## LIST OF FIGURES

NO.	TITLE	PAGE
CHAPTER 1		
1.1	A simplified view of the water cycle	1
CHAPTER 2		
2.1	Biofilm formation in bioactive activated carbon system	34
2.2	pH profile in photo fenton processes	61
2.3	Schematic representation of the band energetic model of	66
	overall process of semiconductor of photocatalysis for water	
	purification	
2.4	Photo degradation of pentachlorophenol (PCP) sensitizes by	67
	dispersion of semi-conductors	
2.5	The concept of integrated chemical and biological treatment	75
CHAPTER 3		
3.1	Effect of contact time and initial concentration on % removal	115
	of 3-aminophenol by adsorption on fly ash A	
	[Temp.= 30 ±1 °C, pH= 7.0, Adsorbent mass= 2.5 g/100 ml]	
3.2	Effect of contact time and initial concentration on % removal	116
	of 3-aminophenol by adsorption on fly ash A	
	[Temp.= 45 ±1 °C, pH= 7.0, Adsorbent mass= 2.5 g/100 ml]	
3.3	Effect of contact time and initial concentration on % removal	116
	of 3-aminophenol by adsorption on fly ash A	
	[Temp.= 60 ±1 °C, pH= 7.0, Adsorbent mass= 2.5 g/100 ml]	
3.4	Effect of dose of FLY ASH A on percentage removal of	122
	phenols [Temp.= 30 ±1 °C, pH= 7.0, Initial phenol conc.=	
	100 mg/l, contact time= 4 h]	
3.5	Effect of dose of FLY ASH B on percentage removal of	123
	phenols [Temp.= 30 ±1 °C, pH= 7.0, Initial phenol conc.=	
	100 mg/l, contact time= 4 h]	
3.6	Effect of dose of FLY ASH C on percentage removal of	123
	phenols [Temp.= 30 ±1 °C, pH= 7.0, Initial phenol conc.=	
	100 mg/l, contact time= 4 h]	

3.7	Effect of dose of FLY ASH D on percentage removal of	124
	phenols [Temp.= 30 ±1 °C, pH= 7.0, Initial phenol conc.=	
	100  mg/l, contact time= 4 h]	
3.8	Effect of dose of ACTIVATED CARBON on percentage	124
	removal of phenols [Temp.= $30 \pm 1$ °C, pH= 7.0, Initial	
	phenol conc.= 300 mg/l, contact time= 4 h]	
3.9	Effect of Temperature on equilibrium uptake capacity of	128
	adsorbent [Fly Ash A / 3-Aminophenol system]	
3.10	Comparison of experimental and predicted amount of phenol,	131
	catechol, resorcinol, hydroquinone, 2-aminophenol and 3-	
	aminophenol adsorbed on fly ash A	
3.11	van't Hoff plot to calculate equilibrium constant	148
	[Fly Ash A / 3-Aminophenol system]	
3.12	Typical Fractional up take curve (Weber-Morris plot) for 3-	160
	aminophenol adsorption on fly ash A at 30 °C using	
	different initial concentration	
3.13	Plot to determine first order kinetics (Lagergren equation) for	160
	adsorption of 3-aminophenol on fly ash A at 30 °C	
3.14	Plot to calculate effective Diffusion coefficient at 30 °C using	161
	Vermeulen or Urano approximations	-
	[Fly Ash A / 3-Aminophenol system]	
3.15	Typical Fractional up take curve (Weber-Morris plot) for 3-	161
	aminophenol adsorption on fly ash A at 45 °C using different	
	initial concentration	
3.16	Plot to determine first order kinetics (Lagergren equation) for	162
	adsorption of 3-aminophenol on fly ash A at 45 °C	
3.17	Plot to calculate effective Diffusion coefficient at 30°C using	162
	Vermeulen or Urano approximations	
•	[Fly Ash A / 3-Aminophenol system]	
3.18	Typical Fractional up take curve (Weber-Morris plot) for 3-	163
	aminophenol adsorption on fly ash A at 60 °C using different	
	initial concentration	
3.19	Plot to determine first order kinetics (Lagergren equation) for	163

