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APPENDICES

APPENDIX A

Colorimetric Method for Chromium (VI) Analysis

1. Principle

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

2. Special reagents

2.1 *Stock chromium solution*: dissolve 141.1 mg $K_2Cr_2O_7$ in double distilled water and dilute to 100 mL; 1.00 ml = 500.0 $\mu\text{g Cr}^{+6}$.

2.2 *Diphenylcarbazide solution*: dissolve 250 mg 1,5-diphenylcarbazide in 50 ml acetone. Store in a brown bottle. Discard when solution becomes discolored.

3. Procedure

a. Sample measurement

1. Transfer solution to a 100-ml.
2. Use 0.2 N H_2SO_4 and a pH meter to adjust solution to pH 1.0 ± 0.3 , diluted to 100 ml, and mixed.
- 3 Add 2.0 ml diphenylcarbazide solution, mix and allow 5 to 10 minute for full color development.
4. Transfer an appropriate portion to a 1-cm absorption cell and measure its absorbance at 540 nm. Use distilled water as a reference.
5. Correct absorbance reading of sample by subtracting absorbance of a blank carried through the method.

b) Film formation

Example : Preparation of TiO₂/chitosan film in condition 1% chitosan with 0.4%Ti (5x6 cm)

Total weight of slurry are 5 g

$$\text{Chitosan content} = 1\% = 0.05 \text{ g}$$

$$\text{Ti content} = 0.4\% = 0.02 \text{ g}$$

Used TiO₂

$$\text{M.W of Ti} = 48 \text{ g}$$

$$\text{M.W of TiO}_2 = (48)+2(16) = 80 \text{ g}$$

$$\text{Used TiO}_2 = (0.02 * 80)/48 = 0.033 \text{ g}$$

$$\begin{aligned} \text{Total weight of slurry} &= 20\% \text{acetic acid solution} + \text{g of Chitosan} + \text{g of TiO}_2 \\ &= 4.917 + 0.05 + 0.033 \text{ g} \\ &= 5 \text{ g} \end{aligned}$$

APPENDIX B

Table B-1 Adsorption of chromium (VI) using TiO₂ /chitosan film that prepared from 1% w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300
Weight of film (g)	0.0841	0.0896	0.0865	0.0898	0.0899	0.0841	0.0896	0.0865	0.0898	0.0899	0.0841	0.0898	0.0866	0.0898	0.0899
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)				
0	46.58	106.94	209.36	261.26	310.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	44.01	103.32	207.32	257.93	305.04	5.52	3.38	0.97	1.28	1.71	30.57	40.38	23.58	37.12	58.91
15	42.02	102.55	203.26	256.83	304.98	9.79	4.11	2.91	1.70	1.73	54.21	49.00	70.50	49.37	59.62
30	35.81	95.81	198.76	249.22	294.34	23.13	10.40	5.06	4.61	5.16	128.09	124.13	122.57	134.04	177.96
45	32.40	90.19	191.26	239.46	282.88	30.44	15.66	8.65	8.35	8.85	168.60	186.92	209.25	242.80	305.45
60	27.19	85.29	184.48	232.63	272.16	41.61	20.25	11.88	10.96	12.30	230.48	241.63	287.63	318.86	424.61
90	16.88	70.50	171.31	221.91	260.28	63.77	34.08	18.18	15.06	16.13	353.17	406.70	439.91	438.23	556.80
120	15.46	65.63	166.98	215.11	257.42	66.81	38.63	20.24	17.67	17.05	370.02	461.05	489.97	513.96	588.57
150	15.26	65.93	166.36	214.43	255.12	67.25	38.35	20.54	17.93	17.79	372.43	457.68	497.13	521.53	614.24

Table B-2 Adsorption of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5% w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300
Weight of film (g)	0.1181	0.1126	0.1145	0.1113	0.1164	0.1181	0.1126	0.1145	0.1113	0.1164	0.1181	0.1126	0.1145	0.1113	0.1164
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)				
0	53.60	109.09	212.92	255.82	315.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	51.21	105.04	211.76	251.10	312.85	4.46	3.71	0.54	1.84	0.89	20.26	35.95	10.13	42.39	24.22
15	47.04	102.46	206.48	247.22	306.86	12.24	6.08	3.02	3.36	2.79	55.56	58.90	56.24	77.30	75.70
30	41.69	97.00	199.70	241.96	295.73	22.23	11.09	6.21	5.42	6.32	100.89	107.41	115.46	124.50	171.35
45	35.73	90.33	193.59	230.91	284.40	33.34	17.20	9.08	9.74	9.90	151.30	166.61	168.79	223.85	268.61
60	30.67	82.83	185.18	221.83	275.40	42.78	24.07	13.03	13.29	12.76	194.19	233.18	242.27	305.45	345.93
90	20.31	70.53	167.73	209.59	260.67	62.11	35.35	21.23	18.07	17.42	281.90	342.49	394.71	415.42	472.51
120	12.21	61.84	159.10	200.36	250.49	77.22	43.31	25.28	21.68	20.65	350.47	419.61	470.01	498.33	560.00
150	12.26	61.79	158.56	200.94	250.09	77.13	43.36	25.53	21.45	20.77	350.07	420.12	474.76	493.13	563.37

