CHAPTER V

CONCLUSIONS

5.1 Conclusions

Composites of bismuth and carbon nanotube or Bi–CNT composites were prepared by polyol process. X-ray diffractive (XRD), transmission electron microscopic (TEM), energy dispersive X-ray fluorescence (EDXRF) spectroscopic, and cyclic voltammetric results confirmed the deposition of bismuth particles onto CNTs and the successful fabrication of Bi–CNT composite modified glassy carbon (Bi–CNT/GC) electrodee. Bi–CNT/GC electrodes were used to detect cadmium (II) and lead (II) ions at low $\mu g \cdot L^{-1}$ levels by means of square wave anodic stripping voltammetry (SWASV). Interestingly, the results indicated that the Bi–CNT/GC electrodes exhibited more attractive voltammetric responses than the *in situ* bismuth film on CNT modified glassy carbon (*in situ* BiF/CNT/GC) electrode.

According to experimental condition optimization, the 0.50% Nafion and 2.00 mol % of bismuth in Bi–CNT composite were selected. The deposition potential of –1.10 V *versus* silver/silver chloride (Ag/AgCl) electrode and the deposition time of 120 s were set for the determination of cadmium (II) and lead (II) ions by SWASV. Method validation obtained by the calibration curves revealed that the first linear range was between 5 to 150 $\mu g \cdot L^{-1}$ and the second linear range was between 150 to 240 $\mu g \cdot L^{-1}$ for both cadmium (II) and lead (II) ions. The correlation coefficients (R^2) of both metals were more than 0.995. Limits of detection (LODs) were as low as 2.0 $\mu g \cdot L^{-1}$ for both cadmium (II) and lead (II) ions, while the limits of quantification (LOQs) were 5.0 $\mu g \cdot L^{-1}$ for these two heavy metal ions. The detection limits obtained from this work were lower than those of bismuth electrodes in previous research [32]. Moreover, the reproducibility of Bi–CNT/GC electrodes, indicated as the relative standard deviation of 8 measurements (n = 8) at 25 $\mu g \cdot L^{-1}$ concentration level, was 2.44% for cadmium (II) ion and 3.19% for lead (II) ion, illustrating the electrode with better reproducibility than the *in situ* BiF/CNT/GC electrodes. Moreover, in terms of electrode stability, the Bi–CNT/GC electrode can at least be repetitively used to detect

cadmium (II) and lead (II) ions for three and six times, respectively. Therefore, the main advantages of Bi–CNT/GC electrode as an easy-to-prepare and reusable electrode plus better electrochemical performance made the Bi–CNT modified electrode superior than the *in situ* BiF/CNT/GC electrode.

Finally, the determination results of lead (II) and cadmium (II) ions in tap water and waste water samples on Bi–CNT/GC electrode were compared to ICP-AES data. Overall, the Bi–CNT/GC electrode was successfully applied to test the presence of metal ions in real sample of tap water, but this electrode could not be used for metal analysis of waste water due to interference or matrix effect. However, several experimental parameters will be continuously optimized to improve the ability of the Bi–CNT/GC electrodes toward the determination of the heavy metal ions in real samples.

5.2 Suggestion for Further Work

It is known that the interferences or matrices in sample solution have still affected the analytical performance of Bi–CNT/GC electrode. In the near future, the investigation of interference and matrix effects must be continued. Furthermore, new modification or preparation of the Bi–CNT electrode is an interesting aspect to be developed in order to obtain the electrode with better sensitivity and higher stability.