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Accessible Editor's Pick Examine Composite and Inherent Hydrogels as Potential Materials to Reduce Antimicrobial Resistance

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Introduction

Antimicrobial resistance has emerged as one of the most pressing global health challenges of the 21st century. The rise of AMR threatens to undo the advances made in modern medicine, as antibiotics, antiviral agents, and antifungal drugs become increasingly ineffective against a growing number of pathogens. According to the World Health Organization, AMR leads to estimated deaths annually, and if left unchecked, this figure could rise to million deaths per year by 2050. This has underscored the urgent need for innovative strategies to combat infections and curb the spread of resistant microorganisms. In the context of AMR, the development of alternative treatment strategies is paramount. Among the most promising materials for this purpose are hydrogels. Hydrogels are three-dimensional polymeric networks capable of holding large amounts of water or biological fluids, and they are widely used in biomedical applications due to their biocompatibility, ability to mimic biological tissues, and flexibility in design. In recent years, composite and inherent hydrogels have gained attention for their potential to serve as platforms for antimicrobial agents, offering a unique mechanism to both deliver antimicrobial compounds and act as barriers to microbial growth [1].

Description

Hydrogels are versatile materials that consist of hydrophilic polymers capable of absorbing and retaining large quantities of water, which gives them their unique properties. They can be composed of natural, synthetic, or hybrid polymers and their structure can be designed to suit specific medical applications. Some of the key properties that make hydrogels attractive for biomedical applications include biocompatibility, high water content, controlled release, and flexibility. Hydrogels are non-toxic and can be engineered to be compatible with human tissues, reducing the risk of immune reactions. The high water retention capacity of hydrogels allows them to mimic biological tissues, making them ideal for use in wound care, drug delivery systems, and tissue engineering. Furthermore, hydrogels can be designed to release incorporated therapeutic agents in a controlled and sustained manner, making them useful in applications where prolonged release is desired, such as in antimicrobial treatments. The physical and chemical properties of hydrogels can also be customized to suit different medical needs, including their mechanical strength, degradation rate, and swelling behavior [2].

Composite hydrogels are materials that combine two or more components to achieve improved or synergistic properties. These materials are typically made by incorporating inorganic particles, nanoparticles, or bioactive agents into a hydrogel matrix to enhance its mechanical strength, antimicrobial activity, or other functional properties. In the context of AMR, composite hydrogels can be designed to achieve multiple goals: sustained release of antimicrobial agents, prevention of microbial colonization, and inhibition of resistance development. For instance, composite hydrogels can incorporate silver nanoparticles, antimicrobial peptides, or natural antimicrobial compounds like cur cumin to provide a localized, controlled release of these agents directly at the site of infection. This targeted delivery system can help reduce the systemic use of antibiotics, which is a key factor in the development of AMR. