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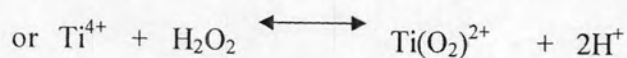
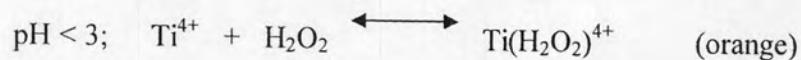
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APPENDICES

APPENDIX A

SPECTROPHOTOMETRIC DETERMINATION OF
HYDROGEN PEROXIDE**Principle**

Titanium (IV) gives the well-known orange coloration by the action of hydrogen peroxide on an acidified solution (Mori et al., 1956). The production of color is due to the reactions:

**Reagents**

Titanium oxalate reagent is prepared by adding 35.4 g of $\text{K}_2\text{TiO}(\text{C}_2\text{O}_4)_2 \cdot 2\text{H}_2\text{O}$ into the solution of 300 mL of DI water and 27.2 mL H_2SO_4 (conç.) in 1 L volumetric flask. After the chemical dissolves, adjust volume to 1 L.

Procedure

1. Add 5 mL of titanium oxalate reagent into 25 mL volumetric flask.
2. Transfer 1 mL of sample to 25 mL Erlenmeyer flask.
3. Adjust the volume to 25 mL, and wait 15 minutes for the stable coloration.
4. The absorbance of sample will be measured by the the Spectronic™ GENESYS™ 20 spectrophotometer at 400 nm.

APPENDIX B

Table B-1 *O*-toluidine remaining of control experiments

Time (min)	<i>O</i> -toluidine Remaining					
	Free Fenton's Reagent		1 mM of Fe ²⁺		17 mM of H ₂ O ₂	
	mM	C/C ₀	mM	C/C ₀	mM	C/C ₀
0	1.132	1	0.938	1	1.129	1
2	1.093	0.966	0.908	0.968	1.068	0.946
5	1.072	0.947	0.917	0.978	1.076	0.953
10	1.064	0.940	0.915	0.976	1.054	0.933
20	1.072	0.947	0.912	0.97	1.058	0.937
40	1.067	0.943	0.907	0.967	1.065	0.943
60	1.077	0.952	0.911	0.971	1.056	0.935
80	1.061	0.937	0.908	0.98	1.047	0.927
100	1.072	0.947	0.914	0.974	1.052	0.931

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-2 Chemicals remaining for Run#1 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.982	1.139	0.792	-	0.981
2	0.980	1.109	0.833	0.711	0.947
5	0.978	1.079	0.792	0.728	0.931
10	0.974	1.178	0.792	0.694	0.926
20	0.971	1.119	0.792	0.711	0.918
30	0.970	1.188	0.708	0.711	0.889
60	0.969	1.228	0.708	0.694	0.856
90	0.953	1.178	0.750	0.711	0.856
120	0.932	1.109	0.708	0.694	0.769

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 1 mM of H₂O₂, 50 g of SiO₂, pH 2

Table B-3 Chemicals remaining for Run#2 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.933	1.114	0.960	-	0.945
2	0.926	1.091	1	0.787	0.940
5	0.870	1.079	1	0.635	0.938
10	0.869	1.178	0.920	0.635	0.924
20	0.870	1.188	0.960	0.609	0.919
30	0.860	1.181	0.880	0.660	0.856
60	0.822	1.223	0.880	0.584	0.820
90	0.803	1.172	0.840	0.559	0.773
120	0.776	1.011	0.800	0.533	0.726

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 1 mM of H₂O₂, 300 g of SiO₂, pH 4

Table B-4 Chemicals remaining for Run#3 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.951	1.126	0.423	-	0.010
2	0.956	0.718	0.231	0.897	0.005
5	0.956	0.913	0.154	0.728	0.005
10	0.934	1.136	0.115	0.711	0.002
20	0.916	1.136	0.115	0.728	0
30	0.900	1.029	0.115	0.711	0
60	0.873	1.029	0.115	0.728	0
90	0.872	1.175	0.115	0.728	0
120	0.851	1	0.115	0.728	0

