# APPENDICES FOR
# DEGRADATION OF TEXTILE WASTEWATER USING ULTRA-SMALL β-FeOOH/$TiO_2$ HETEROJUNCTION STRUCTURE AS A VISIBLE LIGHT PHOTOCATALYST

**By**

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# APPENDICES

## Appendix A.

**Table A.1:** The measured absorbances for different MO concentrations correlated to make a calibration curve

| Concentration (mg/L) | Absorption (Abs) |
|---|---|
| 0 | 0 |
| 1 | 0.042 |
| 2.5 | 0.072 |
| 5 | 0.28 |
| 10 | 0.744 |
| 20 | 1.267 |
| 30 | 2.083 |
| 40 | 2.823 |

**Table A.2:** Experimental conditions for photocatalytic performance of 5%β-FeOOH/$TiO_2$ compared to $TiO_2$ (Anatase), P25, Peroxide and β-FeOOH photocatalysts

| Photocatalyst | MO (mg) | Catalyst (g) | Peroxide(mL) | Light(W) | pH |
|---|---|---|---|---|---|
| Blank | 80 | 0 | 0 | 300 | 4.5 |
| Simulated solar light | 80 | 0 | 3 | 300 | 4.5 |
| β-FeOOH | 80 | 0,01 | 3 | 300 | 4.5 |
| $TiO_2$ (Anatase) | 80 | 0,01 | 3 | 300 | 4.5 |
| Peroxide | 80 | 0 | 3 | 300 | 4.5 |
| Degusa P25 | 80 | 0,01 | 3 | 300 | 4.5 |
| 10% β-FeOOH/$TiO_2$ | 80 | 0,01 | 3 | 300 | 4.5 |
| 2% β-FeOOH/$TiO_2$ | 80 | 0,01 | 3 | 300 | 4.5 |
| 5% β-FeOOH/$TiO_2$ | 80 | 0,01 | 3 | 300 | 4.5 |

**Table A.3:** Raw data and real concentration calculation for photocatalytic performance of 5%β-FeOOH/$TiO_2$ compared to $TiO_2$ (Anatase), P25, Peroxide and β-FeOOH photocatalysts

| Method | Time(min) | Conc (mg/L) | $C_t/C_0$ | ln $C_t/C_0$ | μ |
|---|---|---|---|---|---|
| 1. Blank | 0 | 80 | 1 | 0 | 0 |
| | 30 | 80 | 1 | 0 | 0 |
| | 60 | 80 | 1 | 0 | 0 |
| 2. Simulated solar light | 0 | 73,87245 | 1 | 0 | 0 |
| | 30 | 72,88028 | 0,986569 | 0,013522 | 1,343089 |
| | 60 | 72,21862 | 0,977612 | 0,022642 | 2,238776 |
| 3. $TiO_2$ (Anatase) | 0 | 86,6923 | 1 | 0 | 0 |
| | 30 | 67,4242 | 0,777742 | 0,251361 | 22,22585 |
| | 60 | 48,8671 | 0,563684 | 0,573261 | 43,63156 |
| 4. 10% β-FeOOH/$TiO_2$ | 0 | 74,631 | 1 | 0 | 0 |
| | 30 | 41,95 | 0,562099 | 0,576078 | 43,79011 |
| | 60 | 17,0143 | 0,227979 | 1,478502 | 77,2021 |
| 5. 5% β-FeOOH/$TiO_2$ | 0 | 63,5137 | 1 | 0 | 0 |
| | 30 | 22,7023 | 0,357439 | 1,028789 | 64,25606 |
| | 60 | 1,9411 | 0,030562 | 3,488001 | 96,94381 |
| 6. 2% β-FeOOH/$TiO_2$ | 0 | 72,4012 | 1 | 0 | 0 |
| | 30 | 32,8696 | 0,453992 | 0,789675 | 54,60075 |
| | 60 | 10,7575 | 0,148582 | 1,90662 | 85,14182 |
| 7. Peroxide | 0 | 75,5296 | 1 | 0 | 0 |
| | 30 | 60,883 | 0,806081 | 0,215571 | 19,39187 |
| | 60 | 52,2799 | 0,692178 | 0,367913 | 30,78224 |
| 8. β-FeOOH | 0 | 75,1741 | 1 | 0 | 0 |
| | 30 | 73,04821 | 0,97172 | 0,028687 | 0,02828 |
| | 60 | 69,68518 | 0,926984 | 0,075819 | 0,073016 |
| 9. $TiO_2$ P25 | 0 | 94.0987 | 1 | 0 | 0 |
| | 15 | 82.3454 | 0,87234 | 0,136576 | 12,76596 |
| | 30 | 75.3546 | 0,797872 | 0,225807 | 20,21277 |
| | 45 | 62.7642 | 0,659574 | 0,41616 | 34,04255 |
| | 60 | 58.1462 | 0,617021 | 0,482852 | 38,29787 |

