Synthesis, Characterization, and Multifunctional Applications of Moosa balbeesiaana Peel-Derived NCQDs-PEG-400 Composite in Photocatalysis and Electrochemical Energy Storage

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Abstract

The degradation analysis of toxic and non-biodegradable dyes, widely used in textiles, paper, plastics, and food industries, is critical for protecting aquatic ecosystems. Additionally, the use of bio-waste for designing high-performance electrodes for supercapacitors aligns with environmental conservation efforts. In this study, we report the synthesis and characterization of a composite of metal oxide nitrogen doped carbon quantum dots (NCQDs) and polyethylene glycol-400 (PEG-400) using *Moosa balbeesiaana* peels extract.

The photocatalytic degradation potential of the composite was investigated for Malachite Green (MG) and Rhodamine B (Rh-B) dyes. Furthermore, the degradation potential of the composite without PEG-400 was examined for Fluorescein (Fl) and Methylene Blue (MB) dyes.

The correlation coefficients for the composite with PEG-400 in zero-order, first-order, and second-order kinetics were 0.8802, 0.9654, and 0.8144 respectively, for MG, and 0.8256, 0.8378, and 0.8497, respectively, for Rh-B. For the composite without PEG-400, the respective values for Fl were 0.9452, 0.9514, and 0.9519, while for MB they were 0.8882, 0.8879, and 0.8874.

Electrochemical analysis was conducted using cyclic voltammetry (CV), galvanostatic charge-discharge (GCD), electrical impedance spectroscopy (EIS), cyclic stability (C_{sta}) measurements. The specific capacitance values were found to be 1873.14 (F/g) at $10mVs^{-1}$, and 1806.27 (F/g) at $1Ag^{-1}$.EIS measurements showed a series resistance (Rs) of 13.79 Ω, a charge transfer resistance (Rct) of 28.56 Ω, and a Warburg impedance (Zw) of 1.15 $x10^{-7}$ Ω. The capacitance retention of 110% from 1500 to 5000 cycles demonstrated excellent stability over 5000 cycles.

Keywords: dyes, photocatalic analysis, bio-waste, cyclic stability