Biogenic Synthesis of Ag Nanoparticles, ZnO Nanoparticles, and Ag@ZnO Nanocomposites as Photocatalysts for Degradation of Brilliant Blue Dye

Utilizing green nanomaterials in a biomimetic setting to treat wastewater emulates the sustainability and efficiency of natural systems. In this study, wood apple outer shells (WA) extract was used as a reducing and stabilizing agent in a simple, inexpensive, and environmentally friendly green approach to synthesize Ag nanoparticles (NPs), ZnO NPs, and Ag@ZnO nanocomposites (NCs) as potential photocatalysts for the degradation of an industrial dye Brilliant Blue (BB). Synthesis parameters of Ag NPs, ZnO NPs, and Ag@ZnO NCs were evaluated in this research utilizing various analytical methods. Surface plasmon resonance peaks for Ag NPs, ZnO NPs, and Ag@ZnO NCs, were observed at 400–470 nm, 320–370 nm, and 400–500 nm, respectively. Appearance of a Fourier transform infrared band in the 500–700 cm^{-1} region is attributed to the Zn-O bond stretching mode, indicating the formation of ZnO NPs and Ag@ZnO NCs. The SEM images of WA-mediated Ag NPs, ZnO NPs, and Ag@ZnO NCs illustrate spherical, flake, and flower-shapes, respectively, while the average sizes of these three types of particles are determined to be 15.04 ± 5.40 nm, 82.40 ± 3.24 nm, and 12.08 ± 2.91 nm, respectively, as per transmission electron microscopic investigation. Moreover, X-ray diffraction patterns confirm the synthesis of pure crystalline structures, with a face-centered cubic structure for Ag and a hexagonal wurtzite structure for ZnO NPs during the synthesis of Ag@ZnO NCs. The biogenic WA-mediated ZnO NPs show a remarkable photodegradation efficiency of 65.8% under the optimum conditions of catalytic load, pH, and dye concentration, whereas WA-mediated Ag NPs and Ag@ZnO NC show 13.9% and 63.7% photodegradation efficiency, respectively, at 240 min. The study reveals that WA-mediated ZnO NPs and Ag@ZnO NCs exhibit nearly identical photo-catalytic activity against the BB dye, presenting new opportunities for sustainable use in textile and wastewater treatment.

Keywords- Ag NPs, Ag@ ZnO NCs, Brilliant Blue, Photocatalytic activity, Wood apple, ZnO NPs