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 1 mM of H₂O₂, 50 g of SiO₂, pH 4

Table B-5 Chemicals remaining for Run#4 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.940	1.007	0.261	-	0.216
2	0.925	0.949	0.130	0.889	0
5	0.914	1.029	0.087	0.939	0
10	0.907	0.971	0.087	0.889	0
20	0.915	1.029	0.130	0.914	0
30	0.896	1.037	0.087	0.939	0
60	0.876	1.022	0.087	0.939	0
90	0.853	1.059	0.087	0.914	0
120	0.838	1.022	0.087	0.914	0

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 1 mM of H₂O₂, 300 g of SiO₂, pH 4

Table B-6 Chemicals remaining for Run#5 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.749	1	0.838	-	0.992
2	0.811	0.904	0.500	0.660	0.991
5	0.712	1.022	0.417	0.381	0.990
10	0.692	1	0.396	0.355	0.988
20	0.687	1.074	0.383	0.381	0.979
30	0.672	0.912	0.363	0.381	0.973
60	0.670	0.912	0.350	0.305	0.968
90	0.661	0.912	0.346	0.305	0.968
120	0.652	0.779	0.346	0.305	0.967

Note: 1 mM of OT, 1 mM of Fe²⁺, 1 mM of H₂O₂, 50 g of SiO₂, pH 2

Table B-7 Chemicals remaining for Run#6 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.787	0.836	0.672	-	0.998
2	0.827	0.921	0.504	0.609	0.996
5	0.768	0.921	0.471	0.432	0.990
10	0.716	0.849	0.483	0.381	0.987
20	0.704	0.724	0.492	0.355	0.983
30	0.694	0.789	0.471	0.330	0.981
60	0.700	0.789	0.483	0.330	0.981
90	0.680	0.822	0.475	0.355	0.974
120	0.656	0.796	0.500	0.355	0.975

Note: 1 mM of OT, 1 mM of Fe²⁺, 1 mM of H₂O₂, 300 g of SiO₂, pH 2

Table B-8 Chemicals remaining for Run#7 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.848	0.670	0.319	-	0.958
2	0.681	0.745	0.307	0.218	0.915
5	0.667	0.585	0.155	0.218	0.863
10	0.657	0.543	0.046	0.245	0.820
20	0.639	0.894	0.038	0.272	0.807
30	0.644	0.713	0.038	0.245	0.795
60	0.642	0.745	0.050	0.272	0.760
90	0.621	0.691	0.059	0.299	0.746
120	0.624	0.883	0.071	0.299	0.744

Note: 1 mM of OT, 1 mM of Fe²⁺, 1 mM of H₂O₂, 50 g of SiO₂, pH 4

Table B-9 Chemicals remaining for Run#8 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.701	0.875	0.390	-	0.879
2	0.723	0.875	0.278	0.246	0.821
5	0.686	0.830	0.193	0.301	0.722
10	0.654	0.875	0.049	0.274	0.608
20	0.607	0.830	0.063	0.219	0.580
30	0.612	0.839	0.027	0.164	0.513
60	0.616	0.866	0.027	0.192	0.477
90	0.598	0.821	0.040	0.192	0.418
120	0.560	0.812	0.049	0.164	0.402

Note: 1 mM of OT, 1 mM of Fe²⁺, 1 mM of H₂O₂, 300 g of SiO₂, pH 4

Table B-10 Chemicals remaining for Run#9 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.840	0.940	0.917	-	0.970
2	0.840	0.960	0.875	0.934	0.958
5	0.836	0.990	0.792	0.918	0.901
10	0.836	0.900	0.833	0.928	0.890
20	0.835	0.950	0.833	0.947	0.898
30	0.832	0.960	0.750	0.944	0.886
60	0.834	0.940	0.792	0.941	0.881
90	0.813	0.910	0.750	0.947	0.864
120	0.809	0.960	0.792	0.947	0.865

