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Comprehensive Review of Nanoemulsion Systems

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Abstract: *Nanoemulsions are advanced colloidal dispersions composed of oil, water, surfactants, and co-surfactants, with droplet diameters typically ranging from 20 to 200 nm. Their nanoscale dimensions confer unique physicochemical attributes such as high kinetic stability, enhanced solubilization capacity, optical clarity, and improved bioavailability, distinguishing them from conventional emulsions and microemulsions. Owing to their small droplet size and large interfacial surface area, nanoemulsions enable superior drug dissolution, enhanced permeation across biological membranes, and effective protection of encapsulated actives from chemical and enzymatic degradation. These advantages have positioned nanoemulsions as a highly versatile platform for drug delivery across oral, topical, transdermal, ocular, nasal, pulmonary, and parenteral routes.*

This review provides a comprehensive overview of nanoemulsion systems, covering their fundamental principles, types, formulation components, and preparation techniques—including high-pressure homogenization, ultrasonication, microfluidization, phase inversion temperature (PIT), and spontaneous emulsification. The article further highlights the mechanistic basis of nanoemulsion stability, focusing on destabilization pathways such as coalescence, flocculation, creaming, and Ostwald ripening. In addition to pharmaceutical applications, the review discusses the growing use of nanoemulsions in cosmetics, food technology, agriculture, and biotechnology. Finally, current challenges—including high surfactant requirements, potential toxicity, scalability limitations, and regulatory barriers—are examined alongside emerging strategies aimed at enhancing stability, efficacy, and industrial feasibility. Collectively, this review underscores the broad scientific and commercial relevance of nanoemulsion systems and outlines future directions for their optimized design and application..

Keywords: Nanoemulsion, Drug Delivery Systems, Colloidal Stability, High- and Low-Energy Emulsification

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