TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
ABSTRACT (ENGLISH)	iv
ABSTRACT (THAI)	vi
TABLE OF CONTENTS	viii
LIST OF TABLES	xiii
LIST OF FIGURES	XV
ABBREVIATIONS AND SYMBOLS	xvii
CHAPTER 1 INTRODUCTION	
1.1 Overview of the research	1
1.2 Introduction to cadmium and lead	3
1.2.1 Occurrence and application of cadmium and lead	3
1.2.2 Toxicology of cadmium and lead	3
1.3 Water pollution	6
1.4 Anodic Stripping Voltammetry	8
1.4.1 Principle Anodic Stripping Voltammetry	8
1.4.2 Working electrode	10
1.4.3 Bismuth Film Working electrode	11
1.4.4 Flow based anodic stripping voltammetry	13
1.5 Research objectives	15

CHAPTER 2 EXPERIMENTAL

2.1	Chemicals, apparatus and instruments		
	2.1.1 Chemicals	16	
	2.1.2 Software	17	
	2.1.3 Materials and instruments	17	
2.2	Preparation of reagents	18	
	2.2.1 Acetate buffer solution	18	
	2.2.2 Metal standard solution	18	
	2.2.3 Working standard solution of Cd(II) and Pb(II)	18	
	2.2.4 Nitric acid solution	19	
	2.2.5 Bi(III) solution	19	
2.3	Preparation of electrode	19	
	2.3.1 Preparation of electrode before analysis	19	
	2.3.2 Keep of electrode surface	19	
2.4	Manifold of flow based anodic stripping voltammetric system for		
	determination of cadmium and lead		
2.5	Operational procedure of the system 21		
2.6	Optimization of flow based- ASV system using bismuth film electrode		
	As working electrode		
	2.6.1 Concentration of cleaning solution	25	
	2.6.2 Effect of times for polishing and storage of GCE	26	

ix

	2.6.3	Concentration of acetate buffer pH 4.5	26
	2.6.4	Effect of pH of acetate buffer solution	27
	2.6.5	Effect of concentration Bi(III) plating solution	27
	2.6.6	Flow rate	28
	2.6.7	Stripping sweep mode	28
	2.6.8	Deposition potential	29
	2.6.9	Deposition time	30
	2.6.10	The stability of sensitivity of the calibration graphs	30
2.7	Analyti	cal characteristics of the procedure	31
	2.7.1	Calibration curves and limit of detection	31
	2.7.2	Precision study	32
	2.7.3	Accuracy of the system	32
2.8	Prepara	tion of sample for analysis	33
	2.8.1	Water sample	33
CHA	PTER 3	RESULTS AND DISCUSSION	

ala	HAPTER :	3 RESULTS AND DISCUSSION	
3.1	1 Optim	ization of flow based – ASV system using bismuth film electrode	34
	as a w	vorking electrode	
	3.1.1	Concentration of cleaning solution	34
	3.1.2	Effect of times for polishing and storage of GCE	35
	3.1.3	Concentration of acetate buffer pH 4.5	37

	3.1.4 Effect of pH of acetate buffer solution	38		
	3.1.5 Effect of concentration Bi(III) plating solution	39		
	3.1.6 Flow rate	41		
	3.1.7 Sweep mode	42		
	3.1.8 Deposition potential	45		
	3.1.9 Deposition time	46		
	3.1.10 The optimum operational conditions	47		
	3.1.11 The stability of sensitivity of the calibration graphs	48		
3.2	Analytical characteristics of the procedure	48		
	3.2.1 Calibration curves and limit of detection	48		
	3.2.2 Precision study	51		
	3.2.3 Accuracy of the system	52		
	3.2.4 Interferences	54		
3.3	Real sample analysis	55		
	3.3.1 Application of real sample water I	55		
	3.3.2 Application of real sample water II	59		
CHAPTER 4 CONCLUSION 62				
REFERENCES 2 1 t S 1 e S e 1 V e 64				
APP	ENDICES	69		

Appendix A Calculation of detection limit of flow based – As	SV system	70
using bismuth film electrode as a working electr	rode	
Appendix B The t-Test with multiples samples for the compar	rison	72
of two methods		
Appendix B Proceeding Article		74
CURRICULUM VITAE		75
THE RELEVANCY OF THE RESEARCH WORK TO THAIL	AND	79

