CONTENTS

2181216	
	Page
Acknowledgments	iii
Abstract in Thai	v
Abstract in English	vii
List of Table	xii
List of Figures	xiv
List of Abbreviation	xvi
Chapter 1 Introduction	1
1.1 Rationale	1
1.2 Research Objectives	5
1.3 Usefulness of the research	5
Chapter 2 Literature Review	6
2.1 Overview	6
2.2 Activated Sludge Process	7
2.3 Constructed Wetlands	9
2.4 Hydraulic Retention Time (HRT)	10
2.5 Relative Growth Rate of Water Hyacinth	11
Chapter 3 Materials and Method	13
3.1 Instrument, Apparatus and Chemicals	13
3.1.1 Instruments	13
3.1.2 Apparatus	13
3.1.3 List of Chemicals	14 0
3.1.3.1 Chemicals for BOD analysis	14
3.1.3.2 Chemicals for orthophosphate analysis	14

3.1.3.3 Chemicals for ammonium nitrate analysis	15
3.2 Pilot Scale Reactor Design	15
3.3 Operation of Reactor and Water sampling	18
3.4 Water Sample Analysis	19
3.4.1 Preparation of standard solution	19
3.4.2 Analysis of water sample and relative growth rate	19
3.4.4 Statistical Data Analysis	20
3.4.5 Mathematical Modeling for BOD Degradation	21
3.4.6 Standardizing of Inlet Pollutant Concentrations.	21
Chapter 4 Results and Discussion	22
4.1 Characteristics of Raw Wastewater	22
4.2 Effect of HRT on Total Suspended Solid Removal Efficiency	24
4.3 Effect of HRT on Biological Oxygen Demand Removal Efficiency	27
4.4 Effect of HRT on Nitrate Nitrogen Removal Efficiency	31
4.5 Effect of HRT on Ammonium Nitrogen Removal Efficiency	35
4.6 Effect of HRT on Ortho Phosphate Removal Efficiency	38
4.7 Relative growth rate of water hyacinth	42
4.8 Multiple statistical correlation between concentration and removal efficiency	45
4.8.1 Multiple statistical correlation at 6 h HRT	45
4.8.2 Multiple statistical correlation at 12 h HRT	49
4.8.3 Multiple statistical correlation at 18 h HRT	49
4.9 Principle component analysis	52
4.10 Mathematical Modeling of Activated Sludge Unit	61
Chapter 5 Conclusion	66
Recommendations	68
References	69
Appendices	77
All rights reserv	e (
Appendix A	/8
Appendix C	89



LIST OF TABLE

ુ ગામાધાલ ?	Page	
Table 3.1 Specifications of aeration tank , clarifier unit and FAMCW unit.	17	
Table 3.2 RPM value set up for each HRT value	19	
Table 3.3 Parameters and methods used to analyze water samples.	20	
Table 3.4 Average inlet concentrations of pollutants at 95% confidence range	21	
Table 4.1 Characteristic of raw wastewater discharge from cafeteria	22	
Table 4.2 Average $[\pm(S.D.)(t_{\alpha/2\nu})]$ TSS concentrations and removal efficiencies		
at HRT of 6, 12, and 18 h in different treatment steps	24	
Table 4.3 Average $[\pm(S.D.)(t_{\alpha/2\nu})]$ BOD concentrations and removal efficiencies	385	
at HRT of 6, 12, and 18 h in different treatment steps	27	
Table 4.4 Average $[\pm(S.D.)(t_{\alpha/2\nu})]$ NO ₃ - N concentrations and removal	41	
efficiencies at HRT of 6, 12, and 18 h in different treatment steps	32	
Table 4.5 Average $[\pm(S.D.)(t_{\alpha/2\upsilon})]$ NH ₄ - N concentrations and removal	n //	
efficiencies at HRT of 6, 12, and 18 h in different treatment steps	37	
Table 4.6 Average $[\pm(S.D.)(t_{\alpha/2\upsilon})]$ O-PO ₄ concentrations and removal		
efficiencies at HRT of 6, 12, and 18 h in different treatment steps	40	
Table 4.7 Paired comparison of HRTs in each treatment step	41	
Table 4.8 Fresh & dry weight, growth rate and relative growth rates of water		
hyacinth in HRT of 6, 12, and 18h	44	
Table 4.9 Multiple correlation analysis between physicochemical parameters		
and pollutant removal efficiencies at 6 h HRT	46	
Table 4.10 Multiple correlation analysis between physicochemical parameters		
and pollutant removal efficiencies at 12 h HRT	47	ite
Table 4.11 Multiple correlation analysis between physicochemical parameters	ven	sir)
and pollutant removal efficiencies at 18 h HRT	48	
Table 4.12 Wastewater quality parameters associated with PCA and		
abbreviations	52	

