

TABLE OF CONTENTS

	Page
Acknowledgements	iii
Abstract (Thai)	v
Abstract (English)	vii
Table of contents	ix
List of tables	xiii
List of figures	xiv
Abbreviations	xvii
Chapter 1 Introduction	1
1.1 Principles and rationale	1
1.2 General objectives	2
1.3 Usefulness of research	3
Chapter 2 Literature reviews	4
2.1 Bird chilli	4
2.1.1 Nutritive value and medicinal use of chilli	5
2.1.2 Diseases and pests of chilli	6
2.1.4 Harvesting and yield	9
2.1.5 Storage conditions	10
2.2 Principles of insect-pest control	10
2.2.1 Physical and mechanical control	10
2.2.2 Cultural control	11
2.2.3 Host plant resistance	11
2.2.4 Biological control	11
2.2.5 Legislative or regulatory method	12
2.2.6 Chemical control	12
2.3 Concerns about pesticides	13

TABLE OF CONTENTS (continued)

	Page
2.4 Chlorpyrifos	14
2.4.1 Chemical and properties of chlorpyrifos	14
2.4.2 Mode of action	16
2.4.3 Acute toxicity	17
2.4.4 Environmental levels and human exposure	18
2.4.5 Kinetics and metabolism in laboratory animals and humans	19
2.4.6 Effects on laboratory animals and <i>in vitro</i> test systems	19
2.4.7 Effect on humans	22
2.5 Strategies for pesticides removal	23
2.5.1 Washing with salt	23
2.5.2 Potassium permanganate	23
2.5.3 Washing with detergent	23
2.5.4 Washing with vinegar	24
2.5.5 Using a commercial fruit cleaner	24
2.5.6 Fruit and vegetable super-cleaner	24
2.5.7 Rinsing with tap water	24
2.5.8 Blanching	25
2.6 Advanced oxidation processes	25
2.7 Ultrasonication	26
2.7.1 The sonochemical hot-spot	28
2.7.2 Sonochemistry in homogeneous liquids	29
2.7.3 Ultrasonication for chemical degradation	29
2.8 Ozonation	31
2.8.1 Chemical and physical properties of ozone	31
2.8.2 Ozone generation	32
2.8.3 Ozone decomposition in water	33
2.8.4 Ozone for chemical degradation	35
2.9 Combination of ultrasonication and ozone for chemical degradation	36

TABLE OF CONTENTS (continued)

	Page
2.10 Bioassay systems and techniques	37
2.10.1 <i>in vivo</i> techniques	37
2.10.2 <i>in vitro</i> techniques	37
2.10.3 <i>ex vivo</i> techniques	38
2.11 Brine shrimp bioassay for chemical toxicity test	38
Chapter 3 Optimum conditions and oxidative degradation of treated chlorpyrifos solution by ultrasonication and ozonation	40
3.1 Introduction	41
3.2 Materials and methods	42
3.2.1 Degradation percentage of chlorpyrifos by ultrasonication, ozonation and the combination	45
3.2.2 Oxidative degradation of treated chlorpyrifos solution by ultrasonication, ozonation and the combination	48
3.3 Results and discussion	48
3.3.1 Degradation percentage of chlorpyrifos by ultrasonication, ozonation and the combination	60
3.3.2 Oxidative degradation of treated chlorpyrifos solution by ultrasonication, ozonation and the combination	78
3.4 Conclusion	77
Chapter 4 Reduction of chlorpyrifos in fresh bird chilli using ultrasonication and ozonation	79
4.1 Introduction	79
4.2 Materials and methods	80
4.2.1 Chlorpyrifos degradation in fresh bird chilli after washing using ultrasonication and ozonation	81
4.2.2 Effects of ultrasonication and ozonation on postharvest qualities of bird chilli	81

TABLE OF CONTENTS (continued)

