ANTIBACTERIAL PROPERTIES OF ZINC OXIDE-CONTAINING COMPOSITE MATERIALS BASED ON SILICA AND POLYLACTIC ACID

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Antimicrobial resistance poses a critical threat to global health, as conventional drugs increasingly fail against multidrug-resistant pathogens. A key challenge lies in the inability of many antimicrobials to penetrate microbial membranes or act effectively against intracellular infections. Nanoparticles (NPs) offer a promising alternative due to their unique physicochemical properties and broad-spectrum antimicrobial activity. Among these, zinc oxide nanoparticles (ZnO NPs) are especially notable for their low cytotoxicity and effectiveness against resistant strains.

The antimicrobial action of ZnO NPs is multifactorial. They release Zn^{2+} ions, which disrupt microbial membranes and interfere with protein function by binding to thiol and imidazole groups. Concurrently, ZnO NPs generate reactive oxygen species, leading to oxidative stress, lipid peroxidation, protein oxidation, and DNA damage. This combined assault compromises cellular integrity and function, resulting in cell death. Their efficacy depends on particle size, surface characteristics, and dispersion state, which govern their interaction with microbial cells.

To improve stability, dispersion, and bioavailability, ZnO was immobilized on nanosilica (SiO_2), selected for its high surface area and tunable porosity. Polylactic acid (PLA) was added to enhance biocompatibility, reduce ZnO toxicity, and support biodegradability. This study synthesized and characterized SiO_2-ZnO and SiO_2-ZnO-PLA nanocomposites, and evaluated their antibacterial activity against both Gram-positive and Gram-negative bacteria.

ZnO was deposited on silica via impregnation and thermal treatment, with PLA added through in situ L-lactide polymerization. FTIR confirmed chemical bonding, XRD identified ZnO crystallinity, and TGA assessed thermal stability. Zeta potential analysis showed reduced SiO_2-ZnO stability in alkaline media; PLA improved stability in neutral to mildly alkaline pH, likely by reducing aggregation.

Antibacterial activity was assessed via a resazurin-based microdilution assay against *S. aureus* and *K. pneumoniae*. SiO_2-ZnO exhibited limited efficacy, inhibiting only select *S. aureus* strains, with no effect on *K. pneumoniae*. PLA modification enhanced performance, notably against *K. pneumoniae*, while maintaining or slightly improving activity against *S. aureus*. This improvement likely results from altered surface properties and enhanced nanoparticle–cell interactions, underscoring the antibacterial potential of PLA-modified ZnO–silica composites.

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