Development of a Simple Electrochemical Sensor for Simultaneous Determination of Cadmium and Lead

Suneerat Fuangjan[1], Jaroon Junsomboon[2], Pijika Mool-am-kha[2] , Tharinee Sridara[2], Wasin Somboot[1,*]

[1]Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

[2]Department of Science Service (DSS), Bangkok, Thailand

Corresponding author's e-mail: wasin.s@cmu.ac.th

Abstract

In this research, a simple electrochemical sensor was developed for the simultaneous determination of Cd^{2+} and Pb^{2+}. A screen printed carbon electrode (SPCE) was modified with carbon black, and differential pulse anodic stripping voltammetry (DPASV) was employed for analysis. Key parameters including modifier type and volume, bismuth concentration, electrolyte pH, deposition potential, deposition time, and stirring speed were optimized. Under optimal conditions, linear calibration curves were obtained over the range of 5–100 µg/L. The limits of detection (LODs) were 2.0 µg/L for Cd^{2+} and 1.1 µg/L for Pb^{2+}, with relative standard deviation (%RSD) values of 4.5% and 4.2% (n = 10), respectively. The method was applied to concrete roof tile samples, with recoveries ranging from of 85.5 to 93.8% for Cd^{2+} and 85.4 to 95.8% for Pb^{2+}. The results showed excellent agreement with graphite furnace atomic absorption spectrometry (GFAAS).

Introduction

- Cadmium and lead are toxic heavy metals that readily contaminate water due to their solubility.
- These ions originate from inorganic pigments (CdS and $PbCrO_4$) used in concrete roof tiles to enhance weather resistance and color opacity.
- Chronic exposure to Cd^{2+} causes kidney damage and Itai-Itai disease, while Pb^{2+} exposure leads to neurological and bone disorders.