Table B-3 Adsorption of chromium (VI) using TiO₂ /chitosan film that prepared from 2 % w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300
Weight of film (g)	0.1391	0.1395	0.1416	0.143	0.1386	0.1391	0.1395	0.1416	0.142	0.1406	0.1391	0.1395	0.1416	0.142	0.1406
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)				
0	49.60	116.49	200.36	262.82	311.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	48.21	114.95	199.43	258.10	302.32	2.81	1.32	0.46	1.80	2.80	10.01	11.04	6.54	32.99	62.78
15	43.04	110.62	195.24	250.22	296.50	13.23	5.04	2.55	4.80	4.67	47.17	42.08	36.14	88.14	104.76
30	35.69	100.60	186.76	243.96	288.69	28.05	13.64	6.79	7.17	7.18	100.04	113.91	96.07	131.87	161.11
45	31.73	91.65	178.79	233.91	278.60	36.02	21.32	10.77	11.00	10.42	128.46	178.06	152.33	202.20	233.90
60	26.67	84.37	165.57	226.83	265.74	46.23	27.57	17.36	13.70	14.56	164.87	230.25	245.69	251.72	326.69
90	13.31	69.71	148.18	204.59	250.63	73.17	40.16	26.04	22.16	19.42	260.91	335.35	368.49	407.24	435.70
120	7.21	59.97	136.67	193.36	239.75	85.46	48.52	31.79	26.43	22.92	304.75	405.18	449.79	485.76	514.22
150	7.06	59.91	136.91	193.14	239.07	85.77	48.57	31.67	26.51	23.13	305.85	405.58	448.08	487.31	519.14

Table B-4 Adsorption of chromium (VI) using TiO₂ /chitosan film that prepared from 2.5 % w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300
Weight of film (g)	0.1691	0.1665	0.1696	0.1686	0.1675	0.1691	0.1665	0.1696	0.1686	0.1675	0.1691	0.1665	0.1696	0.1686	0.1675
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)				
0	54.00	110.06	203.79	259.98	318.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	52.45	108.52	202.86	257.02	308.25	2.87	1.40	0.45	1.14	3.19	9.17	9.25	5.46	17.55	60.72
15	47.40	104.19	198.67	250.86	303.17	12.22	5.33	2.51	3.51	4.79	39.03	35.26	30.18	54.06	91.03
30	40.68	94.17	190.18	242.33	295.14	24.67	14.44	6.68	6.79	7.31	78.77	95.44	80.21	104.63	139.00
45	32.78	84.22	182.22	234.02	284.96	39.30	23.48	10.58	9.98	10.51	125.49	155.20	127.18	153.90	199.77
60	25.89	76.94	169.00	220.24	266.34	52.06	30.09	17.07	15.29	16.36	166.23	198.92	205.13	235.66	310.96
90	11.86	61.28	148.61	200.06	246.28	78.04	44.32	27.08	23.05	22.66	249.20	292.98	325.34	355.33	430.71
120	2.45	51.54	132.10	181.20	235.13	95.46	53.17	35.18	30.30	26.16	304.85	351.48	422.70	467.15	497.28
150	2.50	51.48	132.34	181.00	235.55	95.37	53.22	35.06	30.38	26.03	304.57	351.82	421.27	468.36	494.76

Table B-5 Adsorption of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5 % w/w chitosan with 0.2% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300
weigh of film (g)	0.1018	0.0988	0.1006	0.0999	0.1007	0.1018	0.0988	0.1006	0.0999	0.1007	0.1018	0.0988	0.1006	0.0999	0.1007
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)				
0	50.44	103.56	200.70	256.68	291.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	48.79	102.56	198.00	255.44	288.88	3.27	0.97	1.35	0.48	0.90	16.18	10.12	26.84	12.37	25.99
15	47.85	100.25	196.40	252.26	285.97	5.13	3.20	2.14	1.72	1.90	25.42	33.50	42.74	44.16	54.91
30	46.97	99.89	195.60	249.79	282.74	6.88	3.54	2.54	2.68	3.01	34.09	37.12	50.70	68.89	87.04
45	44.15	96.79	189.40	243.06	275.91	12.48	6.54	5.63	5.31	5.35	61.83	68.57	112.33	136.31	154.80
60	41.68	92.68	184.00	238.44	269.29	17.38	10.51	8.32	7.10	7.62	86.10	110.14	166.00	182.54	220.52
90	32.62	82.54	175.57	229.09	259.76	35.34	20.30	12.52	10.75	10.89	175.08	212.80	249.83	276.16	315.15
120	23.29	73.96	165.97	218.06	250.96	53.82	28.58	17.31	15.05	13.91	266.67	299.55	345.26	386.56	402.59
150	23.22	73.52	165.21	217.94	249.21	53.97	29.01	17.68	15.09	14.51	267.42	304.05	352.78	387.74	420.00

