastewater can calculate:

A = 97.48 cm^2 /round* 12*2 *1050 round = 245.65 m^2

8. Calculation of amount of TiO_2 use in one experiment, mg

- amount of TiO_2 used can calculate:

0.226 mg/cm^2* 97.48 cm^2 *12* 2 = 528 mg

APPENDIX C

EXPERIMENTAL DATAS

Table C-1 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 25 ppm, wastewater flow rate 90 ml/s, rotating speed disc 200 rpm and TiO_2 coating surface area 0.234 m^2 in the initial pH of 3, 7 and 11.

Time (min)	Residual chromium (VI) concentration, (ppm)								
	pH 3			pH 7			pH 11		
	1	2	Average	1	2	Average	1	2	Average
0	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
15	20.34	20.30	20.32	24.67	24.64	24.65	24.69	24.73	24.71
25	18.97	19.03	19.00	24.33	24.33	24.33	24.98	25.02	25.00
35	15.22	14.84	15.03	24.06	24.04	24.05	24.66	24.72	24.69
45	13.01	13.09	13.05	23.70	23.68	23.69	24.68	24.67	24.68
60	9.77	9.87	9.82	23.42	23.43	23.42	25.03	25.02	25.02
75	5.93	6.07	6.00	23.21	23.21	23.21	24.90	24.96	24.93
105	0.07	0.07	0.07	23.09	23.09	23.09	24.66	24.84	24.75
135	0	0	0	22.77	22.77	22.77	25.01	24.72	24.86
165				22.26	22.27	22.27	24.86	24.60	24.73
195				21.54	21.55	21.55	24.98	24.91	24.94

Table C-2.1 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 25 ppm, rotating speed disc 50 rpm, initial pH of wastewater was 3 and TiO_2 coating surface area were 0.234 m^2 in the wastewater flow rate of 20, 40, 60 ml/s.

Time (min)	Residual chromium (VI) concentration, (ppm)								
	Flow rate 20 ml/s			Flow rate 40 ml/s			Flow rate 60 ml/s		
	1	2	Average	1	2	Average	1	2	Average
0	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
15	22.42	22.41	22.42	21.67	22.06	21.87	22.54	22.63	22.59
25	20.22	21.78	21.00	18.51	20.56	19.54	20.07	20.11	20.09
35	18.80	20.88	19.84	17.35	19.24	18.29	19.02	19.10	19.06
45	17.68	19.63	18.66	16.58	17.23	16.91	17.59	17.63	17.61
60	15.81	18.89	17.35	14.94	15.06	15.00	15.02	15.00	15.01
75	14.78	17.21	15.99	12.89	13.06	12.98	13.56	13.76	13.66
105	12.04	13.77	12.91	10.66	10.75	10.71	9.45	9.53	9.49
135	8.69	10.13	9.41	7.12	7.23	7.18	6.12	6.02	6.07
165	4.52	5.91	5.22	3.25	3.27	3.26	1.89	2.03	1.96
195	1.17	1.68	1.42	0.00	0.00	0.00	0.00	0.00	0.00
225	0.00	0.00	0.00						

Table C-2.2 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 25 ppm, rotating speed disc 50 rpm, initial pH of wastewater was 3 and TiO_2 coating surface area was 0.234 m^2 in the wastewater flow rate of 80, 90 ml/s.

Time (min)	Residual chromium (VI) concentration, (ppm)					
	Flow rate 80 ml/s			Flow rate 90 ml/s		
	1	2	Average	1	2	Average
0	25.00	25.00	25.00	25.00	25.00	25.00
15	21.95	22.07	22.01	22.09	22.15	22.12
25	20.32	20.19	20.26	20.07	20.09	20.08
35	17.94	18.21	18.07	18.66	18.77	18.71
45	16.49	16.54	16.52	17.24	17.54	17.39
60	14.96	15.06	15.01	15.09	15.42	15.25
75	12.17	12.63	12.40	12.28	12.36	12.32
105	8.02	8.11	8.07	5.48	5.58	5.53
135	3.26	3.19	3.22	1.49	1.36	1.42
165	0.00	0.00	0.00	0.00	0.00	0.00

Table C-3.1 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 25 ppm, wastewater flow rate 90 ml/s, initial pH of wastewater was 3 and TiO_2 coating surface area were 0.234 m^2 in the rotating disc speed of 10, 50 and 100 rpm.

