Table of contents

Title                                                                 Pg. No.

Certificates                                                    i
Acknowledgements                                               iii
Table of contents                                              v
List of figures                                                 xi
List of tables                                                  xiv
List of abbreviations and symbols                               xvii
Abstract                                                       xix

Chapter 1: Introduction and background                          1

1.1 Need of pure water                                          2
1.2 Major constituents of water pollutants                      2
    1.2.1 Contamination of water resources due to pesticides    3
1.3 Conventional methods used for the treatment of wastewater  4
    and their limitations
1.4 Advanced oxidation processes (AOPs)                         5
1.5 Cavitation                                                  6
    1.5.1 Types of cavitation                                   7
    1.5.2 Acoustic cavitation                                   8
    1.5.3 Hydrodynamic cavitation                               9
1.6 Fenton process                                              11
1.7 Photo-Fenton process                                        12
1.8 Photocatalytic process                                      13
    1.8.1 Photocatalysts                                       15
1.9 Oxidation using various combinations of ozone, H\textsubscript{2}O\textsubscript{2} and UV  16
1.10 Limitations of individual AOPs                             17
    1.10.1 Limitations of Fenton process                        17
    1.10.2 Limitations of ozonation process                    18
    1.10.3 Limitations of photocatalytic process               18
    1.10.4 Limitations of cavitation processes                 18
1.11 Need of hybrid techniques based on cavitation              19
Chapter 2: Literature Survey

2.1 Introduction

2.2 Degradation of organic pollutants using ultrasound cavitation (US)

2.3 Degradation of organic pollutants using hydrodynamic cavitation (HC)

2.4 Degradation of organic pollutants using cavitation based hybrid techniques
   2.4.1 Combination of ultrasound cavitation and hydrogen Peroxide, US + H\textsubscript{2}O\textsubscript{2}
   2.4.2 Combination of hydrodynamic cavitation and hydrogen Peroxide, HC + H\textsubscript{2}O\textsubscript{2}
   2.4.3 Combination of ultrasound cavitation and Fenton process, US + Fenton
   2.4.4 Combination of hydrodynamic cavitation and Fenton Process, HC + Fenton
   2.4.5 Combination of ultrasound cavitation and ozone, US + Ozone
   2.4.6 Combination of hydrodynamic cavitation and ozone, HC + Ozone
   2.4.7 Combination of ultrasound cavitation and photocatalytic Process, Sono-photocatalytic process
   2.4.8 Combination of hydrodynamic cavitation and photocatalytic process

2.5 Degradation of selected organic pollutants
   2.5.1 Degradation of imidacloprid
   2.5.2 Degradation of methomyl
   2.5.3 Treatment of pesticide industry effluent

2.6 Overall findings from the literature review

2.7 Scope of the present work based on the gaps of the earlier studies

2.8 Processes studied in the present work

References
Chapter 3: Intensification of degradation of imidacloprid by using hydrodynamic cavitation in combination with other AOPs

3.1 Introduction

3.2 Materials and methods

3.2.1 Materials

3.2.2 Experimental set-up

3.2.3 Degradation using hydrodynamic cavitation

3.2.4 Degradation using hydrodynamic cavitation based hybrid Techniques

3.2.5 Analytical methods

3.3 Results and discussion

3.3.1 Flow characteristics of cavitating device and effect of cavitation number

3.3.2 Effect of inlet pressure

3.3.3 Effect of operating pH

3.3.4 Hydrodynamic cavitation (HC) and H₂O₂ process

3.3.5 Hydrodynamic cavitation + Fenton process

3.3.6 Hydrodynamic cavitation + Photo-Fenton process

3.3.7 Hydrodynamic cavitation + Photolytic process

3.3.8 Hydrodynamic cavitation + Photocatalytic process

3.3.9 Comparison of energy efficiency based on cavitation yield

3.3.10 Mineralization study

3.3.11 Possible degradation byproducts and reaction mechanism

3.4 Conclusions

3.5 Need for the study of degradation of an additional pesticide

References

Chapter 4: Effect of process intensifying parameters on the hydrodynamic cavitation based degradation of commercial pesticide (Methomyl)

4.1 Introduction

4.2 Materials and methods

4.2.1 Materials
5.3.1 Characterisation of graphene oxide (GO) 148
5.3.2 Characterisation of anatase TiO$_2$ and rGO- TiO$_2$ nano-composite 150
5.3.3 Effect of the power density 152
5.3.4 Effect of the initial pH of solution 155
5.3.5 Combination of ultrasonic cavitation and H$_2$O$_2$ 156
5.3.6 Combination of ultrasonic cavitation and Fenton process 159
5.3.7 Combination of ultrasonic cavitation and photo-Fenton process 161
5.3.8 Sono-photocatalytic degradation of methomyl using anatase TiO$_2$ 163
5.3.9 Enhancement in the photocatalytic and sono-photocatalytic degradation of methomyl using rGO-TiO$_2$ nano-composite 165
5.3.10 Synergistic effect of coupling ultrasound cavitation and photocatalytic process 168
5.3.11 Mineralization study 170
5.3.12 Power consumption and cost effectiveness of various processes 171
5.3.13 Comparison of ultrasound and hydrodynamic cavitation based hybrid processes 173
5.4 Conclusions 176
5.5 Need for the study of treatment of actual pesticide industry effluent 178
Appendix 5A 178
Appendix 5B 179
References 180

Chapter 6: Treatment of the pesticide industry effluent using hydrodynamic cavitation and its combination with process intensifying additives 185
6.1 Introduction 186
6.2 Materials and methods 188
   6.2.1 Materials 188
   6.2.2 Experimental set-up 188
   6.2.3 Experimental methodology 188
   6.2.4 Analysis 190
6.3 Results and discussion

6.3.1 Effect of dilution of COD reduction using hydrodynamic cavitation (HC) 190

6.3.2 Effect of loading of ozone on the mineralization of the effluent using HC + Ozone 193

6.3.3 Effect of HC and HC + Ozone processes on the biodegradability index 195

6.3.4 Effect of loading of H$_2$O$_2$ on the TOC reduction using HC+ H$_2$O$_2$ process 197

6.3.5 Influence of H$_2$O$_2$ on the standard COD estimation of the effluent 199

6.3.6 Effect of loading of H$_2$O$_2$ on the rate of COD reduction Using HC+ H$_2$O$_2$ process (based on corrected COD values) 201

6.3.7 Comparison of energy efficiency and cost effectiveness 204

6.4 Conclusions 206

Appendix 6A 207

References 207

Chapter 7: Overall conclusions 210

Chapter 8: Recommendations for the future Work 214

List of publications 216