**Table A.4:** Raw data and real concentration calculation for the effect of the hydrogen peroxide load on the degradation of MO without photocatalyst performance of 5%β-FeOOH/$TiO_2$

| **5mL (of 30% $H_2O_2$)/L** | | | | |
|---|---|---|---|---|
| **Time (min)** | **Concentration (mg/L)** | **$C_t/C_o$** | **ln ($C_t/C_o$)** | **μ** |
| 0 | 79.8667 | 1 | 0 | 0 |
| 15 | 68 | 0.851419 | 0.160851 | 14.85813 |
| 30 | 59.8165 | 0.748954 | 0.289077 | 25.10458 |
| 45 | 53 | 0.663606 | 0.410067 | 33.63943 |
| 60 | 47.3029 | 0.592273 | 0.523787 | 40.77269 |
| 90 | 39.7 | 0.497078 | 0.699008 | 50.29217 |
| **0 mL (of 30% $H_2O_2$)/L** | | | | |
| **Time** | **Concentration (mg/L)** | **$C_t/C_o$** | **ln ($C_t/C_o$)** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 15 | 79 | 0.9875 | 0.012579 | 1.25 |
| 30 | 80 | 1 | 0 | 0 |
| 45 | 79 | 0.9875 | 0.012579 | 1.25 |
| 60 | 79 | 0.9875 | 0.012579 | 1.25 |
| 90 | 80 | 1 | 0 | 0 |
| **3 mL (of 30% $H_2O_2$)/L** | | | | |
| **Time** | **Concentration (mg/L)** | **$C_t/C_o$** | **ln ($C_t/C_o$)** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 15 | 70 | 0.875 | 0.133531 | 12.5 |
| 30 | 61 | 0.7625 | 0.271153 | 23.75 |
| 45 | 55 | 0.6875 | 0.374693 | 31.25 |
| 60 | 52 | 0.65 | 0.430783 | 35 |
| 90 | 43 | 0.5375 | 0.620827 | 46.25 |
| **1 mL (of 30% $H_2O_2$)/L MO** | | | | |
| **Time** | **Concentration (mg/L)** | **$C_t/C_o$** | **ln ($C_t/C_o$)** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 15 | 78 | 0.975 | 0.025318 | 2.5 |
| 30 | 75.103 | 0.938788 | 0.063166 | 6.12125 |
| 45 | 73 | 0.9125 | 0.091567 | 8.75 |
| 60 | 70 | 0.875 | 0.133531 | 12.5 |
| 90 | 66.64 | 0.833 | 0.182722 | 16.7 |
| **0.5 mL (of 30% $H_2O_2$)/L MO** | | | | |
| **Time** | **Concentration (mg/L)** | **$C_t/C_o$** | **ln ($C_t/C_o$)** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 15 | 78 | 0.975 | 0.025318 | 2.5 |
| 30 | 78 | 0.975 | 0.025318 | 2.5 |
| 45 | 77 | 0.9625 | 0.038221 | 3.75 |
| 60 | 77 | 0.9625 | 0.038221 | 3.75 |
| 90 | 76 | 0.95 | 0.051293 | 5 |

**Table A.5:** Raw data and real concentration calculation for the effect of the hydrogen peroxide load on the degradation of MO with 5%β-FeOOH/$TiO_2$ photocatalyst

