

# CONTENTS

---

Title page.....	i
Certificate.....	ii
Declaration by the candidate.....	iii
Copyright transfer certificate.....	iv
Acknowledgment.....	v
Contents.....	vii
List of table.....	xiii
List of figure .....	xvi
Abbreviations & notations .....	xxi
Preface.....	xxiii

## CHAPTER – I : INTRODUCTION

1.1. General.....	1
1.2. Historical background of pesticides .....	1
1.3. Classification of pesticides.....	2
1.4. Usage of pesticides .....	5
1.4.1. World scenario of pesticides.....	7
1.4.2. Indian scenario of pesticides.....	8
1.5. Sources of pesticides in environment .....	12
1.6. Adverse effects of pesticides.....	13
1.6.1. Health effects .....	13
1.6.2. Environmental effects .....	14
1.7. Pesticides regulations.....	15
1.8. Pesticides control technologies .....	15
1.8.1. Adsorption .....	16
1.8.2. Coagulation-flocculation .....	17
1.8.3. Photo-degradation .....	18
1.8.4. Oxidation process.....	18
1.8.5. Gamma radiation.....	19
1.8.6. Biodegradation .....	19
1.9. Problem identification .....	19
1.10. Objective of the present study.....	20

**CHAPTER – II : THEORY AND LITERATURE REVIEW**

2.1. Methyl parathion .....	22
2.1.1. Environmental levels of methyl parathion.....	23
2.1.1.1. Air .....	23
2.1.1.2. Soil and water .....	23
2.1.1.3. Food .....	23
2.1.2. Toxicity of methyl parathion .....	24
2.1.3. Effect of methyl parathion .....	25
2.1.4. Guideline value of methyl parathion .....	25
2.1.5. Uses of methyl parathion.....	25
2.1.6. Reaction pathway of methyl parathion .....	25
2.1.7. Technologies used for methyl parathion degradation.....	27
2.1.7.1. Adsorption.....	27
2.1.7.2. Cavitation and sonication.....	30
2.1.7.3. Photocatalytic degradation.....	32
2.1.7.4. Fenton oxidation .....	35
2.1.7.5. Electro-Fenton process.....	35
2.1.7.6. Electrochemical oxidation.....	38
2.1.7.7. Ozonation .....	40
2.1.7.8. Sonocatalytic degradation .....	40
2.1.7.9. Other techniques .....	42
2.2. Chlorpyrifos .....	42
2.2.1. Environmental levels of chlorpyrifos .....	43
2.2.1.1. Air .....	43
2.2.1.2. Soil and water .....	43
2.2.1.3. Food .....	44
2.2.2. Toxicity of chlorpyrifos.....	44
2.2.3. Effect of chlorpyrifos.....	44
2.2.4. Guideline value of chlorpyrifos .....	44
2.2.5. Uses of chlorpyrifos.....	45
2.2.6. Reaction pathway of chlorpyrifos.....	45
2.2.7. Technologies used for chlorpyrifos degradation .....	46
2.2.7.1. Irradiation process.....	47

2.2.7.2. Biodegradation .....	48
2.2.7.3. Fenton and photo-Fenton.....	55
2.2.7.4. Photocatalytic degradation .....	58
2.2.7.5. Electrocoagulation method.....	60
2.3. Carbofuran .....	62
2.3.1. Environmental levels of carbofuran .....	62
2.3.1.1. Air.....	62
2.3.1.2. Soil and water .....	63
2.3.1.3. Food.....	63
2.3.2. Toxicity of carbofuran.....	64
2.3.3. Effect of carbofuran .....	64
2.3.4. Guideline value of carbofuran.....	65
2.3.5. Uses of carbofuran .....	65
2.3.6. Reaction pathway of carbofuran .....	66
2.3.7. Technologies used for carbofuran degradation .....	68
2.3.7.1. Adsorption .....	68
2.3.7.2. Photocatalytic degradation .....	73
2.3.7.3. Fenton oxidation and photo-Fenton.....	78
2.3.7.4. Other techniques .....	79

**CHAPTER – III : TREATMENT PROCESS**

3.1. Coagulation-flocculation .....	81
3.1.1. Background of coagulation-flocculation process.....	81
3.1.2. Hydrolysis of Al(III) and Fe(III).....	82
3.1.3. Coagulation mechanisms .....	83
3.1.4. Coagulants.....	85
3.2 Fenton oxidation .....	86
3.2.1. Fenton reaction mechanism.....	86
3.2.2. Iron as Fenton catalyst .....	89