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 17 mM of H₂O₂, 50 g of SiO₂, pH 2

Table B-11 Chemicals remaining for Run#10 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.875	0.922	0.875	-	0.952
2	0.875	0.862	0.875	0.906	0.947
5	0.859	0.871	0.792	0.952	0.946
10	0.857	0.865	0.792	0.967	0.926
20	0.857	0.845	0.792	0.944	0.888
30	0.868	0.793	0.833	0.966	0.906
60	0.848	0.879	0.750	0.943	0.861
90	0.852	0.853	0.750	0.943	0.816
120	0.8011	0.922	0.750	0.941	0.791

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 17 mM of H₂O₂, 3000 g of SiO₂, pH 2

Table B-12 Chemicals remaining for Run#11 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.930	0.957	0.333	-	0.881
2	0.916	0.966	0.250	0.985	0.969
5	0.896	0.931	0.125	0.915	0.765
10	0.869	0.853	0.083	0.947	0.605
20	0.880	0.914	0.125	0.934	0.216
30	0.860	0.983	0.083	0.920	0.146
60	0.813	0.974	0.083	0.922	0
90	0.847	0.879	0.042	0.932	0
120	0.787	0.940	0.083	0.932	0

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 17 mM of H₂O₂, 50 g of SiO₂, pH 4

Table B-13 Chemicals remaining for Run#12 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.887	0.895	0.174	-	0.334
2	0.872	1.056	0.174	0.993	0.329
5	0.873	1.040	0.130	0.960	0.077
10	0.863	0.895	0.130	0.924	0
20	0.851	0.847	0.130	0.984	0
30	0.840	1.065	0.130	0.985	0
60	0.837	0.766	0.087	0.982	0
90	0.838	0.782	0.087	0.985	0
120	0.834	0.944	0.087	0.984	0

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 17 mM of H₂O₂, 300 g of SiO₂, pH 4

Table B-14 Chemicals remaining for Run#13 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.573	0.755	0.473	-	0.994
2	0.570	0.770	0.469	0.924	0.986
5	0.562	0.856	0.415	0.905	0.990
10	0.540	0.691	0.429	0.911	0.984
20	0.528	0.770	0.420	0.916	0.982
30	0.508	0.806	0.366	0.892	0.975
60	0.531	0.748	0.348	0.882	0.976
90	0.414	0.691	0.304	0.865	0.966
120	0.395	0.633	0.290	0.840	0.981

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 50 g of SiO₂, pH 2

Table B-15 Chemicals remaining for Run#14 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.623	0.867	0.577	-	0.992
2	0.616	0.825	0.559	0.952	0.989
5	0.589	0.867	0.507	0.916	0.986
10	0.591	0.842	0.507	0.919	0.982
20	0.592	0.667	0.445	0.910	0.989
30	0.567	0.783	0.441	0.903	0.982
60	0.468	0.833	0.366	0.906	0.972
90	0.427	0.658	0.273	0.897	0.978
120	0.358	0.633	0.326	0.884	0.973

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 300 g of SiO₂, pH 2

Table B-16 Chemicals remaining for Run#15 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.614	0.951	0.283	-	0.968
2	0.609	0.934	0.252	0.874	0.936
5	0.563	0.967	0.027	0.863	0.881
10	0.539	0.787	0.027	0.860	0.889
20	0.520	0.852	0.0177	0.857	0.841
30	0.551	0.738	0.022	0.837	0.823
60	0.506	0.648	0.0177	0.852	0.779
90	0.482	0.664	0.013	0.844	0.715
120	0.472	0.795	0.013	0.836	0.719

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 50 g of SiO₂, pH 4

Table B-17 Chemicals remaining for Run#16 of two-level factorial design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.570	0.718	0.208	-	0.900
2	0.544	0.773	0.154	0.918	0.883
5	0.523	0.945	0.118	0.902	0.768
10	0.472	0.764	0.063	0.889	0.733
20	0.480	0.755	0.027	0.878	0.709
30	0.472	0.809	0.027	0.898	0.674
60	0.453	0.745	0.032	0.881	0.571
90	0.411	0.773	0.032	0.859	0.541
120	0.369	0.745	0.018	0.869	0.501

