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Synergistic Nanodelivery Platforms for Sustainable Biomedical and Agrichemical Innovations

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ABTRACT

The convergence of nanoscience, biotechnology, and sustainable material design is opening transformative pathways in healthcare and agriculture. This work highlights nanocolloidal systems and advanced nanostructures as versatile delivery platforms that unite scientific innovation with societal needs. In biomedicine, palm-based nanoemulsions show promise for targeted lung cancer therapy by overcoming challenges of solubility, stability, and toxicity. Their physicochemical and aerodynamic profiles demonstrate suitability for deep lung deposition and enhanced therapeutic outcomes. Complementary nanostructures including graphene derivatives, mesoporous silica, iron oxides, and reticular frameworks such as MOFs, ZIFs, and COFs offer high porosity, pH-responsive release, and functionalised precision for theranostic applications. In vitro and in vivo studies reveal controlled drug release, favourable cellular interactions, and optimised aerosolisation for inhalation therapies. Beyond medicine, nanotechnology also advances sustainable agriculture. Calcium-based MOFs encapsulating fungicides provide targeted protection against Ganoderma boninense, a devastating crop pathogen. Molecular simulations guide the rational design of nanocarriers, ensuring efficient delivery while minimising environmental burden. Integration of nanofibres, nanotubes, and nanoporous systems further extends potential in both biomedical and agrichemical fields, creating synergies that enhance performance and sustainability. Collectively, these findings underscore how nanodelivery systems can bridge science, technology, and humanity paving the way for sustainable theranostics, resilient food systems, and future-ready innovations that strengthen human and planetary well-being.