Screen-Printed Electrochemical Sensor Platform for Nitrate, Nitrite, and Ammonium Detection in water

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Monitoring nitrate (NO3–), nitrite (NO2–), and ammonium (NH4+) ions levels in water is crucial due to their significant impact on environmental and human health. Using screen-printing technology, electrodes with reproducible chemical performances can be developed. A screen-printed electrochemical cell is composed of three electrodes: working electrode (WE), reference electrode (RE), and counter electrode (CE). The inks used for printing determine the properties of the electrochemical cell, and the appropriate modification of the WE surface plays a key role in the development of sensitive and selective electrochemical sensors for molecules/target detection. Nitrate ions detection involved the use of copper (Cu) due to the high conductivity (5.8 × 107 S/m), which improves charge transfer. Cu crystals with a well-defined morphology were electrodeposited on a carbon screen-printed electrode using cyclic voltammetry. Cu micro-flowers returning high catalytic activity toward NO3– electroreduction. This sensor exhibits a sensitivity of 44.71 µA/mM, a low detection limit (LoD) of 0.87 µM, and a dynamic linear range from 50 µM to 3 mM. Additionally, the NO3– sensor shows good stability (maximum RSD of 5% after ten measurements), reproducibility (maximum RSD of 4%), and repeatability (RSD of 5.5% after ten measurements). Nitrite ions detection involved the electrodeposition of manganese and copper oxides onto a carbon working electrode. CuO and MnO■ act synergistically as efficient catalysts for the electrooxidation of nitrite to nitrate, thanks to their complementary redox properties. The resulting sensor exhibits high catalytic activity toward the electrooxidation of NO■■, with a sensitivity of 10.83 µA/µM, a LoD of 0.071 µM, and a good linear dynamic concentration range (0.2–60 µM). Reproducibility (maximum standard deviation 2.91%) and repeatability (usable up to three times) were also evaluated. Ammonium ions detection involved the electropolymerization of Polyaniline (PANI) and gold nanoparticles (Au NPs) electrodeposition on carbon WE. PANI is considered one of the most versatile conducting polymers, with a wide variety of controllable properties. The unique properties of polyaniline and gold nanoparticles enable efficient electrochemical signal transduction upon exposure to NH4+, leading to the accurate quantification of ammonium concentrations in water. The Au/PANIep/C electrode exhibits excellent sensitivity at lower concentrations with LoD of 0.03 µM. The electrode shows good reproducibility, with a maximum relative standard deviation of 3.68%. Furthermore, simultaneous monitoring of NO3–, NO2–, and NH4+ ions is viable by employing portable multichannel potentiostats, which allow independent multiple measurements. This approach enables efficient, real-time, and on-site multiplexed water quality analysis.