| **0 mL Peroxide + 5% beta-FeOOH + Light** | | | | |
|---|---|---|---|---|
| **Time** | **Concentration (mg /L)** | **$C_t/C_o$** | **$\ln(C_t/C_o)$** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 15 | 78 | 0.975 | 0.025318 | 2.5 |
| 30 | 75 | 0.9375 | 0.064539 | 6.25 |
| 45 | 72 | 0.9 | 0.105361 | 10 |
| 60 | 70 | 0.875 | 0.133531 | 12.5 |
| 90 | 65 | 0.8125 | 0.207639 | 18.75 |
| **0.5 mL Peroxide + 5% beta-FeOOH + Light** | | | | |
| **Time** | **Concentration (mg/L)** | **$C_t/C_o$** | **$\ln(C_t/C_o)$** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 15 | 70 | 0.875 | 0.133531 | 12.5 |
| 30 | 59 | 0.7375 | 0.304489 | 26.25 |
| 45 | 45 | 0.5625 | 0.575364 | 43.75 |
| 60 | 35 | 0.4375 | 0.826679 | 56.25 |
| 90 | 10 | 0.125 | 2.079442 | 87.5 |
| **1 mL Peroxide + 5% beta-FeOOH + Light** | | | | |
| **Time** | **Concentration (mg/L)** | **$C_t/C_o$** | **$\ln(C_t/C_o)$** | **μ** |
| 0 | 74.26402 | 1 | 0 | 0 |
| 15 | 61.45 | 0.827453 | 0.189403 | 17.25468 |
| 30 | 51 | 0.686739 | 0.375801 | 31.3261 |
| 45 | 40 | 0.538619 | 0.618747 | 46.13812 |
| 60 | 30 | 0.403964 | 0.906429 | 59.60359 |
| 90 | 8 | 0.107724 | 2.228185 | 89.22762 |
| **3 mL Peroxide + 5% beta-FeOOH + Light** | | | | |
| **Time** | **Concentration** | **$C_t/C_o$** | **μ** | **ln $C_t/C_o$** |
| 0 | 68 | 1 | 0 | 0 |
| 15 | 50 | 0.735294 | 26.47059 | 0.307485 |
| 30 | 36 | 0.529412 | 47.05882 | 0.635989 |
| 45 | 20 | 0.294118 | 70.58824 | 1.223775 |
| 60 | 1 | 0.014706 | 98.52941 | 4.219508 |
| **5 mL Peroxide + 5% beta-FeOOH + Light** | | | | |
| **Time** | **(mg/L)** | **$C_t/C_o$** | **ln ($C_t/C_o$)** | **μ** |
| 0 | 75 | 1 | 0 | 0 |
| 15 | 47 | 0.626667 | 0.467341 | 37.33333 |
| 30 | 32 | 0.426667 | 0.851752 | 57.33333 |
| 45 | 14.35 | 0.191333 | 1.653738 | 80.86667 |
| 60 | 0.7 | 0.009333 | 4.674163 | 99.06667 |

**Table A.6:** Contribution of $H_2O_2$ on the degradation of MO

| Peroxide + Catalyst | | | | Peroxide + Light | | | |
|---|---|---|---|---|---|---|---|
| **Volume peroxide (mL)** | **K** | **Intercept** | **$R^2$** | **peroxide (mL)** | **K** | **intercept** | **$R^2$** |
| 5 | 0.039 | -0.1955 | 0.96 | 5 | 0.0068 | 0.094 | 0.99 |
| 3 | 0.03 | -0.3022 | 0.95 | 3 | 0.0058 | 0.091 | 0.99 |
| 1 | 0.016 | -0.0347 | 0.99 | 1 | 0.002 | 0.0069 | 0.98 |
| 0.5 | 0.014 | -0.104 | 0.98 | 0.5 | 0.0004 | 0.0123 | 0.99 |

**Table A.7:** Raw data and real concentration calculation for the effect of the initial dye concentration on the photocatalytic performance of 5%β-FeOOH/$TiO_2$

| **200 mg/L** | | | | |
|---|---|---|---|---|
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 190 | 1 | 0 | 0 |
| 15 | 145 | 0.763158 | 0.27029 | 23.68421 |
| 30 | 117 | 0.615789 | 0.48485 | 38.42105 |
| 45 | 97 | 0.510526 | 0.672313 | 48.94737 |
| 60 | 70 | 0.368421 | 0.998529 | 63.15789 |
| 75 | 47 | 0.247368 | 1.396876 | 75.26316 |
| 90 | 23 | 0.121053 | 2.11153 | 87.89474 |
| 105 | 1.78 | 0.009368 | 4.670411 | 99.06316 |
| **150 mg/L** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 141.802 | 1 | 0 | 0 |
| 15 | 103 | 0.726365 | 0.319703 | 27.3635 |
| 30 | 62 | 0.437229 | 0.827297 | 56.27706 |
| 45 | 48.42 | 0.341462 | 1.074519 | 65.85379 |
| 60 | 23 | 0.162198 | 1.818937 | 83.7802 |
| 75 | 8 | 0.056417 | 2.87499 | 94.35833 |
| 90 | 1 | 0.007052 | 4.954432 | 99.29479 |
| **80 mg/L** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 65 | 1 | 0 | 0 |
| 15 | 12.79 | 0.196769 | 1.625724 | 80.32308 |
| 30 | 1.71924 | 0.02645 | 3.632505 | 97.35502 |

