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APPENDICES

APPENDIX A

Standard of Wastewater

Table A.1 Standard quality of wastewater defined by Pollution Control Department (PCD) Ministry of Natural Resources and Environment [86]

Parameters	Units	PCD (Guideline Value)
1. Physical Quality		
Colour and odour	Not dislike	-
Turbidity	mg L^{-1}	50
Temperature	°C	40
pH	-	5.5-9.0
2. Chemical Quality		
TDS (Total Dissolved Solids)	mg L^{-1}	3000
BOD (Biochemical Oxygen Demand)	mg L^{-1}	20
COD (Chemical Oxygen Demand)	mg L^{-1}	120
TKN (Total Kjeldahl Nitrogen)	mg L^{-1}	100
Sulfide as H_2S	mg L^{-1}	1.0
Cyanide	mg L^{-1}	0.2
Fat, Oil and Grasesae	mg L^{-1}	5.0
Formaldehyde	mg L^{-1}	1.0
phenols	mg L^{-1}	1.0
Free Chlorine	mg L^{-1}	1.0

Note 1 mg = 1000 μg

Table A.1 (Continued)

Parameters	Units	PCD (Guideline Value)
Pesticide	mg L^{-1}	None
Zinc	mg L^{-1}	5.0
Hexavalent Chromium	mg L^{-1}	0.25
Trivalent Chromium	mg L^{-1}	0.75
Copper	mg L^{-1}	2.0
Cadmium	mg L^{-1}	0.03
Barium	mg L^{-1}	1.0
Lead	mg L^{-1}	0.2
Nickel	mg L^{-1}	1.0
Manganese	mg L^{-1}	5.0
Arsenic	mg L^{-1}	0.25
Selenium	mg L^{-1}	0.02
Mercury	mg L^{-1}	0.005

Note 1 mg = 1000 μg

APPENDIX B

The student *t*-Test [83]

$$t = \frac{\bar{x}_d \sqrt{n}}{S_d}$$

$$S_d = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

$$\bar{x}_d = \frac{\sum x_d}{n}$$

Where;

x_d	the difference between two method
$\bar{x}_d$	the mean difference
S_d	the standard deviation
n	number of sample
n-1	number of degree of freedom

The Table B.1 gives the concentration of cadmium (mg L^{-1}) determined by the proposed FIA and ICP-MS methods for each eight test portions.

Table B.1 Calculation of *t*-test for cadmium(II) determination of FIA method

Wastewater samples	Cd(II) concentrations (mg L^{-1})		$\bar{x}$	s_d	$\bar{x}_d$	$t_{calculated}$
	FIA*	ICP-MS*				
Wastewater 1	0.025	0.027	0.025	0.0007	-0.0017	-4.206
Wastewater 2	ND**	ND**	ND**	-	-	-
Wastewater 3	0.028	0.026	0.028	0.0010	0.0020	3.464
Wastewater 4	0.017	0.013	0.017	0.0020	0.0043	3.724
Wastewater 5	0.029	0.027	0.029	0.0017	0.0020	2.038
Wastewater 6	0.031	0.029	0.031	0.0007	0.0023	5.691
Wastewater 7	0.015	0.017	0.015	0.0020	-0.0017	-1.472
Wastewater 8	0.018	0.019	0.018	0.0020	-0.0013	-1.126
Wastewater 9	0.040	0.037	0.040	0.0010	0.0030	5.196
Wastewater 10	0.069	0.073	0.069	0.0016	-0.0043	-4.655

*average of triplicate results

**not detected

For example: **Wastewater 1**

$$\bar{x} = \frac{\sum x_i}{n}$$

$$= \frac{0.025 + 0.026 + 0.025}{3}$$

$$= 0.025$$

$$S_d = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

$$= \sqrt{\frac{0.000001}{3-1}}$$

$$= 0.0007$$

$$\bar{x}_d = \frac{(0.025 - 0.027) + (0.026 - 0.027) + (0.025 - 0.027)}{3}$$

$$= -0.0017$$

$$t = \frac{\bar{x}_d \sqrt{n}}{S_d}$$

$$= \frac{-0.0017\sqrt{3}}{0.0007}$$

$$= -4.206$$

The cadmium(II) content found in wastewater samples by the proposed FIA procedure and ICP-MS was compared and then the results were given in Table B.1. The calculated value of *t* are less than the *t* value from Table B.3 for two degrees of freedom indicating that results obtained by both methods show no significant difference at 95% confidence intervals.