Table 4.13 Importance of components at 6 H HRT	53
Table 4.14 Importance of components at 12 H HRT	55
Table 4. 15 Importance of components at 18 H HRT	56
Table 4.16 Order of decay and degradation coefficient of BOD in different Δt	63
Table 4.17 Order of decay and degradation coefficient of BOD at $\Delta t = 3$	64



LIST OF FIGURES

ง พมยหุด	Page
Figure 2.1 Schematic diagram of activated sludge process layout	8
Figure 3.1 Schematic diagram of pilot scale reactor	16
Figure 3.2 Calibration curve for determine the flow rate	19
Figure 4.1 TSS removal efficiencies of reactor under HRT of 6, 12, and 18h	25
Figure 4.2 Concentration variation and removal efficiency of total suspended	3024
solid	26
Figure 4.3 Concentration variation and removal efficiency of biological oxygen	QF
demand	29
Figure 4.4 BOD removal efficiencies of reactor under HRT of 6, 12, and 18h	31
Figure 4.5 Concentration variation and removal efficiency of nitrate nitrogen	33
Figure 4.6 NO ₃ -N removal efficiencies of reactor under HRT of 6, 12, and 18h	34
Figure 4.7 Concentration variation and removal efficiency of ammonium	///
nitrogen	36
Figure 4.8 NO ₃ ⁻ -N removal efficiencies of reactor under HRT of 6, 12, and 18h	37
Figure 4.9 Concentration variation and removal efficiency of ortho phosphate	39
Figure 4.10 O -PO ₄ removal efficiencies of reactor under HRT of 6, 12, and	
18h	40
Figure 4.11 Relative growth rates of water hyacinth grown with wastewater	
from cafeteria for 13 days under HRT of 6, 12, and 18 h	42
Figure 4.12 Growth difference of water hyacinth in HRT of 6, 12, and 18h	43
Figure 4.13 Correlation between inlet temperature and BOD removal	versitv
efficiencies at HRT of 6, 12, and 18h	50
Figure 4.14 Correlation between inlet temperature and O-PO ₄ removal	ved
efficiencies at HRT of 6, 12, and 18h	50

Figure 4. 15 Correlation between inlet pH and BOD removal efficiencies at	
HRT of 6, 12, and 18h 51	
Figure 4. 16 Correlation between inlet pH and O-PO ₄ removal efficiencies at	
HRT of 6, 12, and 18h 51	
Figure 4. 17 Relative importance of the principal components at HRT 654	
Figure 4. 18 Correlation circle between a variable and a PC at HRT 654	
Figure 4. 19 Relative importance of the principal components at HRT 1255	
Figure 4. 20 Correlation circle between a variable and a PC at HRT 12 56	
Figure 4. 21 Relative importance of the principal components at HRT 18 57	
Figure 4. 22 Correlation circle between a variable and a PC at HRT 1857	
Figure 4. 23 PCA Biplot of variables at HRT 0658	
Figure 4. 24 PCA Biplot of variables at HRT 1259	
Figure 4. 25 PCA Biplot of variables at HRT 18	
Figure 4. 26 The aeration tank process of activated sludge diagram	
Figure 4. 27 Experimental and model data for BOD degradation in AS system 64	
HAI UNIVERSIT	

LIST OF ABBREVIATION

		ANEIKO
	10	5000 °4
	AS	Activated Sludge
	ASBR	anaerobic sequencing batch reactor
//	BAF	biological aerated filter
	BOD	Biological Oxygen Demand
	CMU	Chiang Mai University
110	COD	Chemical Oxygen Demand
Ĩ	CW	Constructed wetland
11	DW	Dry Weight
	EC	Electrical Conductivity
	FAMCW	Floating Aquatic Macrophyte Constructed Wetland
	HLR	Hydraulic Loading Rate
	HRT	Hydraulic Retention Time
	HSSCW	horizontal subsurface constructed wetland
	MLVSS	mixed liquor volatile suspended solids
	NH4-N	Ammonium Nitrogen
	NO3-N	Nitrate Nitrogen
	O-PO4	Ortho Phosphate
	PAO	phosphorus accumulating microorganisms
	PC	Principal Component
	PCA	Principal Component Analysis
Com	RGR	Relative Growth Rate
Cob)	RPM	Round per Minute
	SCB	Sequencing Batch Reactor
	TDS	Total Dissolved Solid
	TSS	Total Suspend Solid