**CHAPTER – IV : PROCESS OPTIMIZATION TECHNIQUES**

4.1. Response surface methodology .....	90
4.1.1. Central composite design .....	91
4.1.2. Analysis of variance .....	92

---

4.2. Modeling uses adaptive neuro-fuzzy inference system.....	93
4.2.1. ANFIS architecture.....	94
4.2.2. The index.....	97
<b>CHAPTER – V : EXPERIMENTATION</b>	
5.1. Experimental programme.....	98
5.2. Preparation of simulated wastewater.....	98
5.3. Chemicals used.....	99
5.4. Coagulation-flocculation study.....	101
5.4.1. Experimental programme.....	101
5.4.2. Experimental set-up.....	102
5.4.2.1. Effect of pH.....	103
5.4.2.2. Effect of coagulant dose.....	103
5.4.2.3. Effect operating time and initial pesticide concentration.....	103
5.5. Fenton oxidation study.....	104
5.5.1. Experimental programme.....	104
5.5.2. Experimental procedure.....	105
5.5.2.1. Effect of pH.....	106
5.5.2.2. Effect of H <sub>2</sub> O <sub>2</sub> concentration.....	107
5.5.2.3. Effect of ferrous iron dosage.....	107
5.5.2.4. Effect of pesticide concentration.....	107
5.5.2.5. Effect of temperature.....	107
5.5.4. Kinetic models.....	107
5.6. Coupled Fenton and coagulation study.....	108
5.7. Toxicity study.....	109
5.7.1. Cell lines and cell culture.....	109
5.7.2. Cell proliferation assay.....	110
5.7.3. In-vitro cytotoxicity assay.....	110
5.7.4. Cell viability assay.....	111
5.7.5. Hemolysis assay.....	111
5.7.6. Statistical analysis.....	112
5.8. Analysis and instrumentation.....	113
5.8.1. pH meter.....	113
5.8.2. Determination of pesticide concentration.....	113

5.8.3. COD analysis .....	113
5.8.4. FTIR analysis .....	115
5.8.5. SEM/EDX analysis of flocs .....	115
5.8.6. TGA/DTA analysis of flocs .....	115
5.8.7. H <sub>2</sub> O <sub>2</sub> determination .....	116
 <b>CHAPTER – VI : RESULTS AND DISCUSSIONS</b>	
6.1. Coagulation-flocculation .....	118
6.1.1. Analysis of results of experiments .....	118
6.1.2. Data analysis and experimental design .....	118
6.1.3. Analysis of variance for CPF reductionl.....	120
6.1.4. Response surface and contour plots .....	124
6.1.5. Effect of pH on treatment of MP, CPF and CF.....	125
6.1.6. Effect of coagulant dose on treatment of MP, CPF and CF.....	131
6.1.7. Effect of operating time and initial pesticide concentration .....	136
6.1.8. Adsorption isotherm.....	139
6.1.9. Settling characteristic of the flocs .....	144
6.1.10. FTIR spectroscopic analysis of sludge.....	152
6.1.11. Microstructural and EDX analysis .....	158
6.1.12. Thermal analysis of residue (TGA-DTA).....	161
6.2 Fenton oxidation .....	165
6.2.1. Analysis of results of experiments .....	165
6.2.2. Data analysis and experimental design.....	165
6.2.3. ANOVA regression analysis .....	167
6.2.4. Response surface and contour plots .....	170
6.2.5. Test of ANFIS model .....	172
6.2.6. Effect of initial pH on treatment of MP, CPF and CF.....	176
6.2.7. Effect of hydrogen peroxide dosage on treatment of MP, CPF and CF .....	179
6.2.8. Hydrogen peroxide consumption .....	181
6.2.9. Effect of ferrous iron dosage on treatment of MP, CPF and CF.....	184
6.2.10. Effect of initial concentration on treatment of MP, CPF and CF.....	187
6.2.11. Effect of temperature on treatment of MP, CPF and CF.....	189
6.2.12. Degradation kinetics of MP, CPF and CF.....	191
6.3. Coupled Fenton and coagulation process .....	195

6.4. Toxicity analysis of pre- and post-Fenton oxidation.....	197
6.4.1. Improved proliferation of U-87 cells following Fenton oxidation .....	197
6.4.2. Tolerance DC and Lymphocytes .....	199
6.4.3. Toxicity to RBC.....	199
<b>CHAPTER – VII : CONCLUSIONS AND RECOMMENDATIONS</b>	
7.1. Conclusions .....	202
7.2. Suggestions for future work .....	206
REFERENCES .....	207
APPENDIX .....	228
PUBLICATIONS .....	251