| | | | | |
|---|---|---|---|---|
| 45 | 0.6 | 0.009231 | 4.685213 | 99.07692 |
| **50 mg/L** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 34 | 1 | 0 | 0 |
| 5 | 18 | 0.529412 | 0.635989 | 47.05882 |
| 10 | 10.40911 | 0.30615 | 1.183679 | 69.38497 |
| 15 | 4.53 | 0.133235 | 2.015639 | 86.67647 |
| 20 | 1.773 | 0.052147 | 2.953687 | 94.78529 |
| 30 | 1 | 0.029412 | 3.526361 | 97.05882 |
| 45 | 1 | 0.029412 | 3.526361 | 97.05882 |
| **25 mg/L** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 25 | 1 | 0 | 0 |
| 5 | 18 | 0.72 | 0.328504 | 28 |
| 10 | 10.40911 | 0.416364 | 0.876194 | 58.36356 |
| 15 | 6.7 | 0.268 | 1.316768 | 73.2 |
| 20 | 3 | 0.12 | 2.120264 | 88 |

**Table A.8:** The raw data and real concentration calculation on the effect of light intensity

| | | | | |
|---|---|---|---|---|
| **150 W** | | | | |
| **Time** | **concentration** | **$C_t/C_0$** | **ln $C_t/C_0$** | μ |
| 0 | 76 | 1 | 0 | 0 |
| 15 | 60 | 0.789474 | 0.236389 | 21.05263 |
| 30 | 43 | 0.565789 | 0.569533 | 43.42105 |
| 45 | 20 | 0.263158 | 1.335001 | 73.68421 |
| **250 W** | | | | |
| **Time** | **concentration** | **$C_t/C_0$** | **ln $C_t/C_0$** | **μ** |
| 0 | 73.81 | 1 | 0 | 0 |
| 15 | 40 | 0.541932 | 0.612615 | 45.8068 |
| 30 | 25 | 0.338707 | 1.082618 | 66.12925 |
| 45 | 5.37 | 0.072754 | 2.620666 | 92.72456 |
| **250 W (p25)** | | | | |
| **time** | **Concentration** | **$C_t/C_0$** | **ln $C_t/C_0$** | **μ** |

| | | | | |
|---|---|---|---|---|
| 0 | 94 | 1 | 0 | 0 |
| 15 | 82 | 0.87234 | 0.136576 | 12.76596 |
| 30 | 75 | 0.797872 | 0.225807 | 20.21277 |
| 45 | 62 | 0.659574 | 0.41616 | 34.04255 |
| 60 | 58 | 0.617021 | 0.482852 | 38.29787 |
| 90 | 37 | 0.393617 | 0.932377 | 60.6383 |
| **300 W** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **ln $C_t/C_0$** | **μ** |
| 0 | 65 | 1 | 0 | 0 |
| 15 | 12.79 | 0.196769 | 1.625724 | 80.32308 |
| 30 | 1.71924 | 0.02645 | 3.632505 | 97.35502 |
| 45 | 0.6 | 0.009231 | 4.685213 | 99.07692 |

**Table A.9:** The raw data and real concentration calculation on the effect of the pH of the solution

| **pH 3** | | | | |
|---|---|---|---|---|
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 27 | 1 | 0 | 0 |
| 10 | 5.75 | 0.212963 | 1.546637 | 78.7037 |
| 15 | 4 | 0.148148 | 1.909543 | 85.18519 |
| 25 | 0.38 | 0.014074 | 4.263421 | 98.59259 |
| 30 | 0.38 | 0.014074 | 4.263421 | 98.59259 |
| **pH 4.5** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 65 | 1 | 0 | 0 |
| 10 | 30 | 0.461538 | 0.77319 | 53.84615 |
| 15 | 12.79 | 0.196769 | 1.625724 | 80.32308 |
| 30 | 1.71924 | 0.02645 | 3.632505 | 97.35502 |
| **pH = 7.52** | | | | |

| Time | Concentration | $C_t/C_0$ | ln ($C_t/C_0$) | μ |
|---|---|---|---|---|
| 0 | 56.73076 | 1 | 0 | 0 |
| 10 | 40 | 0.705085 | 0.349437 | 29.49151 |
| 15 | 36.93652 | 0.651085 | 0.429116 | 34.89155 |
| 30 | 25 | 0.440678 | 0.819441 | 55.9322 |
| 45 | 12.44257 | 0.219327 | 1.517193 | 78.06733 |
| 60 | 1.609718 | 0.028375 | 3.562258 | 97.16253 |