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 300 g of SiO₂, pH 4

Table B-18 Chemicals remaining for Run#1 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.889	1.051	0.681	-	0.977
2	0.888	1.020	0.681	0.958	0.987
5	0.888	1.010	0.636	0.799	0.974
10	0.886	1.020	0.681	0.784	0.980
20	0.877	1.020	0.545	0.802	0.954
30	0.874	1.041	0.590	0.745	0.947
60	0.874	0.979	0.636	0.757	0.942
90	0.875	0.948	0.590	0.748	0.930
120	0.872	0.958	0.590	0.729	0.922

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 9 mM of H₂O₂, 100 g of SiO₂, pH 2

Table B-19 Chemicals remaining for Run#2 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.988	1.051	0.333	-	0.972
2	0.965	1.072	0.333	0.775	0.912
5	0.963	1.092	0.208	0.763	0.833
10	0.946	0.969	0.125	0.748	0.586
20	0.946	1.061	0.083	0.760	0.560
30	0.943	0.979	0.083	0.760	0.388
60	0.930	1.010	0	0.763	0.185
90	0.860	0.989	0	0.763	0.148
120	0.829	0.969	0	0.760	0.088

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 9 mM of H₂O₂, 100 g of SiO₂, pH 4

Table B-20 Chemicals remaining for Run#3 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.664	1.058	0.331	-	0.987
2	0.661	0.961	0.318	0.636	0.985
5	0.648	0.873	0.286	0.585	0.977
10	0.646	0.893	0.277	0.578	0.984
20	0.618	0.893	0.290	0.574	0.958
30	0.579	0.883	0.272	0.567	0.991
60	0.564	0.854	0.240	0.567	0.981
90	0.534	0.805	0.209	0.562	0.947
120	0.501	0.805	0.209	0.565	0.948

Note: 1 mM of OT, 1 mM of Fe²⁺, 9 mM of H₂O₂, 100 g of SiO₂, pH 2

Table B-21 Chemicals remaining for Run#4 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.739	1.019	0.202	-	0.926
2	0.638	0.892	0.174	0.740	0.900
5	0.556	0.901	0.080	0.556	0.811
10	0.540	0.901	0.014	0.520	0.776
20	0.511	0.921	0.028	0.525	0.774
30	0.513	0.892	0.023	0.521	0.795
60	0.503	0.823	0.028	0.514	0.774
90	0.506	0.872	0.018	0.518	0.729
120	0.478	0.852	0.023	0.518	0.705

Note: 1 mM of OT, 1 mM of Fe²⁺, 9 mM of H₂O₂, 100 g of SiO₂, pH 4

Table B-22 Chemicals remaining for Run#5 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.861	0.833	0.475	-	0.998
2	0.859	0.844	0.322	0.739	0.986
5	0.845	0.800	0.282	0.793	0.992
10	0.828	0.755	0.314	0.821	0.972
20	0.801	0.766	0.282	0.793	0.968
30	0.822	0.877	0.338	0.821	0.968
60	0.757	0.766	0.290	0.821	0.962
90	0.782	0.877	0.282	0.793	0.960
120	0.703	0.833	0.282	0.793	0.956

Note: 1 mM of OT, 0.55 mM of Fe²⁺, 1 mM of H₂O₂, 100 g of SiO₂, pH 2

Table B-23 Chemicals remaining for Run#6 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.885	0.860	0.598	-	0.966
2	0.797	0.906	0.270	0.061	0.945
5	0.765	0.872	0.172	0.043	0.858
10	0.773	0.813	0.073	0.040	0.785
20	0.761	0.813	0.040	0.038	0.717
30	0.749	0.860	0.032	0.033	0.697
60	0.751	0.837	0.032	0.035	0.645
90	0.669	0.825	0.024	0.033	0.600
120	0.657	0.825	0.024	0.032	0.517

