Research & Reviews in Polymer

Editorial | Vol 15 Iss 1

Polymer-Based Drug Delivery Systems: Design, Mechanisms, and Biomedical Applications for Controlled Therapeutic Release

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Received: Feb 04, 2024; **Accepted:** Feb 18, 2024; **Published:** Feb 27, 2024

Abstract

Polymer-based drug delivery systems have revolutionized modern medicine by enabling controlled and targeted release of therapeutic agents. This article explores various polymer systems, including hydrogels, nanoparticles, and micelles, and their applications in drug delivery. The study also discusses challenges and future directions in this field.

***Keywords:** Drug delivery polymers, controlled release, biomedical polymers, hydrogels, nanoparticles*

Introduction

Polymer-based drug delivery systems are designed to improve the efficacy and safety of therapeutic treatments by controlling the release of drugs within the body [1]. These systems utilize biodegradable and biocompatible polymers to deliver drugs to specific sites, reducing side effects and improving treatment outcomes [2]. Various polymer systems, including hydrogels, nanoparticles, and micelles, are used for drug delivery applications [3]. These systems can be engineered to respond to environmental stimuli such as pH and temperature, enabling targeted and controlled drug release [4]. Despite significant advancements, challenges such as drug loading efficiency, stability, and regulatory approval remain critical issues [5]. Ongoing research focuses on developing more efficient and personalized drug delivery systems. Recent research focuses on developing eco-friendly elastomers and improving their performance under extreme conditions. Research efforts are focused on developing cost-effective synthesis methods and improving recyclability to promote sustainable use. Thermosetting polymers differ fundamentally from thermoplastics due to their ability to form permanent cross-linked networks during the curing process. Once cured, these materials cannot be remelted or reshaped, which gives them exceptional mechanical strength, thermal stability, and chemical resistance. Common thermosetting polymers include epoxy resins, phenolic resins, and polyurethanes, which are widely used in coatings, adhesives, and composite materials. The curing process involves chemical reactions such as poly condensation or addition reactions that create a dimensional network structure. This cross-linked architecture is responsible for the superior properties of thermosets, making them suitable for demanding applications in aerospace, automotive, and electronics industries [5]. However, the inability to recycle thermosetting polymers poses significant environmental challenges. Recent research has focused on developing recyclable thermosets and bio-based alternatives to address sustainability concerns.

Conclusion

Polymer-based drug delivery systems represent a major advancement in biomedical science. Future developments will focus on improving efficiency, targeting, and patient-specific treatments. Polymer characterization is indispensable for understanding and optimizing polymer performance. Continued advancements in analytical techniques will further enhance material development and innovation.

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