Time (min)	Residual chromium (VI) concentration, (ppm)								
	Rpm 10			Rpm 50			Rpm 100		
	1	2	Average	1	2	Average	1	2	Average
0	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
15	21.13	21.49	21.31	22.09	22.07	22.08	22.52	22.56	22.54
25	19.48	19.54	19.51	20.07	20.13	20.10	19.62	19.72	19.67
35	18.27	18.15	18.12	18.66	18.70	18.68	17.07	17.11	17.09
45	16.23	17.73	16.98	17.24	17.60	17.42	14.84	14.86	14.85
60	13.90	15.42	14.66	15.08	15.14	15.11	12.23	12.43	12.33
75	11.81	14.61	13.21	12.28	12.32	12.30	9.44	9.72	9.08
105	9.30	9.30	9.30	6.98	7.26	7.12	4.26	4.34	4.30
135	6.22	6.40	6.31	2.36	2.54	2.45	0.72	0.34	0.53
165	3.30	3.20	3.25	0.05	0.15	0.10	0.00	0.00	0.00
195	0.02	0.04	0.03						

Table C-3.2 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 25 ppm, wastewater flow rate 90 ml/s, initial pH of wastewater was 3 and TiO_2 coating surface area were 0.234 m^2 in the rotating disc speed of 150 and 200 rpm.

Time (min)	Residual chromium (VI) concentration, (ppm)					
	Rpm 150			Rpm 200		
	1	2	Average	1	2	Average
0	25.00	25.00	25.00	25.00	25.00	25.00
15	22.00	21.98	21.99	20.34	20.30	20.32
25	20.01	19.81	19.91	18.97	19.03	19.00
35	17.86	17.78	17.82	15.22	14.84	15.03
45	15.66	15.48	15.57	13.01	13.09	13.05
60	11.60	11.64	11.62	9.77	9.87	9.82
75	7.50	7.38	7.44	5.93	6.07	6.00
105	2.76	2.84	2.80	0.07	0.07	0.07
135	0.00	0.00	0.00	0.00	0.00	0.00

Table C-4.1 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 50 ppm, wastewater flow rate 90 ml/s, rotating disc speed 200 rpm and initial pH of wastewater was 3 in the TiO_2 coating surface area of 0.1170, 0.1754 and 0.2340 m^2

Time (min)	Residual chromium (VI) concentration, (ppm)								
	0.1170 m^2			0.1754 m^2			0.2340 m^2		
	1	2	Average	1	2	Average	1	2	Average
0	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
15	49.07	49.19	49.13	49.17	49.03	49.10	47.60	47.30	47.45
25	48.32	48.42	48.37	48.15	48.03	48.09	45.15	44.99	45.07
35	47.57	47.73	47.65	47.40	47.28	47.34	44.31	44.29	44.30
45	46.39	46.89	46.64	45.88	45.76	45.82	42.59	42.87	42.73
60	45.84	46.02	45.93	44.22	44.10	44.16	41.17	41.03	41.10
75	45.34	45.62	45.48	42.87	42.75	42.81	39.76	39.88	39.82
105	43.76	43.98	43.87	40.59	40.49	40.54	36.59	36.51	36.55
135	41.83	41.85	41.84	37.10	37.44	37.27	33.94	33.62	33.78
165	40.21	40.75	40.48	34.30	34.70	34.50	30.58	30.06	30.32
195	38.28	38.54	38.41	31.58	32.10	31.84	27.39	27.45	27.42
225	36.56	37.48	37.02	29.81	30.15	29.98	24.34	24.34	24.34
255	35.54	35.54	35.54	27.50	27.74	27.62	21.31	21.49	21.40
285	33.85	34.13	33.99	25.08	25.66	25.37	17.56	17.70	17.63
315	32.88	33.18	33.03	23.30	23.66	23.48	14.31	14.73	14.52
345	31.45	31.87	31.66	20.96	21.00	20.98	10.59	11.13	10.86
375	31.06	29.66	30.36	17.50	17.66	17.58	7.57	8.21	7.89
405	29.65	28.95	29.30	15.35	15.33	15.34	2.25	4.05	3.15

Table C-4.2 Photoreduction of chromium (VI) was using RDPR in the operating condition of initial concentration 50 ppm, wastewater flow rate 90 ml/s, rotating disc speed 200 rpm and initial pH of wastewater was 3 in the TiO_2 coating surface area of 0.2630 and 0.2924 m^2.

