Carbon Quantum Dot-Assisted Ultrafast Detection of Pesticides Based on Fluorescence Quenching

Doğa Yüce*, Çisem Kırbıyık Kurukavak, Mahmut Kuş

Department of Chemical Engineering, Konya Technical University, 42075, Konya, Turkey
dogayuce2023@gmail.com

Abstract

The extensive use of agricultural pesticides (particularly herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D)) and their subsequent runoff into aquatic ecosystems and bioaccumulation pose significant environmental and public health risks. Although conventional analytical techniques (e.g., HPLC, GC-MS) offer high sensitivity, their operational complexity, lengthy analysis times, high costs, and laboratory dependency hinder rapid, on-site environmental monitoring. In this study, highly water-dispersible and photostable carbon quantum dots (CQDs) were synthesized via a green hydrothermal route utilizing spent coffee grounds as a sustainable biomass precursor to establish an ultrafast fluorescence quenching-based platform for pesticide determination. CQDs were produced through hydrothermal carbonization at 200 °C for 4 h, and their optical and fluorescence emission characteristics were systematically evaluated by photoluminescence (PL) spectroscopy. Upon exposure to target 2,4-D molecules, an immediate fluorescence "turn-off" quenching response was recorded within seconds, allowing reliable quantitative evaluation through concentration-dependent calibration models. This CQD-based optical sensing platform provides a cost-effective, eco-friendly, and antibody-free analytical solution by valorizing organic waste into high-value functional nanomaterials, exhibiting great promise for integration into portable devices for rapid water quality and pesticide residue monitoring.

Keywords: Carbon quantum dots (CQDs), Fluorescence quenching, 2,4-D pesticide detection, Green synthesis, Water management, Photoluminescence sensor.