	Page
4.3 Results and discussion	84
4.3.1 Chlorpyrifos degradation in fresh bird chilli after washing using ultrasonication and ozonation	84
4.3.2 Effects of ultrasonication and ozonation on postharvest qualities of bird chilli	90
4.4 Conclusion	102
Chapter 5 Toxicity of degraded chlorpyrifos and wastewater after washed chilli by ultrasonication and ozonation	103
5.1 Introduction	103
5.2 Materials and methods	103
5.2.1 Toxicity of degraded chlorpyrifos after ultrasonication and ozonation by bioassay method	103
5.2.2 Toxicity of wastewater from chilli washing with ultrasonication and ozonation by bioassay method	105
5.3 Results and discussion	106
5.3.1 Toxicity of degraded chlorpyrifos after ultrasonication and ozonation by bioassay method	106
5.3.2 Toxicity of wastewater from chilli washing with ultrasonication and ozonation by bioassay method	111
5.4 Conclusion	114
Chapter 6 Overall conclusion	115
References	117
Appendix	129
Curriculum vitae	155


 The logo of Chiang Mai University is a large, faint watermark in the background. It features a central figure of a person holding a torch, surrounded by a circular border with the university's name in Thai and English. The Thai text at the top reads 'มหาวิทยาลัยเชียงใหม่' and at the bottom 'CHIANG MAI UNIVERSITY 1964'.

LIST OF TABLES

Table	Page
2.1 Bird chilli nutrition	6
2.2 Chilli diseases	7
2.3 Chilli pests	8
2.4 Pesticide residue in chilli	13
2.5 Physico-chemical properties of chlorpyrifos	15
2.6 Chlorpyrifos properties and toxicity	17
2.7 Chlorpyrifos toxicity categories	18
2.8 Oxidation-reduction potential of chemical species used in water treatment	26
2.9 Physico-chemical properties of ozone	31
3.1 The first-order kinetic model fitted to the chlorpyrifos degradation	59
5.1 LC ₅₀ values at 18 h to the brine shrimp (<i>Artemia salina</i> L.) toxicity of chlorpyrifos after ultrasonication or/and ozonation treatments for 60 min	107

LIST OF FIGURES

Figure	Page
2.1 Parts of bird chilli	5
2.2 Anthracnose symptoms on chilli fruits	9
2.3 Caterpillar and symptoms in chilli	9
2.4 Chilli thrip	9
2.5 Chlorpyrifos structure	14
2.6 The origin of sonochemistry	28
2.7 Cavitation bubble formation and collapse	29
2.8 Molecular structure of ozone	31
2.9 Ozone generator by corona discharge	32
3.1 Ultrasonic devices at 108, 400, 700 kHz and 1 MHz	42
3.2 Gas chromatography-flame photometric detector	43
3.3 Schematic diagram of experimental set-up	44
3.4 Ion chromatography	46
3.5 Gas chromatography-mass spectrometry	47
3.6 Degradation percentage of standard chlorpyrifos by ultrasonication	50
3.7 The changes of chlorpyrifos concentration and the degradation kinetics of chlorpyrifos under ultrasonication	51
3.8 Degradation percentage of standard chlorpyrifos by ozonation	53
3.9 The changes of chlorpyrifos concentration and the degradation kinetics of chlorpyrifos under ozonation	54
3.10 Degradation percentage of standard chlorpyrifos by ultrasonication and ozonation	57
3.11 The changes of chlorpyrifos concentration and the degradation kinetics of chlorpyrifos under ultrasonication combined with ozonation	58
3.12 Temperature of chlorpyrifos solution after treated with ultrasonication, ozonation and the combination treatments	63
3.13 pH of chlorpyrifos solution after treated with ultrasonication, ozonation and the combination treatments	64

LIST OF FIGURES (continued)