Note: 1 mM of OT, 0.55 mM of Fe²⁺, 1 mM of H₂O₂, 100 g of SiO₂, pH 4

Table B-24 Chemicals remaining for Run#7 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.691	0.857	0.309	-	0.996
2	0.698	0.961	0.277	0.960	0.981
5	0.674	0.909	0.253	0.871	0.988
10	0.655	0.844	0.261	0.856	0.988
20	0.629	0.831	0.253	0.847	0.969
30	0.611	0.857	0.238	0.854	0.959
60	0.603	0.831	0.261	0.858	0.956
90	0.588	0.792	0.253	0.858	0.956
120	0.584	0.779	0.253	0.854	0.945

Note: 1 mM of OT, 0.55 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 2

Table B-25 Chemicals remaining for Run#8 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.700	0.972	0.185	-	0.989
2	0.664	0.918	0.203	0.984	0.866
5	0.661	0.810	0.141	0.874	0.822
10	0.657	0.864	0.035	0.851	0.756
20	0.648	0.891	0.026	0.849	0.762
30	0.650	0.783	0.017	0.851	0.769
60	0.645	0.702	0.017	0.840	0.697
90	0.625	0.702	0.008	0.837	0.626
120	0.609	0.675	0.008	0.843	0.583

Note: 1 mM of OT, 0.55 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 4

Table B-26 Chemicals remaining for Run#9 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.892	1.296	0.739	-	0.962
2	0.868	0.962	0.652	0.492	0.954
5	0.865	1	0.608	0.533	0.946
10	0.869	1.037	0.608	0.574	0.960
20	0.835	0.962	0.565	0.561	0.965
30	0.833	1.111	0.608	0.602	0.925
60	0.820	1.148	0.565	0.547	0.934
90	0.835	1.074	0.565	0.533	0.911
120	0.830	1.185	0.478	0.561	0.898

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 1 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-27 Chemicals remaining for Run#10 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.733	0.960	0.327	-	0.978
2	0.651	0.950	0.322	1	0.980
5	0.635	0.930	0.268	0.038	0.987
10	0.623	0.930	0.259	0.019	0.934
20	0.619	0.920	0.263	0.017	0.931
30	0.585	0.850	0.254	0.017	0.890
60	0.535	0.880	0.227	0.017	0.857
90	0.440	0.830	0.231	0.017	0.795
120	0.440	1	0.240	0.012	0.753

Note: 1 mM of OT, 1 mM of Fe²⁺, 1 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-28 Chemicals remaining for Run#11 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.959	1	0.590	-	0.996
2	0.943	0.991	0.5	0.906	0.972
5	0.936	0.982	0.5	0.929	0.982
10	0.875	1.025	0.5	0.914	0.953
20	0.892	1.060	0.454	0.898	0.959
30	0.880	1.043	0.454	0.930	0.937
60	0.854	0.956	0.363	0.890	0.930
90	0.880	1	0.363	0.890	0.936
120	0.848	0.948	0.409	0.893	0.912

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-29 Chemicals remaining for Run#12 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.466	0.754	0.256	-	0.982
2	0.446	0.941	0.239	0.972	0.973
5	0.371	0.882	0.194	0.850	0.956
10	0.346	0.843	0.165	0.724	0.915
20	0.225	0.813	0.123	0.653	0.886
30	0.143	0.725	0.115	0.579	0.878
60	0.053	0.519	0.095	0.257	0.878
90	0.031	0.470	0.070	0.186	0.812
120	0.002	0.382	0.061	0.101	0.819

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-30 Chemicals remaining for Run#13 of Box-Behnken design

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.685	0.866	0.488	-	0.986
2	0.680	0.858	0.472	0.713	0.978
5	0.646	0.916	0.424	0.550	0.968
10	0.621	0.858	0.400	0.518	0.924
20	0.608	0.825	0.312	0.529	0.846
30	0.524	0.791	0.240	0.510	0.790
60	0.503	0.758	0.192	0.499	0.686
90	0.425	0.775	0.160	0.476	0.621
120	0.285	0.741	0.136	0.462	0.608