Time (min)	Residual chromium (VI) concentration, (ppm)					
	0.2630 m^2			0.2924 m^2		
	1	2	Average	1	2	Average
0	50.00	50.00	50.00	50.00	50.00	50.00
15	49.37	48.63	49.00	49.22	49.04	49.13
25	47.30	46.58	46.94	47.87	47.17	47.52
35	46.17	45.57	45.87	47.21	46.19	46.70
45	44.84	44.14	44.49	45.49	44.43	44.96
60	43.43	42.71	43.07	43.23	42.43	42.83
75	41.92	41.04	41.48	40.48	39.52	40.00
105	38.28	37.76	38.02	36.26	35.44	35.85
135	35.00	34.46	34.73	33.01	32.03	32.52
165	31.21	30.83	31.02	29.60	28.84	29.22
195	27.02	26.58	26.80	25.90	25.24	25.57
225	22.89	22.91	22.90	20.32	19.8	20.06
255	18.60	17.98	18.29	15.22	14.84	15.03
285	15.86	15.68	15.77	11.66	11.36	11.51
315	12.33	12.23	12.28	8.84	8.62	8.73
345	7.90	7.7	7.80	5.62	5.46	5.54
375	3.79	3.47	3.63	2.05	0.95	1.50
405	0.00	0.00	0.00	0.00	0.00	0.00

Table C-5.1 Photoreduction of chromium (VI) was using RDPR in the operating condition of wastewater flow rate 90 ml/s, rotating disc speed 200 rpm, initial pH of wastewater was 3 and TiO_2 coating surface area were 0.2340 m^2 in the initial concentration of 25, 40 and 50 ppm.

Time (min)	Residual chromium (VI) concentration, (ppm)								
	25 ppm			40 ppm			50 ppm		
	1	2	Average	1	2	Average	1	2	Average
0	25.00	25.00	25.00	40.00	40.00	40.00	50.00	50.00	50.00
15	20.34	20.30	20.32	37.48	37.56	37.52	47.37	47.81	47.59
25	18.97	19.03	19.00	36.01	35.89	35.95	45.19	45.11	45.15
35	15.22	14.84	15.03	34.45	34.37	34.41	77.33	11.29	44.31
45	13.01	13.09	13.05	32.98	33.06	33.02	42.57	42.61	42.59
60	9.77	9.87	9.82	32.06	31.9	31.98	41.14	41.20	41.17
75	5.93	6.07	6.00	29.81	29.71	29.76	39.71	39.81	39.76
105	0.07	0.07	0.07	25.69	25.67	25.68	36.54	36.64	36.59
135	-	-	-	21.30	21.22	21.26	33.87	34.01	33.94
165	-	-	-	18.06	17.92	17.99	30.55	30.61	30.58
195	-	-	-	13.41	12.89	13.15	27.38	27.40	27.39
225	-	-	-	9.61	9.39	9.50	24.33	24.35	24.34
255	-	-	-	6.09	5.91	6.00	21.21	21.41	21.31
285	-	-	-	2.49	2.61	2.55	17.62	17.50	17.56
315	-	-	-	0.00	0.00	0.00	14.36	14.26	14.31
345	-	-	-	-	-	-	10.57	10.61	10.59
375	-	-	-	-	-	-	7.53	7.61	7.57
405	-	-	-	-	-	-	2.19	2.31	2.25
435	-	-	-	-	-	-	0.10	0.18	0.14

Table C-5.2 Photoreduction of chromium (VI) was using RDPR in the operating condition of wastewater flow rate 90 ml/s, rotating disc speed 200 rpm, initial pH of wastewater was 3 and TiO_2 coating surface area were 0.2340 m^2 in the initial concentration of 80, 100 and 150 ppm.

Time (min)	Residual chromium (VI) concentration, (ppm)								
	80 ppm			100 ppm			150 ppm		
	1	2	Average	1	2	Average	1	2	Average
0	80.00	80.00	80.00	100.00	100.00	100.00	150.00	150.00	150.00
15	77.01	76.31	76.66	97.43	97.71	97.57	146.71	146.63	146.67
25	75.91	75.79	75.85	95.74	95.80	95.77	144.60	144.56	144.58
35	75.10	74.12	74.61	95.2	95.32	95.26	141.32	141.18	141.25
45	73.22	73.08	73.15	94.44	94.52	94.48	140.38	140.24	140.31
60	69.67	69.65	69.66	93.43	94.01	93.72	137.15	137.11	137.13
75	66.33	66.13	66.23	89.91	90.11	90.01	132.56	132.42	132.49
105	63.08	62.98	63.03	84.65	84.89	84.77	127.81	127.79	127.80
135	58.11	57.97	58.04	78.83	78.85	78.84	121.30	120.34	120.82
165	52.23	52.21	52.22	72.6	72.88	72.74	115.82	115.40	115.61
195	46.51	46.25	46.38	68.46	70.00	69.23	109.71	109.63	109.67
225	42.92	42.08	42.50	61.53	61.63	61.58	102.36	103.02	102.69
255	38.11	38.05	38.08	57.1	57.32	57.21	93.55	93.59	93.57
285	34.67	34.47	34.57	52.85	53.13	52.99	89.32	89.18	89.25
315	30.53	30.23	30.38	49.74	49.78	49.76	83.44	83.28	83.36
345	25.77	25.67	25.72	44.09	44.25	44.17	78.28	77.92	78.10
375	21.63	21.39	21.51	37.23	37.41	37.32	70.01	69.83	69.92
405	17.29	17.21	17.25	33.13	33.15	33.14	63.09	63.21	63.15
435	13.52	13.26	13.39	26.72	26.78	26.75	55.03	54.27	54.65
465	7.85	7.71	7.78	20.87	21.09	20.98	50.32	50.86	50.59
495	3.12	3.02	3.07	14.3	14.36	14.33	45.42	45.34	45.38
525	0.00	0.00	0.00	9.84	10.10	9.97	45.19	44.73	44.96
555				3.38	3.18	3.28	44.96	44.76	44.86
585				0.03	0.07	0.05	45.10	45.04	45.07