	adsorption of 3-aminophenol on fly ash A at 60 °C	
3.20	Plot to calculate effective Diffusion coefficient at 60 °C using	164
	Vermeulen or Urano approximations [Fly Ash A / 3-	
	Aminophenol system]	
3.21	Plot to determine pseudo second order kinetics for adsorption	164
	of 3-aminophenol on fly ash A at 30°C	
3.22	Plot to determine pseudo second order kinetics for adsorption	165
	of 3-aminophenol on fly ash A at 45°C	
3.23	Plot to determine pseudo second order kinetics for adsorption	165
	of 3-aminophenol on fly ash A at 60°C	
3.24	Pre-exponential factor(Do) and energy of activation(Ed)	166
	determination using Arrhenius equation for diffusion	
	controlled adsorption of 3-aminophenol on fly ash A	

## **CHAPTER 4**

4.1	Biokinetic models	180
4.2	Adapted Pseudomonas aeruginosa (ATCC 9027) in storage	184
	medium	
4.3	Phenol degradation by P. aeruginosa in batch reactor	188
	[Initial conc.= 25 ppm, Temp.= 30°C, pH=7 ]	
4.4	Phenol degradation by P. aeruginosa in batch reactor [Initial	189
	conc.= 50 ppm, Temp.= 30°C, pH=7 ]	
4.5	Phenol degradation by P. aeruginosa in batch reactor	189
	[Initial conc.= 75 ppm, Temp.= 30°C, pH=7]	
4.6	Phenol degradation by P. aeruginosa in batch reactor [Initial	190
	conc.= 100 ppm, Temp.= 30 °C, pH=7]	
4.7	Phenol degradation by P. aeruginosa in batch reactor [Initial	190
	conc.= 200 ppm, Temp.= 30 °C, pH=7]	
4.8	Phenol degradation by P. aeruginosa in batch reactor [Initial	191
	conc.= 300 ppm, Temp.= 30 °C, pH=7]	
4.9	Phenol degradation by P. aeruginosa in batch reactor [Initial	191
	conc.= 400 ppm, Temp.= 30 °C, pH=7]	
4.10	Phenol degradation by <i>P. aeruginosa</i> in batch reactor [Initial	192
	conc.= 500 ppm, Temp.= 30 °C, pH=7]	

.

4.11	Phenol degradation by P. aeruginosa in batch reactor [Initial	192
	conc.= 600 ppm, Temp.= 30 °C, pH=7]	
4.12	Phenol degradation by P. aeruginosa in batch reactor	193
	[Initial conc.= 700 ppm, Temp.= 30 °C, pH=7]	
4.13	Phenol degradation by P. aeruginosa in batch reactor [Initial	193
	conc.= 800 ppm, Temp.= 30 °C, pH=7]	
4.14	3-Aminophenol degradation by P. aeruginosa in batch	194
	reactor [Initial conc.= 25 ppm, Temp.= 30 °C, pH=7]	
4.15	3-Aminophenol degradation by P. aeruginosa in batch	194
	reactor [Initial conc.= 50 ppm, Temp.= 30 °C, pH=7]	
4.16	Aminophenol degradation by P. aeruginosa in batch reactor	195
	[Initial conc.= 75 ppm, Temp.= 30 °C, pH=7]	
4.17	3-Aminophenol degradation by P. aeruginosa in batch	195
	reactor [Initial conc.= 100 ppm, Temp.= 30 °C, pH=7]	
4.18	3-Aminophenol degradation by P. aeruginosa in batch	196
	reactor [Initial conc.= 200 ppm, Temp.= 30 °C, pH=7]	
4.19	3-Aminophenol degradation by P. aeruginosa in batch	196
	reactor [Initial conc.= 300 ppm, Temp.= 30 °C, pH=7]	
4.20	3-Aminophenol degradation by P. aeruginosa in batch	197
	reactor [Initial conc.= 400 ppm, Temp.= 30 °C, pH=7]	
4.21	3-Aminophenol degradation by P. aeruginosa in batch	197
	reactor [Initial conc.= 500 ppm, Temp.= 30 °C, pH=7]	
4.22	Catechol degradation by P. aeruginosa in batch reactor	198
	[Initial conc.= 25 ppm, Temp.= 30 °C, pH=7]	
4.23	Catechol degradation by P. aeruginosa in batch reactor	198
	[Initial conc.= 50 ppm, Temp.= 30 °C, pH=7]	
4.24	Catechol degradation by P. aeruginosa in batch reactor	1 <b>99</b>
٩	[Initial conc.= 75 ppm, Temp.= 30 °C, pH=7]	
4.25	Catechol degradation by P. aeruginosa in batch reactor	199
	[Initial conc.= 100 ppm, Temp.= 30 °C, pH=7]	
4.26	Catechol degradation by P. aeruginosa in batch reactor	200
	[Initial conc.= 200 ppm, Temp.= 30 °C, pH=7]	

