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Research Article

Disposable Carbon Dots Modified Screen Printed Carbon Electrode Electrochemical Sensor Strip for Selective Detection of Ferric Ions

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A disposable electrochemical sensor strip based on carbon nanodots (C-Dots) modified screen printed carbon electrode (SPCE) was fabricated for selective detection of ferric ions (Fe^{3+}) in aqueous solution. C-Dots of mean diameters within the range of 1–7 nm were synthesized electrochemically from spent battery carbon rods. The analytical performance of this electrochemical sensor strip was characterized using cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). The deposition of C-Dots had enhanced the electron-transfer kinetics and current intensity of the SPCE remarkably by 734% as compared to that of unmodified SPCE. Under optimized conditions, the electrochemical sensor strip exhibited a linear detection range of 0.5 to 25.0 ppm Fe^{3+} with a limit of detection (LOD) of 0.44 ± 0.04 ppm (at S/N ratio = 3). Validation of results by the electrochemical sensor strip was done by comparing analysis results obtained using an Atomic Absorption Spectrometer (AAS).

1. Introduction

Ferric ions (Fe^{3+}) are transition metal ions which play essential roles in biological activities, such as oxygen carriers in haemoglobin [1] and growth nutrients for phytoplankton [2, 3]. Deficiency in iron can result in anemia [4], yet high level of iron in human body may result in serious health problems, for instance, Alzheimer and Parkinson diseases [5, 6]. Iron may speed up the formation of reactive oxygen species in redox-active forms [7, 8]; hence overdose of iron may result in diseases. Therefore it is important to monitor the level of iron in human body or in tap water supplies.

Conventionally, Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) are being used for heavy metals analysis due to their wide range of detection and high sensitivity [9]. However, these instruments are costly, time-consuming, and bulky as well as not portable for on-site testing. Furthermore, samples have to be transported from sites to laboratories, and preservation of samples is normally required [10, 11]. A portable, highly sensitive, and selective sensing system is highly desirable for rapid and accurate detection of heavy metals ions especially for in situ environmental monitoring.

Several ion-selective electrodes for detection of Fe^{3+} have been reported. An ion-selective electrode based on μ-bis(tridentate) ligand was shown to be highly selective towards Fe^{3+} with a limit of detection (LOD) of 0.276 ppm (evaluated as 5.0×10^{-6} M) [12]. Some researchers had proposed the use of poly(vinyl chloride) (PVC) membrane electrode incorporating 4,4′-dimethoxybenzil bisthiosemicarbazone (DBTS) and porphyrins as receptors [13, 14]. Fong et al. [15] had reported a fluorescence chemosensor based on carbon nanoparticles (CNP) synthesized from sodium alginate using nanoprecipitation and thermal acid carbonization method. This sensor worked by determining the fluorescence quenching of CNP in the presence of Fe^{3+} and a LOD of 1.06 μM was reported. However, these sensors for Fe^{3+} ions still posed challenges of requiring the use of hazardous or expensive chemicals and complicated fabrication process. Therefore, a low-cost, portable, ecofriendly, and highly sensitive electrochemical sensor is highly desirable for on-site rapid detection of Fe^{3+} ions.