Table B-6 Adsorption of chromium (VI) using TiO₂/chitosan film that prepared from 1.5 % w/w chitosan with 0.6 % w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300
Weight of film (g)	0.131	0.1286	0.1351	0.1306	0.1285	0.131	0.1286	0.1351	0.1306	0.1285	0.131	0.1286	0.1351	0.1306	0.1285
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)				
0	49.00	103.36	205.13	251.34	298.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	48.54	102.89	203.10	245.29	293.14	0.93	0.45	0.99	2.41	1.87	3.49	3.61	15.05	46.38	43.48
15	46.49	100.43	198.50	246.03	285.97	5.13	-0.07	3.23	2.11	4.27	19.19	22.77	49.10	40.69	99.31
30	42.40	95.54	193.83	239.86	278.76	13.47	7.57	5.51	4.57	6.68	50.38	60.82	83.64	87.95	155.39
45	38.26	87.39	182.03	223.77	269.59	21.92	15.45	11.26	10.97	9.76	82.01	124.14	170.98	211.11	226.79
60	32.43	75.89	172.83	217.34	256.95	33.82	26.57	15.75	13.53	13.99	126.50	213.56	239.08	260.34	325.12
90	13.54	59.64	154.90	198.66	239.51	72.36	42.29	24.49	20.96	19.82	270.67	339.92	371.82	403.41	460.87
120	2.29	48.54	136.27	180.91	222.02	95.34	53.04	33.57	28.02	25.68	356.60	426.29	509.75	539.27	597.00
150	2.06	47.18	135.97	179.83	222.46	95.80	54.35	33.72	28.45	25.53	358.34	430.85	511.97	547.58	593.54

Table B-7 Adsorption of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5 % w/w chitosan with 0.8 % w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	200	250	300	50	100	200	250	300	50	100	200	250	300	
Weight of film (g)	0.1575	0.1545	0.1547	0.151	0.1531	0.1575	0.1545	0.1547	0.151	0.1531	0.1575	0.1545	0.1547	0.151	0.1531	
Time (min)	Residual Cr(VI) Concentrations (mg/L)					%removal					x/m (mg of Cr(VI) / g of film)					
0	49.29	104.50	214.17	253.11	302.77	0.00	00.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	47.29	101.63	213.77	250.37	292.43	4.06	2.74	0.19	1.08	3.42	12.70	18.55	2.59	18.16	67.56	
15	44.57	100.47	209.06	249.20	289.43	9.57	3.86	2.39	1.55	4.41	29.93	26.11	33.06	25.92	87.15	
30	40.11	89.80	198.63	235.46	279.46	18.61	14.07	7.26	6.98	7.70	58.23	95.15	100.47	116.93	152.28	
45	31.91	78.60	183.14	223.34	264.91	35.25	24.78	14.49	11.76	12.50	110.29	167.64	200.57	197.16	247.27	
60	27.40	68.53	174.03	206.97	244.29	44.41	34.42	18.74	18.23	19.32	138.96	232.79	259.49	305.58	382.01	
90	11.29	46.77	150.31	186.06	225.03	77.10	55.25	29.82	26.49	25.68	241.27	373.68	412.78	444.09	507.79	
120	1.49	37.90	132.09	169.06	205.31	96.99	63.73	38.33	33.21	32.19	303.49	431.07	530.61	556.67	636.56	
150	0	37.57	131.06	168.69	204.03	100	64.05	38.81	33.36	32.61	311.66	433.23	537.26	559.13	644.96	

Table B-8 Adsorption of 100 mg/L chromium (VI) using varied amount of TiO₂ powder without chitosan content

Ti content	0.2%	0.4%	0.6%	0.8%	0.2%	0.4%	0.6%	0.8%	0.2%	0.4%	0.6%	0.8%
Initial Concentrations (mg/L)	100	100	100	100	100	100	100	100	100	100	100	100
Weight of TiO ₂ (g)	0.016	0.032	0.048	0.064	0.016	0.032	0.048	0.064	0.016	0.032	0.048	0.064
Time (min)	Residual Cr(VI) Concentrations (mg/L)				%removal				x/m (mg of Cr(VI) / g of TiO ₂)			
0	102.98	109.41	105.65	101.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	102.87	109.30	105.12	100.81	0.11	0.10	0.50	0.64	6.87	3.41	11.02	10.08
15	102.74	109.21	105.01	100.60	0.23	0.18	0.60	0.84	14.81	6.31	13.31	13.30
30	102.67	108.49	104.19	99.04	0.31	0.84	1.38	2.37	19.69	28.81	30.48	37.61
45	102.65	108.46	104.07	99.02	0.33	0.87	1.49	2.39	20.94	29.66	32.88	37.92
60	102.63	108.38	104.02	98.91	0.34	0.94	1.54	2.51	21.69	32.28	33.90	39.74
90	102.60	108.39	104.03	98.89	0.37	0.93	1.53	2.53	24.00	31.94	33.75	40.05
120	102.60	108.50	104.12	99.00	0.37	0.83	1.45	2.42	23.50	28.53	31.85	38.33
150	102.64	108.49	104.17	99.04	0.33	0.84	1.40	2.38	21.25	28.72	30.83	37.72

Table B-9 Adsorption of 100 mg/L chromium (VI) using chitosan film that prepared from 1, 1.5, 2 and 2.5 % w/w chitosan without Ti content

