POLICY BRIEF
AKI RESEARCH GRANTS ON FOOD STUDIES
Volume VIII, No. 9, 2018
ISSN # 2094-3342

De La Salle University
AKI
Angelo King Institute
for Economic and Business Studies

Silver/Bismuth/Nafion Modified Pencil Graphite Electrode for Trace Heavy Metal Determination

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Introduction

Frequent exposure to heavy metals can cause various health problems (Nagles Arancibia, Rojas, & Segura, 2012; Keawkim, Chuanuwatanakul, Chailapakul, & Motomizu, 2013; Xiao et al., 2014). Among the heavy metals, cadmium and lead have a great impact on biota. Cadmium can cause nephrotoxicity, and even lung cancer, when the amount of exposure to the said metal exceeds 26 µg/kg body mass on a monthly basis (Li et al., 2011; Chen et al., 2014; Aragay & Meroçi, 2012). Lead can greatly affect the nervous system (encephalopathy) and the hormones, and it can trigger some cancers at more than 0.02-3 µg/kg for adults and 0.03 to 9 µg/kg for children on a daily basis (Flora, Gupta, & Tiwari, 2012).

Due to the adverse effects of heavy metals on human health, accurate and precise monitoring of these harmful metals in the environment is crucial. Thus, several techniques of detecting heavy metals have

been developed. Among these are spectroscopic and electrochemical techniques. Electrochemical techniques such as anodic stripping voltammetry (ASV) are more popular due to their low cost, high sensitivity, and portability. On the other hand, spectroscopic techniques such as atomic absorption spectroscopy, atomic emission spectroscopy, and mass spectroscopy are expensive, their availability is limited, they are not well suited for in situ measurements, and require complicated instrumentation (Willemse, Tlhomelang, Jahed, Baker, & Iwuoha, 2011).

This study developed a simple and relatively low-cost electrochemical sensor based on modified pencil graphite electrode (PGE) for fast and accurate detection of trace heavy metals in wastewater samples via anodic stripping voltammetry.

Results and Discussion

Graphite rods (2HB) of 3 mm diameter from a commercial brand of pencils were modified by silver nanoparticles (AgNP), bismuth (Bi), and Nafion® via the drop coating technique. Characterization by field emission scanning electron microscopy confirmed the presence of the modifiers on the surface of the fabricated electrodes. The PGE modified by 3 mg AgNP and 2 mg Bi was deemed the best electrode as it yielded the highest anodic peaks as determined by ASV. The

limits of detection of the optimized electrode were found to be 0.19 parts per billion (ppb) for Cd^{2+} and 0.30 ppb for Pb^{2+}. To demonstrate the effectiveness of the fabricated electrode in sensing applications, wastewater samples were tested to determine their heavy metal content. The modified electrode was successful in determining Cd^{2+} and Pb^{2+} as well as Cu^{2+} and Mn^{2+} in the said real samples.

Policy Recommendation

To protect the public from the possible adverse effects caused by heavy metal exposure, local government units and organizations involved in monitoring water pollution should carry out routine analysis using the low-cost sensor developed in this study to determine the presence of heavy metals in drinking water and aquatic systems. Moreover, government and private agencies must prioritize action plans to reduce the release of heavy metals into the environment and remedy polluted water resources.

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This publication is based on a study under the AKI Research Grants on Food Studies.