Note: 1 mM of OT, 0.55 mM of Fe²⁺, 9 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-31 Chemicals remaining for effect of *o*-toluidine concentration 0.5 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.348	0.807	0.135	-	0.981
2	0.241	0.561	0.130	0.882	0.990
5	0.124	0.350	0.121	0.850	0.983
10	0.064	0.245	0.108	0.611	0.956
20	0.022	0.298	0.099	0.315	0.973
30	0	0.134	0.090	0.189	0.972
60	0	0.053	0.067	0.035	0.955
90	0	0	0.054	0.016	0.990
120	0	0	0.130	0.009	0.972

Note: 0.5 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-32 Chemicals remaining for effect of *o*-toluidine concentration 1 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.466	0.754	0.256	-	0.982
2	0.446	0.941	0.239	0.972	0.973
5	0.371	0.882	0.194	0.850	0.956
10	0.334	0.843	0.165	0.724	0.915
20	0.225	0.813	0.123	0.653	0.886
30	0.143	0.725	0.115	0.579	0.878
60	0.053	0.519	0.095	0.257	0.878
90	0.031	0.470	0.070	0.186	0.812
120	0.002	0.382	0.061	0.101	0.819

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-33 Chemicals remaining for effect of *o*-toluidine concentration 2 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.749	0.766	0.253	-	0.969
2	0.698	0.673	0.217	0.935	0.962
5	0.683	0.840	0.185	0.790	0.937
10	0.675	0.713	0.226	0.772	0.956
20	0.627	0.673	0.167	0.747	0.913
30	0.589	0.733	0.162	0.753	0.884
60	0.507	0.653	0.208	0.727	0.859
90	0.434	0.580	0.140	0.716	0.863
120	0.338	0.553	0.144	0.664	0.860

Note: 2 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-34 Chemicals remaining for effect of *o*-toluidine concentration 5 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.880	0.938	0.756	-	0.989
2	0.863	0.894	0.720	0.853	0.986
5	0.854	0.891	0.657	0.793	0.947
10	0.811	0.873	0.635	0.756	0.940
20	0.792	0.850	0.518	0.751	0.916
30	0.756	0.820	0.522	0.724	0.879
60	0.672	0.758	0.500	0.700	0.850
90	0.584	0.747	0.427	0.685	0.817
120	0.509	0.623	0.490	0.629	0.782

Note: 5 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-35 Chemicals remaining for effect of Fe²⁺ concentration 0.1 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.959	1	0.590	-	0.996
2	0.943	0.991	0.500	0.906	0.972
5	0.918	0.982	0.500	0.929	0.982
10	0.887	1.025	0.500	0.914	0.953
20	0.879	1.060	0.454	0.898	0.959
30	0.880	1.043	0.454	0.930	0.937
60	0.854	0.956	0.363	0.890	0.930
90	0.861	1	0.363	0.890	0.936
120	0.848	0.948	0.409	0.893	0.912

Note: 1 mM of OT, 0.1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-36 Chemicals remaining for effect of Fe²⁺ concentration 0.5 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.674	0.988	0.294	-	0.918
2	0.662	0.896	0.276	0.962	0.888
5	0.641	0.862	0.241	0.956	0.865
10	0.615	0.850	0.223	0.958	0.783
20	0.616	0.896	0.187	0.966	0.751
30	0.605	0.919	0.160	0.951	0.726
60	0.550	0.862	0.151	0.940	0.647
90	0.496	0.827	0.133	0.916	0.614
120	0.357	0.793	0.107	0.900	0.564