Differential Pulse Anodic Stripping Voltammetry

❑ Deposition step

$Cd^{2+} + 2e^- \rightarrow Cd^0$

$Pb^{2+} + 2e^- \rightarrow Pb^0$

❑ Stripping step

$Cd^0 \rightarrow Cd^{2+} + 2e^-$

$Pb^0 \rightarrow Pb^{2+} + 2e^-$

Advantages

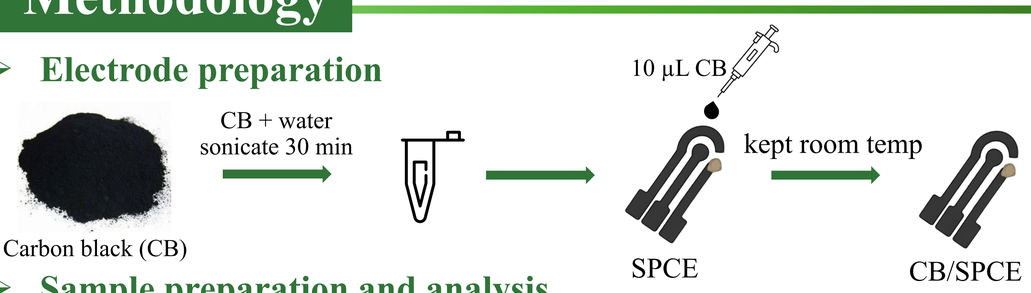
❖High sensitivity

❖Low background noise

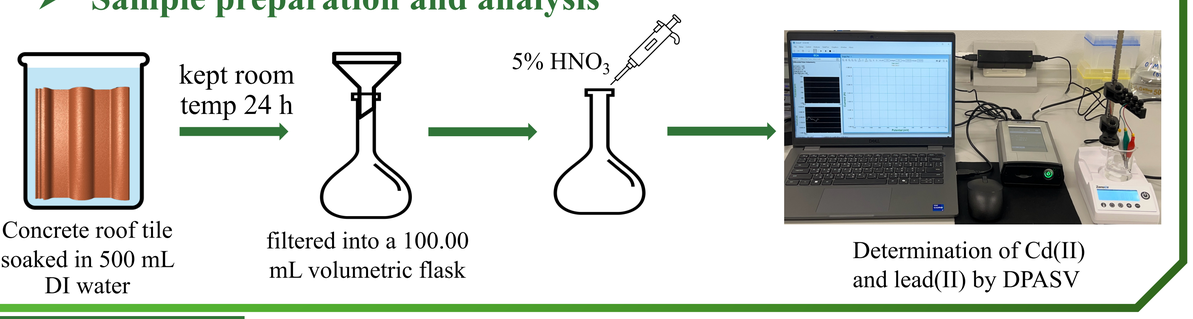
❖Simultaneous detection

Methodology

➢ Electrode preparation



➢ Sample preparation and analysis



Results and Discussion

➢ Materials and Electrochemical study

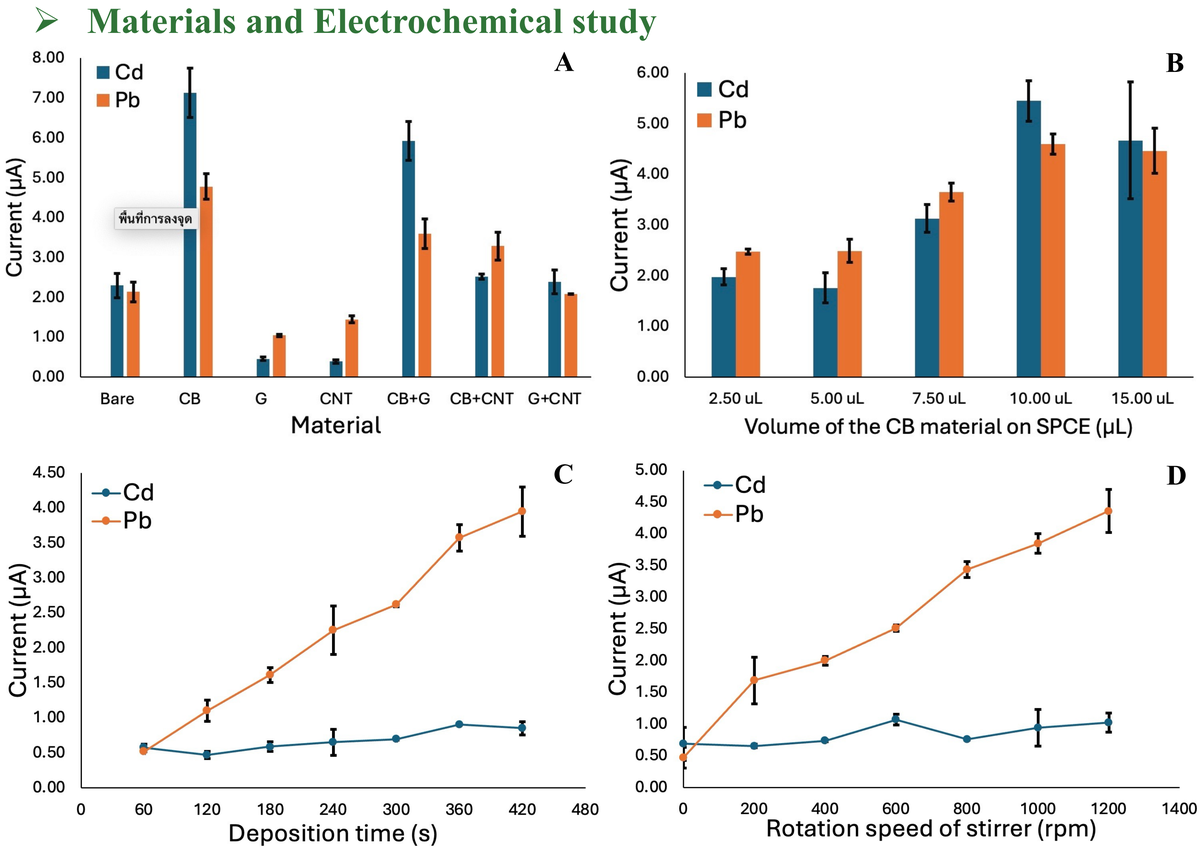


Fig. 1 DPASV current of 100 µg/L Cd^{2+} and Pb^{2+} for optimization: (A) carbon-based materials on different electrodes, (B) volume of the CB suspension on SPCE, (C) deposition time and (D) rotation speed of stirrer using 1000 µg/L Bi^{3+} in 0.1 M acetate buffer pH 4.0

Table 1 The optimal conditions for cadmium(II) and lead(II) analysis by DPASV

Experimental	Optimal conditions
Carbon material	Carbon black (CB)
Volume of carbon black (µL)	10.00
Concentration of Bi(III) solution (µg/L)	1000
pH of acetate buffer	4.0
Deposition potential (mV)	-1200
Deposition time (s)	240
Rotation speed of stirrer (rpm)	800