**Table A.10:** The raw data and real concentration calculation on the effect of the pH of catalyst load

| **0.005 g/ 100 mL** | | | | |
|---|---|---|---|---|
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 74 | 1 | 0 | 0 |
| 15 | 50 | 0.675676 | 0.392042 | 32.43243 |
| 30 | 35 | 0.472973 | 0.748717 | 52.7027 |
| 45 | 15 | 0.202703 | 1.596015 | 79.72973 |
| 60 | 1.22 | 0.016486 | 4.105214 | |
| **0.01 g/ 100 mL** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 74 | 1 | 0 | 0 |
| 15 | 45 | 0.608108 | 0.497403 | 39.18919 |
| 30 | 30 | 0.405405 | 0.902868 | 59.45946 |
| 45 | 14.35 | 0.193919 | 1.640315 | 80.60811 |
| 60 | 0.7 | 0.009459 | 4.66074 | 99.05405 |
| **0.02 g/ 100 mL** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 65 | 1 | 0 | 0 |
| 15 | 12.79 | 0.196769 | 1.625724 | 80.32308 |
| 30 | 1.71924 | 0.02645 | 3.632505 | 97.35502 |
| 45 | 0.6 | 0.009231 | 4.685213 | 99.07692 |

**Table A.11:** The raw data and real concentration calculation for the degradation of commercial metal-complex dyes

| Yellow | | | | |
|---|---|---|---|---|
| **Time[min]** | **Conc** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 28.5 | 1 | 0 | 0 |
| 5 | 13 | 0.45614 | 0.784955 | 54.38596 |
| 10 | 8 | 0.280702 | 1.270463 | 71.92982 |
| 15 | 5 | 0.175439 | 1.740466 | 82.45614 |
| 20 | 1 | 0.035088 | 3.349904 | 96.49123 |
| **Red** | | | | |
| **Time[min]** | **Conc** | **$C_t/C_0$** | **$\ln (C_t/C_0)$** | **μ** |
| 0 | 80 | 1 | 0 | 0 |
| 5 | 44.5 | 0.55625 | 0.586537 | 44.375 |
| 10 | 23.5 | 0.29375 | 1.225026 | 70.625 |
| 15 | 13.5 | 0.16875 | 1.779337 | 83.125 |
| 20 | 3.4 | 0.0425 | 3.158251 | 95.75 |
| **Grey** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 47 | 1 | 0 | 0 |
| 5 | 34 | 0.723404 | 0.323787 | 27.65957 |
| 10 | 28 | 0.595745 | 0.517943 | 40.42553 |
| 15 | 19 | 0.404255 | 0.905709 | 59.57447 |
| 20 | 8 | 0.170213 | 1.770706 | 82.97872 |
| 25 | 2 | 0.042553 | 3.157 | 95.74468 |

**Table A.12:** The raw data and real concentration calculation for the degradation of real wastewater effluent

| Yellow | | | | | | |
|---|---|---|---|---|---|---|
| **Time[min]** | **C1** | **v1** | **c2** | **$C_t/C_0$** | **$\ln C_t/C_0$** | **μ** |
| 0 | 5.5 | 5 | 27.5 | 1 | 0 | 0 |
| 30 | 1.3 | 5 | 6.5 | 0.236364 | 1.442384 | 76.36364 |
| 60 | 1.5 | 5 | 7.5 | 0.272727 | 1.299283 | 72.72727 |
| 90 | 5.6 | 1 | 5.6 | 0.203636 | 1.591419 | 79.63636 |
| 120 | 2.6 | 1 | 2.6 | 0.094545 | 2.358675 | 90.54545 |
| **Red** | | | | | | |