Chitosan content	1%	1.50%	2%	2.50%	1%	1.50%	2%	2.50%	1%	1.50%	2%	2.50%
Initial Concentrations (mg/L)	100	100	100	100	100	100	100	100	100	100	100	100
weight of film (g)	0.0576	0.0806	0.1145	0.1366	0.0576	0.0806	0.1145	0.1366	0.0576	0.0806	0.1145	0.1366
Time (min)	Residual Cr(VI) Concentrations (mg/L)				%removal				x/m (mg of Cr(VI) / g of film)			
0	102.98	109.09	105.65	101.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	101.34	108.04	104.76	101.10	1.59	0.96	0.84	0.34	28.47	13.00	7.77	2.54
15	100.89	106.46	101.48	97.22	2.03	2.41	3.95	4.17	36.28	32.66	36.42	30.98
30	96.56	101.00	99.70	95.96	6.23	7.42	5.63	5.41	111.46	100.42	51.97	40.16
45	94.73	98.33	93.59	88.91	8.01	9.86	11.41	12.36	143.16	133.50	105.29	91.82
60	92.67	95.83	90.18	85.83	10.01	12.15	14.64	15.40	179.01	164.47	135.11	114.39
90	89.31	92.53	83.73	78.59	13.27	15.18	20.75	22.54	237.33	205.51	191.48	167.38
120	87.21	88.84	77.90	70.36	15.31	18.56	26.26	30.65	273.75	251.22	242.32	227.62
150	87.50	88.76	77.60	69.94	15.03	18.64	26.55	31.06	268.75	252.23	244.98	230.70

Table B-10 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 1% w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	46.58	106.94	148.94	210.97	261.26	310.34	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	15.26	65.93	102.78	162.36	209.43	257.12	67.25	38.35	30.99	23.04	19.84	17.15
5	11.99	60.48	100.63	159.90	206.94	254.19	74.26	43.44	32.43	24.21	20.79	18.09
10	9.45	57.99	99.98	156.90	205.06	243.76	79.71	45.77	32.87	25.63	21.51	21.45
15	1.79	53.26	99.51	149.34	193.81	237.65	96.17	50.19	33.19	29.21	25.82	23.42
30	0.12	46.33	85.33	144.41	183.77	221.22	99.74	56.68	42.71	31.55	29.66	28.72
45	0.00	40.37	83.49	132.50	169.56	216.10	100.00	62.25	43.94	37.20	35.10	30.37
60	0.00	32.90	72.88	124.70	158.40	205.79	100.00	69.23	51.07	40.89	39.37	33.69
90	0.00	22.57	55.02	111.19	151.48	194.64	100.00	78.90	63.06	47.30	42.02	37.28
120	0.00	9.92	45.20	105.75	145.63	190.49	100.00	90.72	69.65	49.88	44.26	38.62
150	0.00	4.61	37.24	98.88	140.45	182.93	100.00	95.69	74.99	53.13	46.24	41.05
180	0.00	1.30	32.63	95.18	135.32	179.11	100.00	98.78	78.09	54.88	48.21	42.29

Table B-11 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5% w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	51.60	109.09	147.80	212.92	255.82	315.67	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	12.26	61.79	102.63	158.56	200.94	255.09	76.24	43.36	30.56	25.53	21.45	19.19
5	6.69	60.88	101.35	157.66	198.32	253.02	87.04	44.19	31.43	25.95	22.48	19.85
10	1.34	57.58	100.65	155.44	195.46	236.45	97.40	47.22	31.90	27.00	23.59	25.09
15	0.00	50.86	95.92	151.15	191.86	230.28	100.00	53.38	35.10	29.01	25.00	27.05
30	0.00	46.27	87.08	141.01	185.69	218.71	100.00	57.59	41.08	33.77	27.41	30.71
45	0.00	36.61	71.84	126.76	167.64	212.33	100.00	66.44	51.39	40.46	34.47	32.74
60	0.00	22.53	63.59	116.52	155.26	204.14	100.00	79.35	56.97	45.28	39.31	35.33
90	0.00	11.30	52.51	105.44	142.40	185.54	100.00	89.64	64.47	50.48	44.34	41.22
120	0.00	5.64	39.31	93.23	132.18	179.77	100.00	94.83	73.41	56.21	48.33	43.05
150	0.00	0.90	34.78	88.70	127.26	170.66	100.00	99.17	76.47	58.34	50.25	45.94
180	0.00	0.00	29.67	83.60	120.12	169.52	100.00	100.00	79.92	60.74	53.05	46.30

Table B-12 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 2 % w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	49.60	116.49	153.71	200.36	262.82	311.02	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	7.06	59.91	102.61	133.91	193.14	233.07	85.77	48.57	33.24	33.16	26.51	25.06
5	3.01	55.41	97.33	129.01	186.52	227.00	93.94	52.43	36.68	35.61	29.03	27.02
10	0.30	52.89	96.63	126.79	183.66	210.43	99.40	54.60	37.13	36.72	30.12	32.34
15	0.00	47.99	91.90	122.50	180.06	204.26	100.00	58.80	40.22	38.86	31.49	34.33
30	0.00	36.13	83.06	112.36	167.89	192.69	100.00	68.98	45.96	43.92	36.12	38.05
45	0.00	25.69	67.82	98.12	155.84	186.30	100.00	77.94	55.88	51.03	40.70	40.10
60	0.00	18.79	59.57	87.87	143.46	178.11	100.00	83.87	61.25	56.14	45.41	42.73
90	0.00	5.77	48.49	76.79	130.60	159.51	100.00	95.04	68.45	61.67	50.31	48.71
120	0.00	0.50	35.29	64.59	120.38	153.74	100.00	99.57	77.04	67.77	54.20	50.57
150	0.00	0.00	30.76	60.05	115.46	144.64	100.00	100.00	79.99	70.03	56.07	53.50
180	0.00	0.00	25.65	54.95	108.32	143.49	100.00	100.00	83.31	72.57	58.79	53.86