Table C-5.3 Photoreduction of chromium (VI) was using RDPR in the operating condition of wastewater flow rate 90 ml/s, rotating disc speed 200 rpm, initial pH of wastewater was 3 and TiO_2 coating surface area was 0.2340 m^2 in the initial concentration of 250, 300 and 500 ppm.

Time (min)	Residual chromium (VI) concentration, (ppm)								
	250 ppm			300 ppm			500 ppm		
	1	2	Average	1	2	Average	1	2	Average
0	250.00	250.00	250.00	300.00	300.00	300.00	500.00	500.00	500.00
15	246.11	245.71	245.91	295.07	295.20	295.13	498.80	499.00	498.90
25	244.01	243.64	243.83	292.10	292.16	292.13	491.10	492.10	491.60
35	241.36	241.24	241.30	291.19	291.41	291.30	489.40	490.80	490.10
45	237.85	237.72	237.78	290.90	290.05	290.47	489.50	489.50	489.50
60	233.91	233.85	233.88	290.42	290.11	290.27	485.70	486.10	485.90
75	227.76	227.87	227.81	287.11	287.21	287.16	477.60	480.20	478.90
105	221.35	221.26	221.30	286.20	286.25	286.23	476.80	476.20	476.50
135	213.18	212.96	213.07	279.07	279.09	279.08	472.10	472.50	472.30
165	205.22	206.76	205.99	279.06	279.10	279.08	468.60	468.80	468.70
195	197.53	197.50	197.51	273.98	276.31	275.15	464.30	464.50	464.40
225	190.41	190.36	190.38	2207.41	2752.32	272.45	459.00	461.00	460.00
255	183.26	182.30	182.78	269.01	268.24	268.62	455.50	455.10	455.30
285	175.08	175.06	175.07	263.18	263.30	263.24	450.60	451.60	451.10
315	169.05	168.61	168.83	256.31	256.50	256.40	446.90	447.50	447.20
345	164.00	162.77	163.38	249.58	249.35	249.47	442.60	443.20	442.90
375	158.10	156.83	157.46	245.59	245.68	245.63	438.80	439.00	438.90
405	155.32	154.67	155.00	240.70	240.63	240.66	433.20	434.00	433.60
435	152.10	152.17	152.14	234.82	234.91	234.86	428.20	430.00	429.10
465	149.23	150.08	149.66	226.98	227.21	227.10	423.00	423.60	423.30
495	147.76	147.80	147.78	224.13	224.26	224.20	417.20	419.00	418.10
525	147.51	147.60	147.55	218.25	218.55	218.40	411.60	412.80	412.20
555				213.28	220.41	216.85	409.40	408.40	408.90
585				211.75	215.52	213.63	401.70	401.30	401.50
615				209.34	211.30	210.32	402.50	402.50	402.50
645				207.10	207.12	207.11	402.40	401.20	401.80
675				204.23	204.81	204.52	402.40	402.80	402.60
705				205.62	205.50	205.56	404.50	401.50	403.00

BIOGHAPHY

Miss Pattama Paksaharn was born on June 29, 1982 in Udonthani, Thailand. She received her Bachelor's degree in Environmental Engineering from faculty of Engineering, King Mongkut's University of Technology Thonburi (KMUTT) in 2004. At KMUTT, she has studied in the topic of "Heavy metal wastewater treatment using modifies egg shell" as her senior project which was publication in the topic of "Chicken's Egg Shell Technology for Pretreatment of Waste Solution from Acid Copper Electroplating Bath" in International Conference Hazardous Waste Management for a Sustainable Future, January 10-12, 2006, Bangkok, Thailand .

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