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Drug–Polymer Interactions: Principles and Applications in Drug Delivery Systems

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Editorial

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Introduction

Drug–polymer interactions are a fundamental aspect of pharmaceutical science, particularly in the design and development of advanced drug delivery systems. Polymers are widely used as carriers, coatings, or matrices to control drug release, enhance stability, and improve bioavailability. Understanding how drugs interact with polymers at the molecular and physicochemical levels is essential for optimizing formulation performance, ensuring therapeutic efficacy, and maintaining product safety [1].

Discussion

Drug–polymer interactions involve a range of physical and chemical forces, including hydrogen bonding, electrostatic interactions, hydrophobic forces, and van der Waals interactions. These interactions influence key properties such as drug solubility, release rate, stability, and degradation behavior. For example, hydrophilic polymers can enhance the solubility of poorly water-soluble drugs, while hydrophobic polymers are often used to achieve sustained or controlled drug release [2,3].

Polymers used in pharmaceutical formulations may be natural, semi-synthetic, or synthetic. Natural polymers such as alginate, chitosan, and gelatin are valued for their biocompatibility and biodegradability, whereas synthetic polymers like polyethylene glycol, poly(lactic-co-glycolic acid), and polyvinyl alcohol offer greater control over mechanical strength and degradation rates. The choice of polymer and its interaction with the drug determines the performance of dosage forms such as tablets, capsules, microspheres, nanoparticles, and hydrogels [4,5].

Drug–polymer interactions also play a critical role in stabilizing drugs against environmental factors such as moisture, light, and temperature. In solid dispersions, strong interactions between the drug and polymer can prevent drug crystallization, maintaining the drug in an amorphous state that enhances dissolution and bioavailability. However, excessively strong interactions may hinder drug release, highlighting the need for careful formulation balance.

Analytical techniques such as Fourier transform infrared spectroscopy, differential scanning calorimetry, X-ray diffraction, and nuclear magnetic resonance are commonly used to study drug–polymer interactions. These tools help characterize molecular interactions and predict formulation behavior. Understanding these interactions is particularly important in the development of novel delivery systems, including targeted and stimuli-responsive polymers that release drugs in response to specific physiological conditions.

Conclusion

Drug–polymer interactions are central to the successful design of modern pharmaceutical formulations. By influencing drug stability, release, and bioavailability, these interactions determine therapeutic effectiveness and patient outcomes. Continued research into drug–polymer behavior will support the development of innovative drug delivery systems that are safer, more efficient, and tailored to specific clinical needs.

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