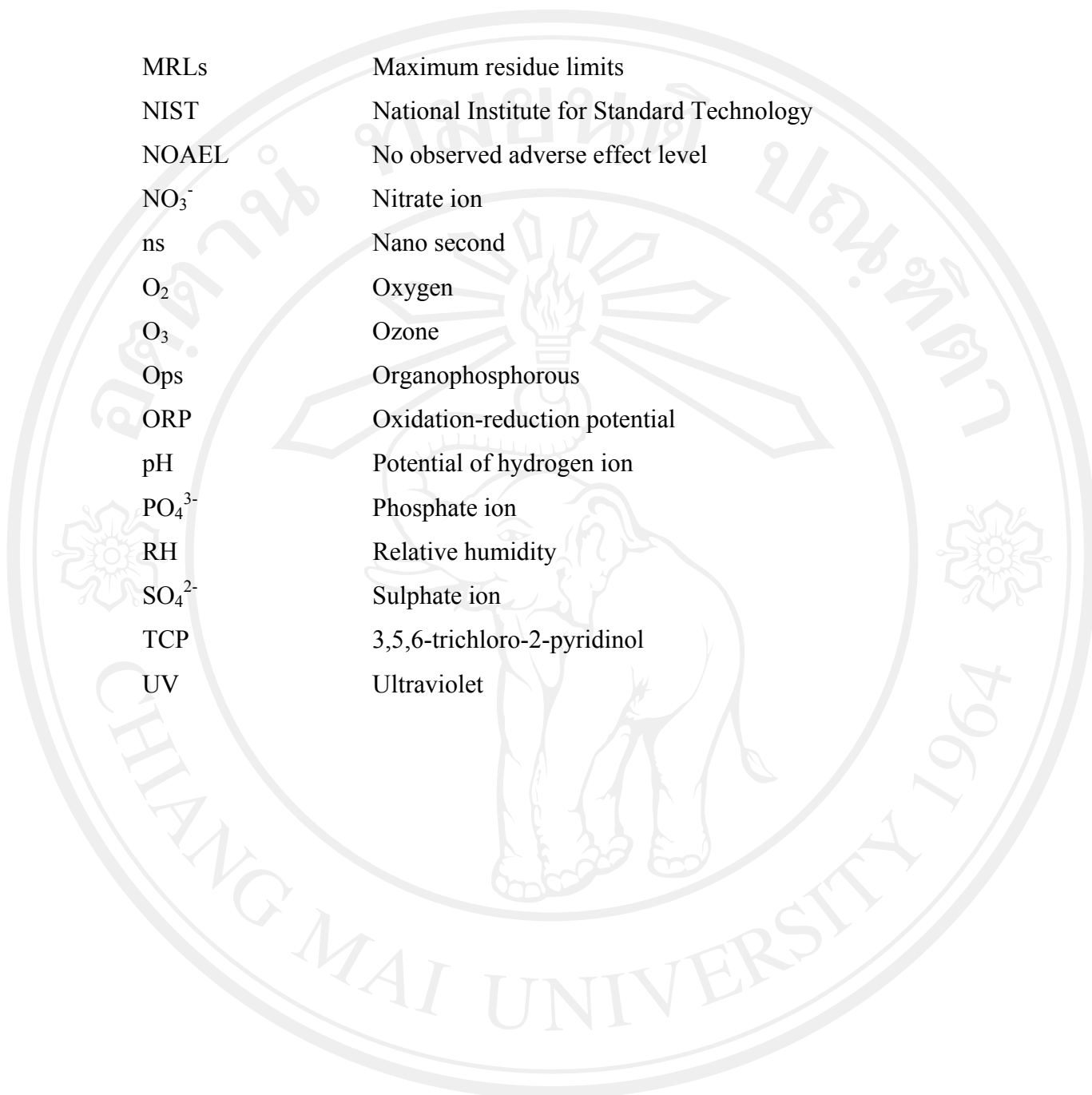
Figure	Page
3.14 Oxidation reduction potential of chlorpyrifos solution after treated with ultrasonication, ozonation and the combination treatments	65
3.15 Chloride concentration of chlorpyrifos solution after treated with ultrasonication, ozonation and the combination treatments	66
3.16 Nitrate concentration of chlorpyrifos solution after treated with ultrasonication, ozonation and the combination treatments	67
3.17 Sulphate concentration of chlorpyrifos solution after treated with ultrasonication, ozonation and the combination treatments	70
3.18 GC-MS chromatograms of chlorpyrifos after treated by ultrasonication, ozonation and the combination for 60 min	72
3.19 GC-MS spectra of chlorpyrifos after treated by ultrasonication, ozonation and the combination for 60 min	73
3.20 Chlorpyrifos degradation pathway 1 by ultrasonication in combination with ozonation	75
3.21 Chlorpyrifos degradation pathway 2 by ultrasonication in combination with ozonation	77
4.1 Ultrasonic device at 1 MHz for chilli washing	80
4.2 Packed bird chilli stored in refrigerator at 13 °C and 95 % RH	83
4.3 Chlorpyrifos degradation in bird chilli after ultrasonication	86
4.4 Chlorpyrifos degradation in bird chilli after ozonation	87
4.5 Chlorpyrifos degradation in bird chilli after 1 MHz ultrasonication combined with ozonation	88
4.6 Chlorpyrifos concentration in bird chilli after ultrasonication combined with ozone treatment	89
4.7 Weight loss of bird chilli fruits after washing with distilled water, ultrasonication, ozonation and the combination for 60 min during storage at 13 °C for 4 weeks.	93
4.8 Disease incidence of bird chilli using ultrasonication, ozonation and the combination treatment, after storage at 13 °C for 4 weeks	94