Table B-13 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 2.5 % w/w chitosan with 0.4% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	55.00	110.06	156.47	203.79	258.54	314.25	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	3.90	51.48	97.94	133.34	187.00	231.55	92.91	53.22	37.41	34.57	27.67	26.32
5	0.70	48.87	95.65	131.44	183.38	228.48	98.73	55.60	38.87	35.50	29.07	27.29
10	0.00	45.88	93.96	128.21	179.52	210.91	100.00	58.32	39.95	37.08	30.56	32.88
15	0.00	39.85	87.22	121.92	173.92	202.74	100.00	63.79	44.25	40.17	32.73	35.48
30	0.00	30.86	75.39	108.79	164.75	188.17	100.00	71.96	51.82	46.62	36.28	40.12
45	0.00	20.68	58.14	92.54	144.70	179.78	100.00	81.21	62.84	54.59	44.03	42.79
60	0.00	13.40	49.90	82.30	132.32	171.60	100.00	87.82	68.11	59.62	48.82	45.39
90	0.00	3.62	38.82	71.21	119.46	152.99	100.00	96.71	75.19	65.05	53.80	51.31
120	0.00	0.00	25.61	59.01	109.24	147.23	100.00	100.00	83.63	71.04	57.75	53.15
150	0.00	0.00	21.08	54.48	104.32	138.12	100.00	100.00	86.53	73.27	59.65	56.05
180	0.00	0.00	15.98	49.38	97.18	136.98	100.00	100.00	89.79	75.77	62.41	56.41

Table B-14 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5 % w/w chitosan with 0.2% w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	50.44	103.56	152.88	200.70	256.68	291.50	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	23.22	73.52	118.78	165.21	217.94	249.21	53.97	29.01	22.31	17.68	15.09	14.51
5	21.37	70.72	116.63	164.70	215.13	247.48	57.63	31.71	23.71	17.94	16.19	15.10
10	21.08	68.14	110.98	160.50	210.35	240.84	58.21	34.21	27.41	20.03	18.05	17.38
15	20.39	61.89	109.51	153.80	203.57	230.34	59.59	40.24	28.37	23.37	20.69	20.98
30	13.87	53.71	95.33	146.48	192.97	223.96	72.50	48.14	37.65	27.02	24.82	23.17
45	7.96	42.71	83.49	133.45	184.12	212.37	84.22	58.76	45.39	33.51	28.27	27.15
60	4.29	35.23	73.88	122.69	173.45	204.52	91.50	65.98	51.68	38.87	32.42	29.84
90	0.00	27.66	62.02	109.07	160.43	188.85	100.00	73.29	59.43	45.65	37.50	35.22
120	0.00	24.69	55.20	100.69	148.80	181.83	100.00	76.15	63.89	49.83	42.03	37.62
150	0.00	22.13	50.24	97.37	147.67	175.20	100.00	78.63	67.13	51.48	42.47	39.90
180	0.00	20.08	49.63	95.02	144.39	173.77	100.00	80.61	67.53	52.65	43.75	40.39

Table B-15 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5 % w/w chitosan with 0.6 % w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	53.00	103.36	151.71	205.13	251.34	298.73	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	5.06	49.18	94.61	135.97	179.51	222.46	90.46	52.42	37.64	33.72	28.58	25.53
5	0.86	49.14	93.46	132.70	176.77	219.06	98.37	52.45	38.40	35.31	29.67	26.67
10	0.00	43.52	92.10	127.22	173.66	214.06	100.00	57.89	39.29	37.98	30.91	28.34
15	0.00	39.80	90.08	124.03	170.03	212.76	100.00	61.49	40.62	39.54	32.35	28.78
30	0.00	30.68	78.69	121.09	163.69	210.16	100.00	70.31	48.13	40.97	34.88	29.65
45	0.00	22.18	68.80	112.68	157.80	192.66	100.00	78.54	54.65	45.07	37.22	35.51
60	0.00	13.12	57.24	104.36	148.34	186.63	100.00	87.30	62.27	49.12	40.98	37.53
90	0.00	4.18	37.24	80.00	122.20	160.83	100.00	95.96	75.45	61.00	51.38	46.16
120	0.00	0.00	25.24	66.36	103.97	143.59	100.00	100.00	83.36	67.65	58.63	51.93
150	0.00	0.00	18.22	54.21	92.31	131.63	100.00	100.00	87.99	73.58	63.27	55.94
180	0.00	0.00	15.02	49.21	89.31	129.63	100.00	100.00	90.10	76.01	64.47	56.61

