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APPENDICES

APPENDIX A

Table 1 Calculation of detection limit of flow based – ASV system using bismuth film electrode as a working electrode determination of cadmium (II)

Cadmium (µg/L)	Yi	$\hat{Y}i$	[Yi-$\hat{Y}i$]	[Yi-$\hat{Y}i$]^2
2.00	1.30	0.75	0.55	0.3073
5.00	5.41	5.78	0.37	0.1394
10.00	14.27	14.17	0.09	0.0086
20.00	30.63	30.95	0.32	0.1033
30.00	47.30	47.74	0.44	0.1899
40.00	65.00	64.52	0.48	0.2335
Σ ([Yi-$\hat{Y}i$]^2)				0.9820
Sy / x				0.4955
C_L, LOD				0.8858
LOQ				2.9526

The linear regression equation is Y = 1.6781x – 2.6072

$$Sy / x = [0.9820 / (6-2)]^{1/2}$$

$$= 0.4955$$

$$C_L, LOD = (3 \times 0.4955)/1.6781$$

$$= 0.8858 \text{ µg/L Cd(II)}$$

$$LOQ = (10 \times 0.4955)/1.6781$$

$$= 2.9526 \text{ µg/L Cd(II)}$$

Table 2 Calculation of detection limit of flow based – ASV system using bismuth film electrode as a working electrode determination of lead (II)

Lead (µg/L)	Yi	$\hat{Y}i$	$[Yi-\hat{Y}i]$	$[Yi-\hat{Y}i]^2$
2.00	2.65	2.34	0.31	0.0931
5.00	5.75	5.85	0.10	0.0097
10.00	11.37	11.68	0.32	0.1007
20.00	23.40	23.36	0.04	0.0014
30.00	35.10	35.04	0.06	0.0036
40.00	46.73	46.72	0.01	0.0001
$\Sigma([Yi-\hat{Y}i]^2)$				0.2086
Sy / x				0.2284
C_L, LOD				0.5867
LOQ				1.9556

The linear regression equation is $Y = 1.1678x + 0.006$

$$Sy / x = [0.2086 / (6-2)]^{1/2}$$

$$= 0.2284$$

$$C_L, LOD = (3 \times 0.2284)/1.1678$$

$$= 0.5867 \text{ µg/L Pb(II)}$$

$$LOQ = (10 \times 0.2284)/1.1678$$

$$= 1.9556 \text{ µg/L Pb(II)}$$

APPENDIX B

The example t –Test with multiple samples for the comparison of two methods

The proposed flow based – ASV system using bismuth film electrode as a working electrode method for the quantification of cadmium (II) in real water was validated against ICP–OES method. In this case, comparison between the proposed method and the reference ICP–OES method was made by t-test [58]. A statistical *t* value was calculated from the difference between cadmium (II) and lead (II) contents obtained from two methods on each sample using Excel 2007 [59].

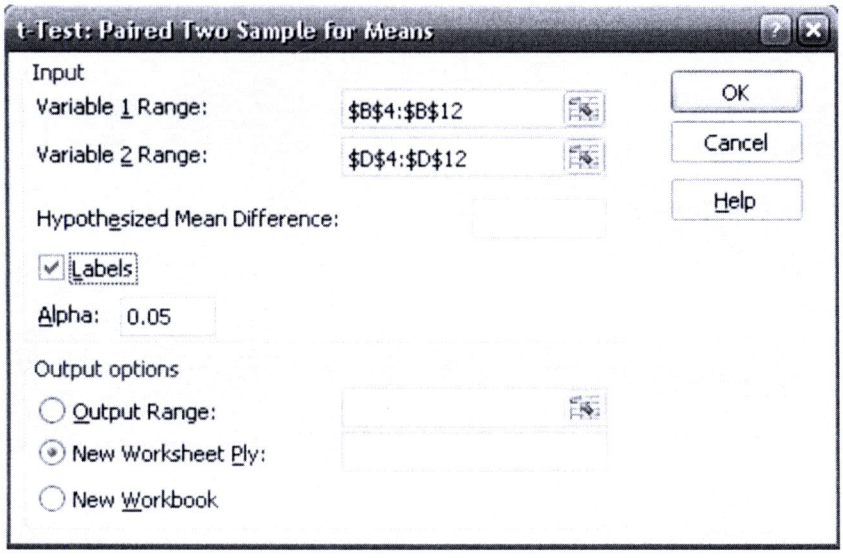

Figure 1 Dependent samples t-test dialog box in Excel 2007

The data obtained from two methods as shown in Table 3.13 of cadmium (II), the hypothesis that there is a significant difference between two methods was decided before computing *t* value. The calculation was performed by selecting Data analysis, t-test: Paired Two Sample for Means. The dialog box is depicted in Figure 1. The values obtained by ICP–OES and the proposed method were entered to Variable 1 and Variable 2, respectively. The test at the 95% confidence level was considered, thus an alpha level of 0.05 was selected as shown. The output table for multiple samples t-test is shown in Figure 2. The calculated *t* value of 0.02 which was less than the t critical value (two-tail) of 2.36 indicated that the values obtained from both methods were insignificantly different at the 95% confidence level.