Note: 1 mM of OT, 0.5 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-37 Chemicals remaining for effect of Fe²⁺ concentration 1 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.466	0.754	0.256	-	0.982
2	0.446	0.941	0.239	0.972	0.973
5	0.371	0.882	0.194	0.850	0.956
10	0.328	0.843	0.165	0.724	0.915
20	0.225	0.813	0.123	0.653	0.886
30	0.143	0.725	0.115	0.579	0.878
60	0.053	0.519	0.095	0.257	0.878
90	0.031	0.470	0.070	0.186	0.812
120	0.002	0.382	0.061	0.101	0.819

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-38 Chemicals remaining for effect of Fe²⁺ concentration 2 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.246	0.611	0.179	-	0.919
2	0.229	0.611	0.143	0.811	0.903
5	0.144	0.595	0.106	0.644	0.896
10	0.043	0.571	0.106	0.555	0.885
20	0.013	0.539	0.075	0.151	0.864
30	0.014	0.428	0.054	0.082	0.880
60	0.008	0.428	0.045	0.030	0.878
90	0.008	0.412	0.061	0.030	0.856
120	0.007	0.365	0.047	0.030	0.836

Note: 1 mM of OT, 2 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-39 Chemicals remaining for effect of H₂O₂ concentration 1 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.733	0.960	0.327	-	0.978
2	0.651	0.950	0.322	0.656	0.980
5	0.635	0.930	0.268	0.328	0.987
10	0.623	0.930	0.259	0.301	0.934
20	0.612	0.920	0.263	0.301	0.931
30	0.585	0.850	0.2545	0.301	0.890
60	0.535	0.880	0.227	0.301	0.857
90	0.501	0.830	0.231	0.218	0.795
120	0.440	1	0.240	0.218	0.753

Note: 1 mM of OT, 1 mM of Fe²⁺, 1 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-40 Chemicals remaining for effect of H₂O₂ concentration 9 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.522	1.047	0.226	-	0.981
2	0.497	1.023	0.212	0.954	0.991
5	0.476	1.071	0.167	0.894	0.975
10	0.453	0.988	0.149	0.839	0.934
20	0.400	1	0.126	0.836	0.912
30	0.340	0.892	0.117	0.818	0.885
60	0.213	0.833	0.104	0.772	0.860
90	0.089	0.738	0.076	0.681	0.874
120	0.034	0.773	0.131	0.258	0.880

Note: 1 mM of OT, 1 mM of Fe²⁺, 9 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-41 Chemicals remaining for effect of H₂O₂ concentration 17 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.466	0.754	0.256	-	0.982
2	0.446	0.941	0.239	0.972	0.973
5	0.371	0.882	0.194	0.850	0.956
10	0.346	0.843	0.165	0.724	0.915
20	0.225	0.813	0.123	0.653	0.886
30	0.143	0.725	0.115	0.579	0.878
60	0.053	0.519	0.095	0.257	0.878
90	0.031	0.470	0.070	0.186	0.812
120	0.002	0.382	0.061	0.101	0.819

Note: 1 mM of OT, 1 mM of Fe²⁺, 17 mM of H₂O₂, 100 g of SiO₂, pH 3

Table B-42 Chemicals remaining for effect of H₂O₂ concentration 34 mM

Time	C/C ₀				
	<i>o</i> -toluidine	COD	Fe ²⁺	H ₂ O ₂	total iron
0	1	1	1	1	1
1	0.612	0.831	0.198	-	0.985
2	0.515	0.950	0.162	0.908	0.975
5	0.467	0.861	0.144	0.744	0.992
10	0.424	0.801	0.135	0.724	0.990
20	0.286	0.821	0.094	0.715	0.980
30	0.227	0.762	0.094	0.638	0.952
60	0.029	0.594	0.081	0.421	0.955
90	0	0.584	0.058	0.271	0.941
120	0	0.623	0.045	0.198	0.960

Note: 1 mM of OT, 1 mM of Fe²⁺, 34 mM of H₂O₂, 100 g of SiO₂, pH 3

APPENDIX C

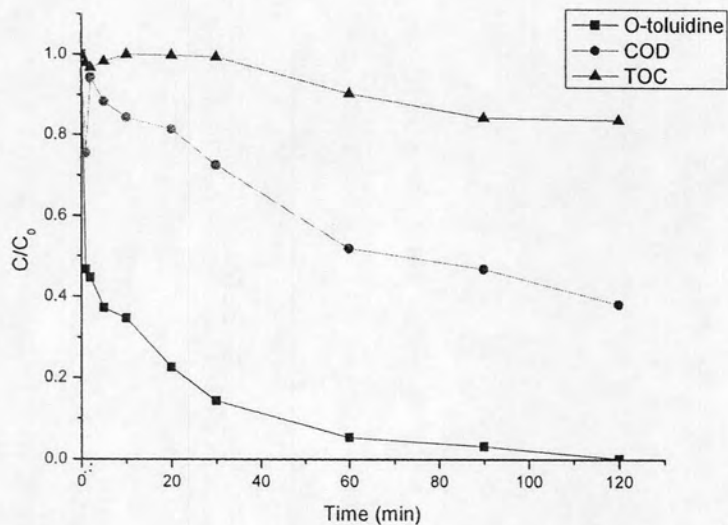
SOME INTERMEDIATES OF *O*-TOLUIDINE DEGRADATION

Figure C-1 *O*-toluidine, COD and TOC abatement by fluidized-bed Fenton process.

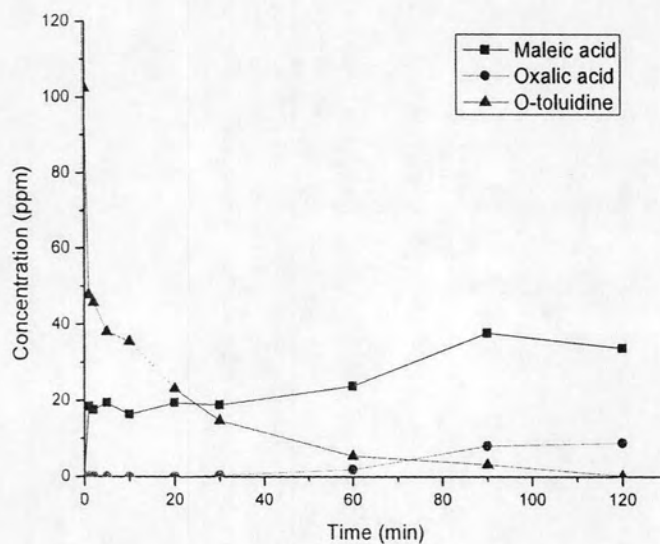


Figure C-2 Intermediates from *o*-toluidine degradation by fluidized-bed Fenton process.

APPENDIX D

EXPERIMENTAL FIGURES



Figure D-1 Operating fluidized-bed reactor



Figure D-2 Carriers in the fluidized-bed reactor

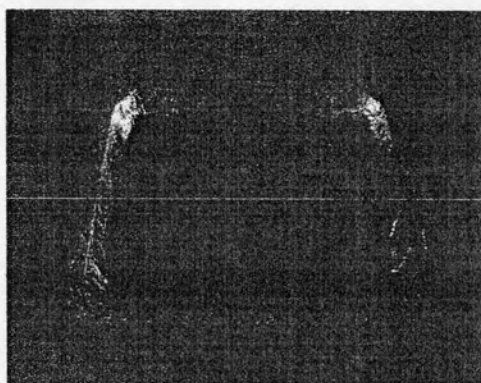


Figure D-3 Silica dioxide (SiO₂) sand

BIOGRAPHY

Mr. Pumis Thuptim dang was born on March 29th, 1985 in Trang, Thailand. He obtained the Bachelor's Degree in General Science from the Faculty of Science, Chulalongkorn University in 2004. He pursued his master degree in the International Postgraduate Program in Environmental Management (Hazardous Waste Management), Inter-Department of Environmental Management at Chulalongkorn University. He has presented his research at the 8th National Environmental Conference held during March 25 to 27, 2009 in Nakhonratchasima, Thailand under the topic of "Removal of *o*-Toluidine by Fluidized-bed Fenton Process."