➢ Analytical performance

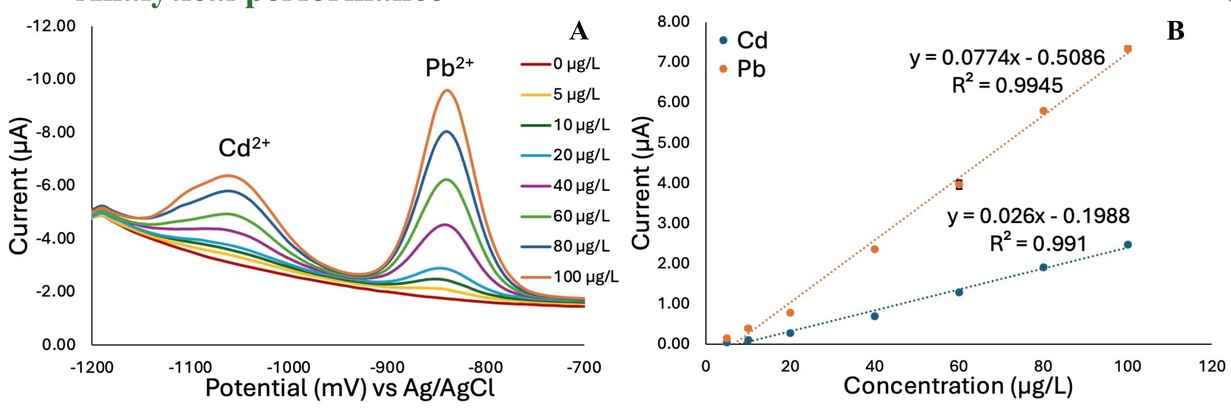


Fig. 2 (A) DPV-gram for simultaneous determination of Cd^{2+} and Pb^{2+} under optimal condition in 0.1 M acetate buffer pH 4.0 and (B) linear calibration graphs of 0 to 100 µg/L Cd^{2+} and Pb^{2+}

Table 2 Validation parameters for the determination of cadmium(II) and lead(II)

Analytical performance	Cd^{2+}	Pb^{2+}
Linearity (µg/L)	5-100	5-100
LOD (µg/L)	2.0	1.1
LOQ (µg/L)	6.6	3.7
%RSD (n=10)	4.5	4.2

➢ Free dissolved heavy metals in concrete roof tile samples

Table 3 Cadmium(II) and lead(II) found in concrete roof tile samples and % recovery

Sample	Metal ions	Spiked (µg/L)	Found (µg/L)	Recovery (%)
1	Cd^{2+}	0	n.d.	-
		20	18.1	90.4
		30	28.2	93.9
	Pb^{2+}	0	n.d.	-
		20	19.2	95.8
		30	27.1	90.5
2	Cd^{2+}	0	n.d.	-
		20	17.9	89.7
		30	25.7	85.5
	Pb^{2+}	0	n.d.	-
		20	18.3	91.5
		30	25.6	85.4

Conclusions

- Successfully develop a simple electrochemical sensor for simultaneous determination of Cd^{2+} and Pb^{2+} employing the modified CB/SPCE to enhance sensitivity with DPASV technique.
- The developed method was used for the determination of free dissolved Cd^{2+} and Pb^{2+} in concrete roof tile samples. Recoveries ranging from 85.5 to 93.8% and 85.4 to 95.8% for Cd^{2+} and Pb^{2+}, respectively, showing excellent agreement with graphite furnace atomic absorption spectrometry (GFAAS).

Acknowledgements

I would like to express my sincere gratitude to my project advisor, Dr. Wasin Somboot, for his guidance and support throughout this project. I would also like to extend my heartfelt appreciation to Dr. Jaroon Junsomboon, Dr. Pijika Mool-Am-Kha, and Dr. Tharinee Sridara at the Department of Science Service (DSS) for their supervision and assistance during the cooperative education training.

References

[1] Junsomboon, J., & Jakmunee, J. (2014). *Chiang Mai J. Sci*, **43**, 1122-1131.

[2] Paukpol, A., & Jakmunee, J. (2016). *CMU J. Nat Sci*, **15**, 77-87.