| Time[min] | c1 | v2 | C2 | $C_t/C_0$ | ln $C_t/C_0$ | μ |
|---|---|---|---|---|---|---|
| 0 | 2.8 | 5 | 14 | 1 | 0 | 0 |
| 30 | 0.7 | 5 | 3.5 | 0.25 | 1.386294 | 75 |
| 60 | 0.6 | 5 | 3 | 0.214286 | 1.540445 | 78.57143 |
| 90 | 2.9 | 1 | 2.9 | 0.207143 | 1.574347 | 79.28571 |
| 120 | 1.2 | 1 | 1.2 | 0.085714 | 2.456736 | 91.42857 |
| **Grey** | | | | | | |
| **Time[min]** | **C1** | **v1** | **c2** | **$C_t/C_0$** | **ln $C_t/C_0$** | **μ** |
| 0 | 3.1 | 5 | 15.5 | 1 | 0 | 0 |
| 30 | 0.9 | 5 | 4.5 | 0.290323 | 1.236763 | 70.96774 |
| 60 | 0.9 | 5 | 4.5 | 0.290323 | 1.236763 | 70.96774 |
| 90 | 2.7 | 1 | 2.7 | 0.174194 | 1.747588 | 82.58065 |
| 120 | 1.7 | 1 | 1.7 | 0.109677 | 2.210212 | 89.03226 |

**Table A.13:** The raw data and real concentration calculation on the effect of recycling 5%β-FeOOH/$TiO_2$ on the degradation of MO

| **Fist recycle** | | | | |
|---|---|---|---|---|
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 65.41207 | 1 | 0 | 0 |
| 15 | 12.79096 | 0.195544 | 1.631968 | 80.44557 |
| 30 | 1.71924 | 0.026283 | 3.638824 | 97.37168 |
| 45 | 0.60863 | 0.009305 | 4.677252 | 99.06954 |
| **Second recycle** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 71.94616 | 1 | 0 | 0 |
| 15 | 42.26902 | 0.587509 | 0.531864 | 41.2491 |
| 30 | 12.64165 | 0.17571 | 1.738921 | 82.42901 |
| 45 | 1.09922 | 0.015278 | 4.181317 | 98.47216 |
| **Third recycle** | | | | |
| **Time** | **Concentration** | **$C_t/C_0$** | **ln($C_t/C_0$)** | **μ** |
| 0 | 76.83073 | 1 | 0 | 0 |
| 15 | 37.96036 | 0.494078 | 0.705062 | 50.59222 |
| 30 | 9.68389 | 0.126042 | 2.071141 | 87.39581 |
| 45 | 1.565636 | 0.020378 | 3.893313 | 97.96223 |

| Fourth recycle | | | | |
|---|---|---|---|---|
| **Time** | **Concentration** | **$C_t/C_0$** | **$\ln(C_t/C_0)$** | **μ** |
| 0 | 78.658 | 1 | 0 | 0 |
| 15 | 65.33386 | 0.830607 | 0.185599 | 16.93933 |
| 30 | 43.71235 | 0.555727 | 0.587479 | 44.42733 |
| 45 | 24.15274 | 0.30706 | 1.180712 | 69.29398 |

## Appendix B:

**Table B.1:** The raw data and standard deviation calculation on the validation of 5%β-FeOOH/$TiO_2$ on the degradation of MO

| N=4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Concentration (mg/L)** | | | | **$C_t/C_0$** | | | |
| **Time** | **Run 1** | **Run 2** | **Run 3** | **Run 4** | **RUN 1** | **RUN 2** | **RUN 3** | **RUN 4** |
| 0 | 65.0918 | 50.9652 | 50.8106 | 70.9767 | 1 | 1 | 1 | 1 |
| 15 | 37.5655 | 32.7076 | 32.6856 | 46.2353 | 0.6417 | 0.577116 | 0.64328 | 0.65141 |
| 30 | 21.4143 | 14.4730 | 18.7709 | 26.8317 | 0.2839 | 0.328986 | 0.36942 | 0.37803 |
| 45 | 8.48201 | 6.38875 | 6.62311 | 12.6348 | 0.1253 | 0.130308 | 0.13034 | 0.17801 |
| 60 | 1.57959 | 1.25818 | 2.11903 | 2.39736 | 0.0246 | 0.024267 | 0.04170 | 0.03377 |

| **μ** | **xi-μ** | | | | **Standard deviation calculation** | | | |
|---|---|---|---|---|---|---|---|---|
| **Average** | **RUN 1** | **RUN 2** | **RUN 3** | **RUN 4** | **Σ(xi-μ)^2** | **(1/N)Σ(xi-μ)^2** | **sqrt((1/N)Σ(xi-μ)^2)** | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.62839 | 0.00017 | 0.00262 | 0.00022 | 0.00053 | 1.27E-05 | 4.22E-06 | 0.00205 | 0.20552 |
| 0.34010 | 0.00315 | 0.00012 | 0.00085 | 0.00143 | 3.1E-05 | 1.03E-05 | 0.00321 | 0.32170 |
| 0.14100 | 0.00024 | 0.00011 | 0.00011 | 0.00137 | 3.4E-06 | 1.13E-06 | 0.00106 | 0.10638 |
| 0.03110 | 4.12E-05 | 4.68E-05 | 0.00011 | 7.12E-06 | 4.3E-08 | 1.43E-08 | 0.00012 | 0.01197 |