	A	B	C
1	t-Test: Paired Two Sample for Means		
2			
3		*ICP-OES*	*FI-VA-BIFE*
4	Mean	0.71	0.71
5	Variance	0.07	0.05
6	Observations	8	8
7	Pearson Correlation	-0.24542	
8	Hypothesized Mean Difference	0	
9	df	7	
10	t Stat	**0.02**	
11	P(T<=t) one-tail	0.49	
12	t Critical one-tail	1.89	
13	P(T<=t) two-tail	0.99	
14	t Critical two-tail	**2.36**	
15			
16			

Figure 2 Dependent samples t-test output table in Excel 2007

APPENDIX C

Proceeding Article

1. W. Powsakul and Jaroon Jakmunee. "Determination of Cadmium, Lead, Copper and Zinc in Ground Water Samples by Anodic Stripping Voltammetry" (Poster Presentation and Full Paper Presentation), The 35th Congress on Science and Technology of Thailand (STT 35), Burapa University, Chonburi, Thailand, 15-17 October 2009.
2. W. Powsakul, P. Sooksamiti, M. Miro and Jaroon Jakmunee. "Greener Anodic Stripping Voltammetric Method Employing In Situ Plated Bismuth Film Electrode for Determination of Cadmium and Lead" (Poster Presentation), 14th Asian Chemical Congress 2011 (14 ACC), Queen Sirikit National Convention Center, Bangkok, Thailand, 5-8 September 2011.

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2011 Committee assistant in meeting for new technology to analyze the amount of plant nutrients in soil and fertilizers for properly management, Department of Chemistry, Faculty of Science, Chiang Mai University, 20 May 2011

2011 Demonstrator in meeting for a new method of analysis of heavy metals in ceramic products by anodic stripping voltammetric method at Department of Chemistry, Faculty of Science, Chiang Mai University, 22 July 2011

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1. W. Powsakul and Jaroon Jakmunee. "Determination of Cadmium, Lead, Copper and Zinc in Ground Water Samples by Anodic Stripping Voltammetry", The 35th Congress on Science and Technology of

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INTERNATIONAL CONFERENCES

1. W. Powsakul, M. Miro and Jaroon Jakmunee. "Flow Injection Anodic Stripping Voltammetric Method for Determination of Cadmium and Lead" (Poster Presentation), The 2nd Regional Electrochemistry Meeting of South-East Asia on Applied Electrochemistry for Modern Life (2nd REMSEA 2010), Maha Chulalongkorn Building, Chulalongkorn University, Thailand, 16-19 November 2010.
2. W. Powsakul, M. Miro and Jaroon Jakmunee. "Determination of Cadmium and Lead by Flow Injection Anodic Stripping Voltammetric Method" (Poster Presentation), Pure and Applied Chemistry International Conference (PACCON2011), Miracle Grand Hotel Bangkok, Thailand, 5-7 January 2011.
3. W. Powsakul, M. Miro and Jaroon Jakmunee. "Flow Injection Anodic Stripping Voltammetric Method for Determination of Cadmium and Lead" (Poster Presentation), The International Congress for Innovation in

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NATIONAL CONFERENCES

3. W. Powsakul and Jaroon Jakmunee. "Determination of Cadmium, Lead, Copper and Zinc in Ground Water Samples by Anodic Stripping Voltammetry" (Poster Presentation and Full Paper Presentation), The 35th Congress on Science and Technology of Thailand (STT 35), Burapa University, Chonburi, Thailand, 15-17 October 2009.
4. W. Powsakul, P. Sooksamiti, M. Miro and Jaroon Jakmunee. "Determination of Cadmium and Lead by Flow Injection Anodic Stripping Voltammetric Method Employing Bismuth Film Electrode" (Poster Presentation), RGJ Seminar Series 84 Research and Innovation in Chemistry for Sustainable Development, University Academic Service Center (UNISERV), Chiang Mai University, Thailand, 2 September 2011

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THE RELEVANCE OF THE RESEARCH WORK TO THAILAND

Quantification of cadmium (II) and lead(II) becomes important for water quality standards from Industrial Effluent, environment and agriculture. These metals are heavy metals that cause adverse health effects at very low exposure levels. They are well known metals seriously affect on health. Many commercial analytical methods for trace metals such as atomic absorption spectrometry (AAS), inductively coupled plasma-optical emission spectroscopy (ICP-OES), inductively coupled plasma-mass spectrometry (ICP-MS) and atomic fluorescence spectrometry (AFS). However, most of these methods rely on sophisticated and expensive instrument and consumes long analysis time that makes their uses quite limited in specific groups.

This research work focuses on developing of method for determination of cadmium (II) and lead(II) in real water samples based on flow – ASV system using bismuth film electrode as a working electrode. This method is a greener analytical method as an 'environmentally friendly'. This system consumes little amount of reagent with minimum waste generation, reduces cost of analytical instrumentation and sample analysis and convenient operation for the determination of cadmium and lead at trace level. The analytical performance was comparable to the traditional method which should be beneficial to apply in small manufactories or even in large industrial sectors in Thailand. This would be able to help the Thai Government to improve the life quality of Thai citizen and also to prevent some of the environmental problems of Thailand.