•

4.27	Catechol degradation by P. aeruginosa in batch reactor	200
	[Initial conc.= 300 ppm, Temp.= 30 °C, pH=7]	
4.28	Catechol degradation by P. aeruginosa in batch reactor	201
	[Initial conc.= 400 ppm, Temp.= 30 °C, pH=7]	
4.29	Catechol degradation by P. aeruginosa in batch reactor	201
	[Initial conc.= 500 ppm, Temp.= 30 °C, pH=7]	
4.30	Catechol degradation by P. aeruginosa in batch reactor	202
	[Initial conc.= 600 ppm, Temp.= 30 °C, pH=7]	
4.31	Behavior of time lag in biodegradation of phenol using	203
	P. aeruginosa	
4.32	Behavior of time lag in biodegradation of catechol using	203
	P. aeruginosa	
4.33	Behavior of time lag in biodegradation of 3-aminophenol	204
	using P. aeruginosa	
4.34	Determination of specific growth rate in the region of	205
	exponential phase of batch growth curve	
4.35	Monod's growth kinetic model fitted to batch growth data to	207
	evaluate $\mu_{max}$ and $K_s$	
	[Phenol/ P. aeruginosa system, Conc. Range 0-50 ppm]	
4.36	Linearized Haldane's growth kinetic model fitted to batch	208
	growth data to evaluate $\mu_{max}$ and $K_i$	
	[Phenol/ P. aeruginosa system, Conc. Range 50-800 ppm]	
4.37	Haldane's kinetic model fitted to batch growth data to	208
	evaluate $\mu_{max}$ , $K_s$ and $K_i$	
	[Phenol/ P. aeruginosa system, Conc. Range 0-800 ppm]	
4.38	Monod's growth kinetic model fitted to batch growth data to	209
	evaluate $\mu_{max}$ and $K_s$	
	[Catechol / P. aeruginosa system, Conc. Range 0-50 ppm]	
4.39	Linearized Haldane's growth kinetic model fitted to batch	209
, ,	growth data to evaluate $\mu_{max}$ and $K_i$	
	[Catechol / P. aeruginosa system, Conc. Range 50-600 ppm]	
4.40	Haldane's kinetic model fitted to batch growth data to	210
	evaluate $\mu_{max}$ , $K_s$ and $K_i$	
	[Catechol/ P. aeruginosa system, Conc. Range 0-600 ppm]	

4.41	Linearized Haldane's growth kinetic model fitted to batch	210
•	growth data to evaluate $\mu_{max}$ and K <sub>i</sub> [3-Aminophenol / P.	
ł	aeruginosa system, Conc. Range 0-500 ppm]	
4.42	Haldane's kinetic model fitted to batch growth data to	211
	evaluate $\mu_{max}$ , K <sub>s</sub> and K <sub>i</sub> [3-aminophenol / P. aeruginosa	
	system, Conc. Range 0-500 ppm]	
4.43	Complete batch growth cycle for Phenol/ P. aeruginosa	212
	system	
4.44	Decay coefficient Kd evaluation for Phenol/ P. aeruginosa	213
	system using decay phase batch kinetic experimental studies	
4.45	Complete batch growth cycle for Catechol/ P. aeruginosa	213
	system	
4.46	Decay coefficient Kd evaluation for Catechol/ P. aeruginosa	214
	system using decay phase batch kinetic experimental studies	
4.47	Complete batch growth cycle for 3-Aminophenol/P	214
	aeruginosa system	
4.48	Decay coefficient $K_d$ evaluation for 3-Aminophenol/ $P$ .	214
	aeruginosa system using decay phase batch kinetic	
	experimental studies	
4.49	Yield coefficient calculation for Phenol/ P. aeruginosa	215
	system.	
4.50	Yield coefficient calculation for Catechol/ P. aeruginosa	216
	system	
4.51	Yield coefficient calculation for 3-Aminophenol/ P.	216
,	aeruginosa system.	
CHAPTER 5		
5.1	Comparison of different isotherm models for phenol	225
	adsorption on activated carbon with experimental results	
5.2	Comparison of experimental and predicted amount of phenol	226
	adsorbed on activated carbon	
5.3	Typical Fractional up take curve (Weber-Morris plot) for	227
	phenol adsorption on activated carbon using different initial	
	concentration	