**Table B.2:** The % standard error calculation for the kinetics of different runs of the degradation of MO

| RUN | Reaction rate | Average rate | % standard error |
|---|---|---|---|
| 1 | 0.0602 | 0.05692 | 0.018901 |
| 2 | 0.0595 | 0.05692 | 0.011694 |
| 3 | 0.053 | 0.05692 | 0.026996 |
| 4 | 0.0538 | 0.05692 | 0.017102 |
| INITIAL | 0.0581 | 0.05692 | 0.002446 |

**Table B.3:** Experiment details for the degradation of (80 mg/L) Acid Black using (800 mg/L) of 5% β-FeOOH/$TiO_2$ Catalyst load with $H_2O_2$ concentration of 50 mL/L at ph 4.5

| RUN 1 | | | | | |
|---|---|---|---|---|---|
| **Time (min)** | **Absorbance (abs)** | **Concentration (mg/L)** | **Ct/Co** | **ln(Ct/Co)** | **μ** |
| 0 | 1.01 | 57.19698 | 1 | 0 | 0 |
| 15 | 0.4 | 22.6173 | 0.39542822 | 0.927786 | 60.4572 |
| 30 | 0.21 | 11.84658 | 0.207118977 | 1.57446188 | 79.2881 |
| 45 | 0.125 | 7.0281 | 0.122875369 | 2.0965847 | 87.7125 |
| 60 | 0.087 | 4.873956 | 0.08521352 | 2.46259517 | 91.4786 |
| **RUN 2** | | | | | |
| **Time (min)** | **Absorbance (abs)** | **Concentration (mg/L)** | **Ct/Co** | **ln(Ct/Co)** | μ |
| 0 | 1.08 | 61.16514 | 1 | 0 | 0 |
| 15 | 0.185 | 10.42938 | 0.170511831 | 1.7689506 | 82.9488 |
| 30 | 0.1 | 5.6109 | 0.091733625 | 2.38886628 | 90.8266 |
| 45 | 0.08 | 4.47714 | 0.073197576 | 2.61459297 | 92.6802 |
| 60 | 0.052 | 2.889876 | 0.047247108 | 3.05236382 | 95.2753 |
| **RUN 3** | | | | | |
| **Time (min)** | **Absorbance (abs)** | **Concentration (mg/L)** | **Ct/Co** | **ln(Ct/Co)** | μ |
| 0 | 0.655 | 37.07274 | 1 | 0 | 0 |
| 15 | 0.23 | 12.98034 | 0.35013166 | 1.04944602 | 64.9868 |
| 30 | 0.115 | 6.46122 | 0.174284933 | 1.74706377 | 82.5715 |
| 45 | 0.065 | 3.62682 | 0.097829834 | 2.3245257 | 90.217 |
| 60 | 0.037 | 2.039556 | 0.055014979 | 2.90014979 | 94.4985 |

**Table B.4:** The kinetics of different runs for the degradation of Acid black wastewater

| Kinetics | | | | |
|---|---|---|---|---|
| **Time** | **Run 1** | **Run 2** | **Run 3** | **AVERAGE** |

| | | | | |
|---|---|---|---|---|
| 0 | 0.5749 | 0.1892 | 0.1935 | 0.3192 |
| 15 | 1.2694 | 0.8972 | 0.8025 | 0.9897 |
| 30 | 1.9639 | 1.6052 | 1.4115 | 1.6602 |
| 45 | 2.6584 | 2.3132 | 2.0205 | 2.3307 |
| 60 | 3.3529 | 3.0212 | 2.6295 | 3.0012 |

**Table B.5:** The % standard error calculation for the kinetics of different runs of the degradation of Acid black wastewater

| **(X1 - μ)^2** | **(X2 - μ)^2** | **(X3 - μ)^2** | **Σ(xi-μ)^2** | **(1/N)Σ(xi-μ)^2** | **sqrt((1/N)Σ(xi-μ)^2)** |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0.103003472 | 0.270632 | 0.039713 | 0.413349 | 0.137783 | 0.371191 |
| 0.108242381 | 0.235615 | 0.024461 | 0.368319 | 0.122773 | 0.35039 |
| 0.061826701 | 0.072554 | 0.000429 | 0.13481 | 0.044937 | 0.211982 |
| 0.117265901 | 0.061171 | 0.009047 | 0.187483 | 0.062494 | 0.249989 |