Table B-16 Photocatalytic reduction of chromium (VI) using TiO₂ /chitosan film that prepared from 1.5 % w/w chitosan with 0.8 % w/w Ti and dissolved in 20% acetic acid solution

Initial Concentrations (mg/L)	50	100	150	200	250	300	50	100	150	200	250	300
Time (min)	Residual Cr(VI) Concentrations (mg/L)						%removal					
ADS 0	49.29	104.50	154.47	214.17	253.11	302.77	0.00	0.00	0.00	0.00	0.00	0.00
IRR 0	0.00	37.57	87.94	136.06	169.69	211.03	100.00	64.05	43.07	36.47	32.96	30.30
5	0.00	33.77	86.04	134.36	163.58	209.52	100.00	67.69	44.30	37.27	35.37	30.80
10	0.00	28.27	82.67	129.70	161.83	206.04	100.00	72.95	46.48	39.44	36.07	31.95
15	0.00	22.87	79.35	131.79	158.10	204.74	100.00	78.12	48.63	38.46	37.54	32.38
30	0.00	15.13	70.49	120.00	149.20	194.69	100.00	85.52	54.37	43.97	41.05	35.70
45	0.00	8.70	56.78	112.77	140.20	183.97	100.00	91.67	63.24	47.34	44.61	39.24
60	0.00	3.50	45.51	98.53	130.34	171.64	100.00	96.65	70.54	54.00	48.50	43.31
90	0.00	0.00	29.37	75.73	105.92	148.27	100.00	100.00	80.99	64.64	58.15	51.03
120	0.00	0.00	17.92	57.44	90.11	125.28	100.00	100.00	88.40	73.18	64.40	58.62
150	0.00	0.00	10.10	46.12	77.96	115.01	100.00	100.00	93.46	78.47	69.20	62.01
180	0.00	0.00	4.10	43.40	71.77	109.47	100.00	100.00	97.34	79.74	71.65	63.84

Table B-17 Photocatalytic reduction of 100 mg/L chromium (VI) using varied amount of TiO₂ powder without chitosan content

Ti content	0.2%	0.4%	0.6%	0.8%	0.2%	0.4%	0.6%	0.8%
Initial Concentrations (mg/L)	100	100	100	100	100	100	100	100
Time (min)	Residual Cr(VI) Concentrations (mg/L)				%removal			
ADS 0	102.98	109.41	105.65	101.45	0.00	0.00	0.00	0.00
IRR 0	102.64	108.49	104.17	99.04	0.33	0.84	1.40	2.38
5	102.55	108.32	104.79	98.91	0.42	1.00	0.81	2.50
10	102.77	108.24	104.28	98.56	0.21	1.07	1.30	2.85
15	102.53	108.10	103.60	97.95	0.43	1.20	1.94	3.45
30	101.46	107.76	102.22	96.90	1.47	1.51	3.24	4.48
45	101.34	106.81	101.76	95.50	1.60	2.37	3.68	5.87
60	102.08	106.73	100.81	94.69	0.88	2.44	4.58	6.66
90	101.34	105.48	98.70	92.85	1.60	3.59	6.57	8.48
120	101.18	104.96	97.60	91.25	1.75	4.06	7.62	10.06
150	100.72	104.15	96.33	90.04	2.20	4.81	8.82	11.25
180	100.66	103.85	96.13	88.74	2.25	5.08	9.01	12.53

Table B-18 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO_2 /chitosan film that prepared from 1.%chitosan,0.4% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min^{-1})	R^2	
50	0.5844	0.8361	0.1462	0.9143	100.00
100	0.4237	0.9319	0.0155	0.9527	98.78
150	0.4440	0.9076	0.0065	0.9888	78.09
200	0.4383	0.9506	0.0034	0.9613	54.88
250	0.504	0.8252	0.0029	0.8768	48.21
300	0.5367	0.7737	0.0024	0.8340	42.29

Table B-19 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO_2 /chitosan film that prepared from 1.5% chitosan,0.4% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min^{-1})	R^2	
50	0.9169	0.9334	0.2012	0.9434	100.00
100	0.4252	0.8951	0.0183	0.9598	100.00
150	0.4716	0.9416	0.0073	0.9892	79.92
200	0.4891	0.9321	0.0040	0.9685	60.74
250	0.5223	0.9304	0.0032	0.9610	53.05
300	0.5934	0.7956	0.0028	0.8621	46.30

Table B-20 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO_2 /chitosan film that prepared from 2 %chitosan,0.4% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min^{-1})	R^2	
50	0.5536	0.8536	0.2868	0.9212	100
100	0.5805	0.9344	0.0226	0.9507	100
150	0.5051	0.9193	0.0081	0.9913	83.31
200	0.5226	0.9076	0.0055	0.9711	72.57
250	0.5579	0.8968	0.0036	0.9488	58.78
300	0.6269	0.7399	0.0033	0.8351	53.86

Table B-21 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO_2 /chitosan film that prepared from 2.5%chitosan, 0.4% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min^{-1})	R^2	
50	-	-	-	-	100
100	0.4384	0.8377	0.0255	0.9436	100
150	0.544	0.9053	0.0104	0.9937	89.78
200	0.5615	0.8943	0.0062	0.9666	75.76
250	0.5947	0.8958	0.0041	0.9477	62.41
300	0.6658	0.7487	0.0036	0.8421	56.42