LIST OF TABLES

Table		Page
1.1	Possible cadmium-induced health effect in adults	4
1.2	Threshold limit of heavy metals according to Thai Industrial Effluent	7
	Standards	
1.3	Some methods based on flow anodic stripping voltammetry which	14
	employing BiFE as working electrode	
2.1	Description of each operation step determination of cadmium and lead	22
2.2	The conditions for the study of effect of nitric acid	25
2.3	The conditions for the study the effect of concentration Bi(III)	27
	plating solution	
2.4	The conditions for the study of effect of deposition potential	29
3.1	The effect of concentration nitric acid for cleaning of GCE (n=7)	35
3.2	The times of polish for normal storage of electrode within 1 day	36
3.3	The times of polish for special storage of electrode within 2 days	37
3.4	Optimization of FI-ASV system using bismuth film electrode as a	47
	working electrode for determination of Cd(II) and Pb(II)	
3.5	The comparative stability of sensitivity of Cd(II) and Pb(II) two times	48
	and 2 days for determination of Cd(II) and Pb(II)	
3.6	The precision study at the concentration of standard Cd(II) and Pb(II)	51
3.7	The recovery percentage of sample on spiked of Cd(II) and Pb(II) at	53
	5-25 µg/L in samples	

xiii

- 3.8 Determination of cadmium and lead inwater sample by proposed 55 Flow-VA-BiFE method
- 3.9 Comparative determination of cadmium and lead in water sample by 56 proposed Flow-VA-BiFE sytem method and ICP-OES
- 3.10 The according to t-test at 95% confident limit of Cd(II) and Pb(II) 57
- 3.11 Determination of cadmium and lead in water sample by proposed 59 Flow-VA-BiFE method
- 3.12 Comparative determination of cadmium and lead in water sample by 60 proposed Flow-VA-BiFE ststem method and ICP-OES
- 3.13 The according to t-test at 95% confident limit of Cd(II) and Pb(II) 61

LIST OF FIGURES

Figure		Page
1.1	Organ system affect by lead	5
1.2	Diagram of an electrochemical cell for a voltammetrc system	8
1.3	Operating step in anodic stripping voltammetric (ASV) method	9
1.4	Potential ranges of the different working electrodes	10
2.1	Manifold of flow base anodic stripping voltammetric system for	20
	determination of cadmium and lead	
2.2	Flow direction of each operation step	23
2.3	Instrumentation set up for determination of cadmium and lead	24
3.1	Effect of concentration acetate buffer on sensitivity (slope) of Cd(II)	38
	and Pb(II) determination	
3.2	Effect of acetate buffer pH on metal stripping at 20 μ g/L each of	39
	Cd(II) and Pb(II)	
3.3	Effect of Bi(III) concentration (10 and 30 $\mu g/L$ each of Cd(II) and	40
	Pb(II))	
3.4	Effect of flow rate of sample or standard solution on metal stripping	41
	at 20 µg/L each of Cd(II) and Pb(II)	
3.5	Effect of of sweep mode on metal stripping at 20 μ g/L each of Cd(II)	44
	and Pb(II) S I E S E I V	
3.6	Effect of deposition potential on metal stripping at 10 and 20 $\mu g/L$	46
	each of Cd(II) and Pb(II)	

XV

- 3.7 Effect of deposition potential on metal stripping at 10 and 20 µg/L 47 each of Cd(II) and Pb(II)
- 3.8 Square wave anodic stripping voltammograms obtained from VA- 50
 BiFE system of solution containing Cd(II) and Pb(II) of increasing concentration, from 2-40 μg/L
- 3.9 Calibration graphs of Cd(II) and Pb(II) from VA-BiFE system of 50 solution containing Cd(II) and Pb(II) of increasing concentration, from 2-40 μg/L
- 3.10Correlation graphs of (a): Cd(II) and (b): Pb(II) contents determined58by the proposed Flow-VA-BiFE method and ICP –OES method.
- 3.11 Correlation graphs of (a): Cd(II) and (b): Pb(II) contents determined 61 by the proposed Flow-VA-BiFE method and ICP –OES method.

ABBREVIATIONS AND SYMBOLS

AAS	atomic absorption spectrometry
AE	auxiliary or counter electrode
AFS	atomic fluorescence spectrometry
ASV	anodic stripping voltammetry
Ва	barium
BiCCE	cleaved bismuth capillary electrode
BiFE	bismuth film electrode
C _A	concentration of analyte
Cd	cadmium
COPD	chronic obstructive pulmonary disease
Cu	copper
C _L	concentration at limit of detection
cm	centimeter
DPASV	differential pulse anodic stripping voltametry
FC	electrochemical flow cell
FIA, FI	flow injection analysis
g	gram
GCE	glassy carbon working electrode
HDME	hanging drop mercury electrode
Hg	mercury

xvii

Hz	Hertz
i _d	diffusion current
ICP-OES	inductively coupled plasma-optical emission spectrometry
ICP-MS	inductively coupled plasma-mass spectrometry
L	liter
Mn	manganese
μΑ	microampere
μM	micro molar
μg/L	microgram per liter
mg/L	milligram per liter
mL	milliliter
mL/min	milliliter per minute
mm	millimeter
М	Molarity
Ni	nickel
Pb	lead
PC	personal computer
RE	reference electrode
RSD	relative standard deviation
%RSD	percentage relative standard deviation
S	second
SD	standard deviation
Se	selenium

xviii