5.4	Plot to determine first order kinetics (Lagergren equation) for	227
:	phenol adsorption on activated carbon	
5.5	Plot to calculate effective diffusion coefficient using	228
	Vermeulen or Urano approximations [Activated carbon /	
	Phenol system]	
5.6	Plot to determine pseudo second order kinetics for adsorption	228
	of phenol on activated carbon	
5.7	Effect of ACTIVATED CARBON dose on percentage	232
;	removal of phenols [Temp.= 30 ±1 °C, pH= 7.0 Initial	
ŗ	phenol conc.= 800 mg/l, contact time= 48 h]	
CHAPTER 6		
6.1	Phenol removal by a coupled system of P. aeruginosa and	240
•	activated carbon in batch reactor [Temp. = 30 °C, pH=7]	
6.2	Catechol removal by a coupled system of P. aeruginosa and	240
	activated carbon in batch reactor [Temp. = 30 °C, pH=7]	
6.3	3-Aminophenol removal by a coupled system of P.	241
	aeruginosa and activated carbon in batch reactor	
	[Temp. = 30 °C, pH=7]	
6.4	Scanning Electron Micrograph of Virgin Carbon at low	243
	magnification	
6.5	Scanning Electron Micrograph showing partial biofilm on	244
	activated carbon	
	[P.Aeruginosa/ Activated carbon / Phenol system]	
6.6	Scanning Electron Micrograph showing partial biofilm on	244
	activated carbon	
	[P. aeruginosa/ Activated carbon / Phenol system]	
6.7	Scanning Electron Micrograph showing partial biofilm on	245
	activated carbon	
	[P. aeruginosa/ Activated carbon / 3-Aminophenol system]	
6.8	Scanning Electron Micrograph of Virgin Carbon at medium	245
	magnification	
6.9	Scanning Electron Micrograph showing biofilm in pits and	246
	crevices of activated carbon	
	[P. aeruginosal Activated carbon / Phenol system]	

xviii

6.10	Scanning Electron Micrograph showing biofilm in pits and	246
	crevices of activated carbon	
1	[P. aeruginosa/ Activated carbon / Catechol system]	
6.11	Scanning Electron Micrograph showing biofilm in pits and	247
	crevices of activated carbon	
	[P. aeruginosal Activated carbon / 3-Aminophenol system]	
6.12	Scanning Electron Micrograph showing smear on virgin	247
	carbon at high magnification	
6.13	Scanning Electron Micrograph showing smear in biofilm on	248
	activated carbon	
	[P. aeruginosal Activated carbon / Phenol system]	
6.14	Scanning Electron Micrograph showing smear in biofilm on	248
	activated carbon	
	[P. aeruginosal Activated carbon / Catechol system]	
6.15	Scanning Electron Micrograph showing smear in biofilm on	249
	activated carbon	
	[P. aeruginosal Activated carbon / 3-Aminophenol system]	
6.16	Scanning Electron Micrograph of virgin carbon for biofilm	249
	thickness determination	
6.17	Scanning Electron Micrograph for biofilm thickness	250
	determination	
	[P. aeruginosal Activated carbon / Phenol system]	
6.18	Scanning Electron Micrograph for biofilm thickness	250
;	determination	
,	[P. aeruginosal Activated carbon / Catechol system]	
6.19	Scanning Electron Micrograph for biofilm thickness	251
	determination	
	[P. aeruginosal Activated carbon / 3-Aminophenol system]	
CHAPTER 7		
7.1	Comparison of Biodegradation, Adsorption and Biosorption	258
	for phenol removal	
	[Initial conc.= 800 ppm, pH=7.0, Temp.= 30°C]	
	_*_*_*_	