Table B.2 Calculation of *t*-test for cadmium(II) determination of SIA method

Water samples	Cd(II) concentrations (mg L^{-1})		$\bar{x}$	s_d	$\bar{x}_d$	$t_{calculated}$
	SIA*	ICP-MS*				
Wastewater 1	0.028	0.027	0.028	0.0010	0.0010	1.732
Wastewater 2	ND**	ND**	ND**	-	-	-
Wastewater 3	0.023	0.026	0.023	0.0010	-0.0030	-5.196
Wastewater 4	0.015	0.013	0.015	0.0007	0.0017	4.206
Wastewater 5	0.026	0.027	0.026	0.0016	-0.0007	-0.758
Wastewater 6	0.034	0.029	0.034	0.0030	0.0050	2.887
Wastewater 7	0.018	0.017	0.018	0.0007	0.0007	1.732
Wastewater 8	0.016	0.019	0.016	0.0010	-0.0030	-5.196
Wastewater 9	0.032	0.037	0.032	0.0016	-0.0047	-5.088
Wastewater 10	0.065	0.073	0.065	0.0030	-0.0077	-4.446

*average of triplicate results

**not detected

For example: **Wastewater 1**

$$\bar{x} = \frac{\sum x_i}{n}$$

$$= \frac{0.029 + 0.027 + 0.028}{3}$$

$$= 0.028$$

$$S_d = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

$$= \sqrt{\frac{0.000002}{3-1}}$$

$$= 0.0010$$

$$\bar{x}_d = \frac{(0.029 - 0.027) + (0.027 - 0.027) + (0.028 - 0.027)}{3}$$

$$= 0.0010$$

$$t = \frac{\bar{x}_d \sqrt{n}}{S_d}$$

$$= \frac{0.0010\sqrt{3}}{0.0010}$$

$$= 1.732$$

The cadmium(II) content found in wastewater samples by the proposed SIA procedure and ICP-MS was compared and then the results were given in Table B.2. The calculated value of *t* are less than the *t* value from Table B.3 for two degrees of freedom indicating that results obtained by both methods show no significant difference at 95% confidence intervals.

Table B.3 Values of t for various levels of confidence interval

Degrees of freedom	Confidence interval			
	80%	**90%**	**95%**	**99%**
1	3.08	6.31	12.70	63.7
2	1.89	2.92	4.30	9.92
3	1.64	2.35	3.18	5.84
4	1.53	2.13	2.78	4.60
5	1.48	2.02	2.57	4.03
6	1.44	1.94	2.45	3.71
7	1.42	1.90	2.36	3.50
8	1.40	1.86	2.31	3.36
9	1.38	1.83	2.26	3.25
10	1.37	1.81	2.23	3.17
15	1.34	1.75	2.13	2.95
20	1.32	1.72	2.09	2.84
30	1.31	1.70	2.04	2.75
60	1.30	1.67	2.00	2.66
α	1.29	1.64	1.96	2.58

APPENDIX C

Conditions of ICP-MS

Table C.1 Experimental conditions of ICP-MS for cadmium(II) determination

Parameter	Condition
Model	Agilent 7500 C
Nebulizer	Babington type
Power (W)	1000
Normal speed pump (L min^{-1})	30
Sheath gas pump (s)	4.0
Nebulization pressure (bar)	1.0
Argon flow rate (L min^{-1})	Plasma : 15 , Auxillary gas : 0.5
Sample flow rate (mL min^{-1})	1.5
Vacuum	Interface : 4 torr, quadrupole : 2x10-5 torr
Spray chamber	Scott-type
Data acquisition	Peak hopping, replicate time 200 ms

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List of publications

1. Siriwan Uanthuam, Saisunee Liawruangrath, **Devolopment of Flow Injection Spectrophotometry for Cadmium Determination using Rhodamine B,** *The 36th Congress on Science and Technology of Thailand, Bangkok*, 2010.

2. Siriwan Uanthuam, Saisunee Liawruangrath, **Devolopment of Flow Injection Spectrophotometry for Cadmium Determination using Rhodamine B,** *RGJ Seminar Series LXXIX, Chiang Mai, 2011.*