Table B-22 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO₂ /chitosan film that prepared from 1.5%chitosan, 0.2% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min ⁻¹)	R^2	
50	0.2849	0.9666	0.0245	0.9879	100.00
100	0.3778	0.7831	0.0085	0.9222	80.61
150	0.4826	0.8576	0.0058	0.9348	67.53
200	0.479	0.8944	0.0037	0.9352	52.65
250	0.5043	0.8724	0.0028	0.9128	43.75
300	0.5182	0.8619	0.0017	0.9400	40.39

Table B-23 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO₂ /chitosan film that prepared from 1.5 % chitosan, 0.6% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min ⁻¹)	R^2	
50	-	-	-	-	100.00
100	0.3597	0.7915	0.0237	0.9415	100.00
150	0.5132	0.9588	0.0103	0.9823	90.10
200	0.5333	0.9798	0.0058	0.9862	76.01
250	0.5586	0.9787	0.0041	0.98	64.47
300	0.5868	0.9718	0.0033	0.9804	56.61

Table B-24 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO₂ /chitosan film that prepared from 1.5%chitosan, 0.8% Ti with 20% acetic acid solution.

Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
	k_{obs} (mg/L-min)	R^2	k_{obs} (min ⁻¹)	R^2	
50	-	-	-	-	100.00
100	0.5162	0.8299	0.0358	0.9745	100.00
150	0.5352	0.9549	0.0146	0.9587	97.34
200	0.5808	0.9753	0.0066	0.9779	79.74
250	0.6082	0.9777	0.005	0.9931	71.65
300	0.627	0.9805	0.0039	0.9843	63.84

Table B-25 Values of k_{obs} from zero and pseudo-first order equation for photocatalytic process using TiO₂ powder

Ti content (%)	Initial concentrations of chromium(VI) (mg/L)	zero order		pseudo-first order		% Removal
		k_{obs} (mg/L-min)	R^2	k_{obs} (min ⁻¹)	R^2	
0.2	100	0.0001	0.8412	0.0001	0.8538	2.20
0.4	100	0.0003	0.9793	0.0003	0.9807	4.81
0.6	100	0.0005	0.9545	0.0005	0.9673	8.82
0.8	100	0.0006	0.9727	0.0007	0.9869	11.25

Table B-27 Mechanical properties of TiO₂/chitosan film (0.8%Ti, 1.5% chitosan) after UV illumination in distilled water

Time (Hour)	Film number	Force (N)	Distance (mm)	Stress (kg/mm ²)	Elongation at brake (%)	Stress (N/mm ²)
0	Wet flim1	1.607	-23.635	0.094	47.270	0.919
	Wet flim2	1.591	-20.004	0.093	40.008	0.909
	Average	1.599	-21.820	0.093	43.639	0.914
1	Wet flim1	1.511	-22.012	0.088	44.024	0.863
	Wet flim2	1.592	-20.142	0.093	40.284	0.910
	Average	1.552	-21.077	0.090	42.154	0.887
2	Wet flim1	1.525	-17.378	0.089	34.756	0.871
	Wet flim2	1.565	-18.256	0.091	36.512	0.894
	Average	1.545	-17.817	0.090	35.634	0.883
4	Wet flim1	1.520	-13.248	0.089	26.496	0.869
	Wet flim2	1.314	-15.586	0.077	31.172	0.751
	Average	1.417	-14.417	0.083	28.834	0.810
6	Wet flim1	1.212	-9.025	0.071	18.050	0.693
	Wet flim2	1.378	-8.954	0.080	17.908	0.787
	Average	1.295	-8.990	0.075	17.979	0.740
8	Wet flim1	1.191	-7.200	0.069	14.400	0.681
	Wet flim2	1.214	-6.587	0.071	13.174	0.694
	Average	1.203	-6.894	0.070	13.787	0.687
10	Wet flim1	0.993	-6.210	0.058	12.420	0.567
	Wet flim2	1.015	-5.242	0.059	10.482	0.580
	Average	1.004	-5.726	0.059	11.451	0.574
12	Wet flim1	0.827	-2.210	0.048	4.420	0.473
	Wet flim2	0.759	-3.398	0.044	6.796	0.434
	Average	0.793	-2.804	0.046	5.608	0.453

Table B-28 Mechanical properties of TiO₂/chitosan film (0.8%Ti, 1.5% chitosan) after UV illumination in 100 mg/L chromium(VI) solution

Time (Hour)	Film number	Force (N)	Distance (mm)	Stress (kg/mm ²)	Elongation at brake (%)	Stress (N/mm ²)
1	Wet flim1	1.429	-20.416	0.083	40.832	0.817
	Wet flim2	1.422	-20.142	0.083	40.284	0.813
	Average	3.726	-20.279	0.083	40.558	0.815
2	Wet flim1	1.325	-16.378	0.077	32.756	0.757
	Wet flim2	1.265	-14.256	0.074	28.512	0.723
	Average	1.295	-15.317	0.075	30.634	0.740
4	Wet flim1	1.175	-8.311	0.068	16.622	0.671
	Wet flim2	1.104	-9.021	0.064	18.042	0.631
	Average	1.140	-8.666	0.066	17.332	0.651
6	Wet flim1	0.952	-6.895	0.055	13.790	0.544
	Wet flim2	0.875	-5.954	0.051	11.908	0.500
	Average	0.914	-6.425	0.053	12.849	0.522
8	Wet flim1	0.806	-5.336	0.047	10.672	0.461
	Wet flim2	0.864	-4.587	0.050	9.174	0.494
	Average	0.835	-4.962	0.049	9.923	0.477
10	Wet flim1	0.803	2.210	0.047	4.420	0.459
	Wet flim2	0.601	-2.487	0.035	4.974	0.344
	Average	0.702	-0.139	0.041	4.697	0.401
12	Wet flim1	N/D	N/D	N/D	N/D	N/D
	Wet flim2	N/D	N/D	N/D	N/D	N/D
	Average	N/D	N/D	N/D	N/D	N/D

Table B-28 Mechanical properties of chitosan film (0%Ti, 1.5% chitosan) after UV illumination in distilled water

Time (Hour)	Film number	Force (N)	Distance (mm)	Stress (kg/mm ²)	Elongation at brake (%)	Stress (N/mm ²)
0	Wet flim1	3.299	-32.792	0.448	65.584	4.399
	Wet flim2	2.892	-28.561	0.393	57.122	3.856
	Average	3.096	-30.677	0.420	61.353	4.127
1	Wet flim1	2.245	-29.839	0.305	59.678	2.993
	Wet flim2	2.356	-27.546	0.320	55.092	3.141
	Average	2.301	-28.693	0.312	57.385	3.067
2	Wet flim1	2.045	-24.525	0.278	49.050	2.727
	Wet flim2	1.985	-22.568	0.270	45.136	2.646
	Average	2.015	-23.547	0.274	47.093	2.686
4	Wet flim1	1.778	-19.760	0.241	39.520	2.371
	Wet flim2	1.595	-18.145	0.217	36.290	2.127
	Average	1.687	-18.953	0.229	37.905	2.249
6	Wet flim1	1.266	-12.546	0.172	25.092	1.688
	Wet flim2	1.456	-11.546	0.198	23.092	1.941
	Average	1.361	-12.046	0.185	24.092	1.815
8	Wet flim1	1.101	-9.440	0.150	18.880	1.468
	Wet flim2	1.358	-8.236	0.184	16.471	1.811
	Average	1.230	-8.838	0.167	17.676	1.639
10	Wet flim1	0.985	-8.245	0.134	16.490	1.313
	Wet flim2	0.756	-6.235	0.103	12.470	1.008
	Average	0.871	-7.240	0.118	14.480	1.161
12	Wet flim1	0.757	-3.421	0.103	6.842	1.009
	Wet flim2	0.863	-5.570	0.117	11.140	1.151
	Average	0.810	-4.496	0.110	8.991	1.080

Table B-29 Mechanical properties of chitosan film (0%Ti, 1.5% chitosan) after UV illumination in 100 mg/L chromium(VI) solution

Time (Hour)	Film number	Force (N)	Distance (mm)	Stress (kg/mm ²)	Elongation at brake (%)	Stress (N/mm ²)
1	Wet flim1	2.059	-27.250	0.280	54.500	2.745
	Wet flim2	1.924	-26.532	0.261	53.064	2.565
	Average	1.992	-26.891	0.270	53.782	2.655
2	Wet flim1	1.425	-22.235	0.194	44.470	1.900
	Wet flim2	1.722	-23.254	0.234	46.508	2.296
	Average	1.574	-22.745	0.214	45.489	2.098
4	Wet flim1	1.133	-16.560	0.154	33.120	1.511
	Wet flim2	1.236	-15.564	0.168	31.128	1.648
	Average	1.184	-16.062	0.161	32.124	1.579
6	Wet flim1	0.813	-10.255	0.110	20.510	1.083
	Wet flim2	0.985	-9.255	0.134	18.509	1.313
	Average	0.899	-9.755	0.122	19.510	1.198
8	Wet flim1	0.785	-7.589	0.107	15.178	1.047
	Wet flim2	0.812	-6.653	0.110	13.306	1.083
	Average	0.799	-7.121	0.108	14.242	1.065
10	Wet flim1	0.585	-5.568	0.079	11.136	0.780
	Wet flim2	0.653	-4.254	0.089	8.508	0.871
	Average	0.619	-4.911	0.084	9.822	0.825
12	Wet flim1	0.485	-3.542	0.066	7.084	0.647
	Wet flim2	0.530	-2.256	0.072	4.512	0.707
	Average	0.508	-2.899	0.069	5.798	0.677

BIOGRAPHY

Miss Piyaporn Kumket was born on January 1st, 1982 in Nakhonphanom, Thailand. She received her Bachelor's Degree in Environmental Engineering department from King Mongkut's University of Technology Thonburi (KMUTT) in 2005. After that, she pursued her Master's Degree studies in International Postgraduate Program in Environmental Management (Hazardous Waste Management). Inter-Department of Environmental Management Chulalongkorn University, Bangkok, Thailand on May 2005.