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A Study of Eco-Friendly Approaches to Metal Oxide Nanoparticles and Their Biological Uses

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ABSTRACT

Eco-friendly or green approaches for synthesizing metal oxide nanoparticles (MONPs) have gained significant attention in recent years due to their sustainability and minimal environmental impact. Traditional chemical and physical synthesis methods often involve toxic chemicals, high energy consumption, and hazardous by-products. In contrast, green synthesis uses natural resources like plant extracts, microorganisms, and biopolymers to produce nanoparticles in an environmentally benign manner. These biologically mediated methods not only reduce toxicity but also enhance the stability, biocompatibility, and functional properties of the nanoparticles. Metal oxide nanoparticles such as zinc oxide (ZnO), titanium dioxide (TiO_2), and iron oxide (Fe_3O_4) synthesized through eco-friendly methods have demonstrated a wide range of biological applications. They show potent antibacterial, antifungal, antioxidant, and anticancer activities, making them valuable in medicine, pharmaceuticals, and environmental remediation. For instance, ZnO nanoparticles derived from plant extracts have been effective against various pathogenic bacteria, while TiO_2 nanoparticles are used in targeted drug delivery and photocatalytic treatments. The eco-friendly synthesis also allows control over particle size, shape, and surface characteristics, which are critical for optimizing biological activity.