LIST OF FIGURES (continued)

Figure		Page
4.9	L* value of bird chilli peel color treated with ultrasonication at 1 MHz, ozonation and combination for 60 min during storage at 13 °C for 4 weeks	95
4.10	a* value of bird chilli peel color treated with ultrasonication at 1 MHz, ozonation and combination for 60 min during storage at 13 °C for 4 weeks	96
4.11	b* value of bird chilli peel color treated with ultrasonication at 1 MHz, ozonation and combination for 60 min during storage at 13 °C for 4 weeks	97
4.12	Total sensory quality evaluation of bird chilli after treated with ultrasonication and ozone treatment for 60 min during storage at 13°C for 4 weeks	98
4.13	Appearance of bird chilli during storage at 13 °C for 4 weeks	99
4.14	Chlorpyrifos residue in bird chilli after treated ultrasonication combination with ozone treatments for 60 min and storage at 13 °C for 4 weeks, data are present as the mean \pm S.E., significantly different from statistical analysis	101
5.1	Materials and method of brine shrimp hatching: marine salt, eggs of brine shrimp, hatching set-up and adult brine shrimp	104
5.2	LC ₅₀ values to the brine shrimp toxicity of chlorpyrifos after ultrasonication or/and ozonation treatments for 60 min	108
5.3	The brine shrimps at initial time in standard chlorpyrifos solutions and treated chlorpyrifos solutions with 1 MHz, O ₃ and 1 MHz/O ₃ treatments	109
5.4	The brine shrimps at 18 h in standard chlorpyrifos solutions and treated chlorpyrifos solutions with 1 MHz, O ₃ and 1 MHz/O ₃ treatments.	110
5.5	Bioassay toxicity test of wastewater from different chilli washing treatments against brine shrimp	112
5.6	Bioassay toxicity test set-up for wastewater from different chilli washing treatments against brine shrimp time 0 - 18 h	113

ABBREVIATIONS

%	Percent
°C	Degree Celsius
°F	Degree Fahrenheit
μl	Microliter
•O	Oxyl radical
•OH	Hydroxyl radical
•O ₂	Superoxide
ADI	Acceptable daily intake
AOPs	Advanced oxidation processes
Cl ⁻	Chloride ion
g	Gram
GC-FPD	Gas chromatography - flame photometric detector
GC-MS	Gas chromatography - mass spectrometry
GRAS	Generally recognized as safe
FAO	Food and Agriculture Organization of the United Nations
h	Hour
IC	Ion chromatography
<i>k</i>	Kinetic
kHz	Kilohertz
MHz	Megahertz
L	Liter
LC ₅₀	Lethal concentration fifty
LD ₅₀	Lethal dose fifty
mg	Milligram
min	Minute
mM	Millimole
ml	Milliliter
<i>m/z</i>	Mass-to-charge ratio (<i>m</i> = mass of ion, and <i>z</i> = charge)



MRLs	Maximum residue limits
NIST	National Institute for Standard Technology
NOAEL	No observed adverse effect level
NO ₃ ⁻	Nitrate ion
ns	Nano second
O ₂	Oxygen
O ₃	Ozone
Ops	Organophosphorous
ORP	Oxidation-reduction potential
pH	Potential of hydrogen ion
PO ₄ ³⁻	Phosphate ion
RH	Relative humidity
SO ₄ ²⁻	Sulphate ion
TCP	3,5,6-trichloro-2-pyridinol
UV	Ultraviolet

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่

Copyright© by Chiang Mai University
All rights reserved