Plasmon-Enhanced Photocatalysis and Antimicrobial Activity of Green-Synthesized Ag-Decorated ZnO Nanoparticles Using *Mentha pulegium* Extract

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Abstract

Plasmonic nanomaterials have attracted considerable interest owing to their distinctive optical and electronic properties, which significantly enhance their performance in photocatalytic and biomedical applications. In this study, Ag-decorated ZnO (ZnO/Ag) nanoparticles were synthesized via a green approach using *Mentha pulegium* extract, resulting in spherical nanoparticles with a uniform size distribution ranging from 40 to 55 nm. The localized surface plasmon resonance (LSPR) effect of silver markedly improved light absorption and charge carrier separation, leading to a 92.6% degradation efficiency of penicillin G under optimized conditions. Moreover, the Ag-decorated ZnO nanoparticles demonstrated enhanced antibacterial activity, exhibiting a minimum inhibitory concentration (MIC) of 62.5 µg/mL against *Escherichia coli* and *Klebsiella pneumoniae*, outperforming both pristine ZnO and the plant extract. The strong plasmonic interactions further contributed to improved antioxidant performance, achieving an 84% DPPH radical scavenging efficiency. These results highlight the multifunctional potential of Ag-decorated ZnO nanoparticles and emphasize the critical role of plasmonic enhancement in advancing eco-friendly nanotechnological solutions for environmental and biomedical applications.