## Appendix C.

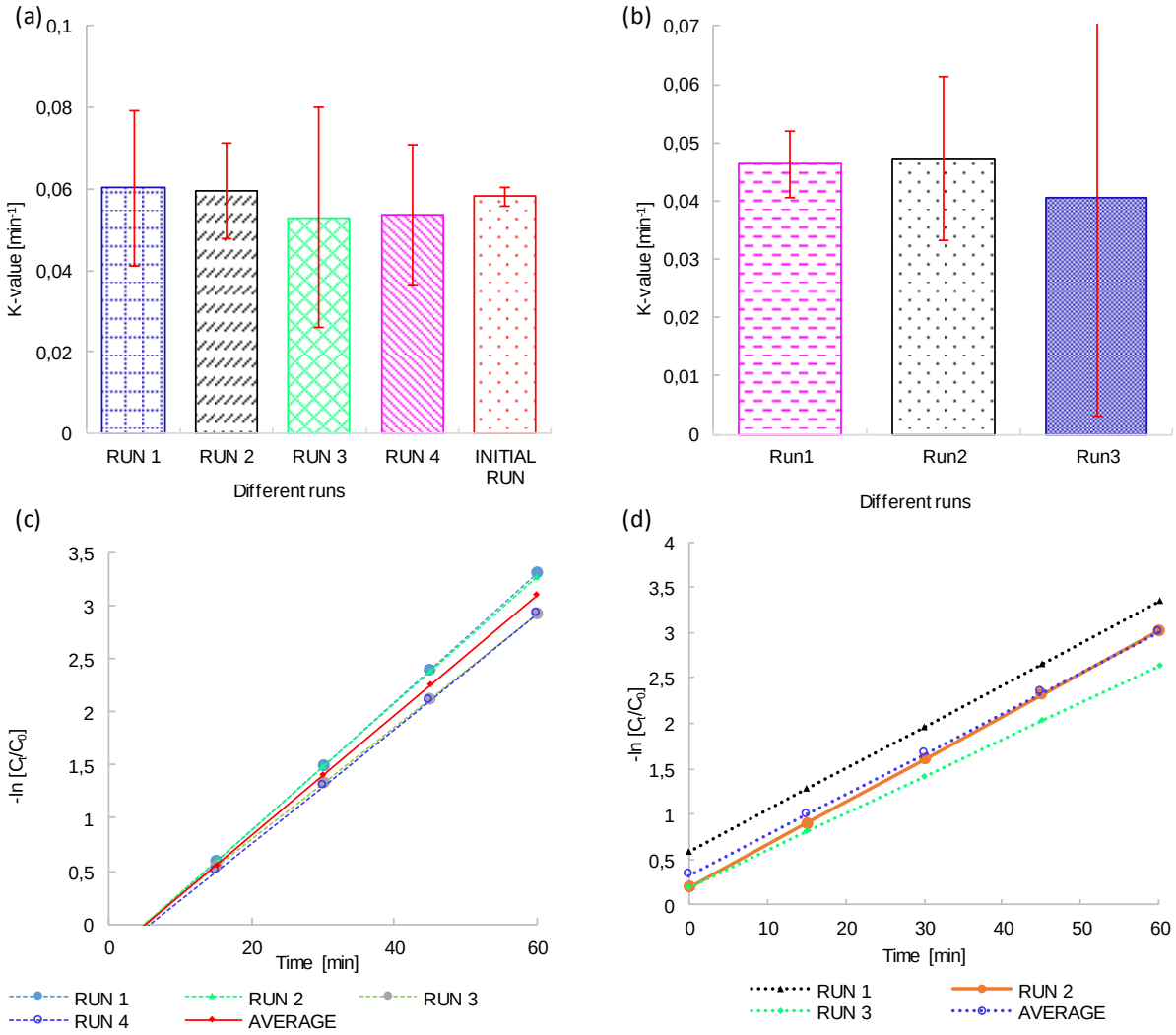


**Figure C.1:** (a) The % error bars calculated for the kinetics of the repeatability of MO and (b) for the repeatability of Acid black. (c) First order reaction rate for MO and (d) First order reaction rate for Acid black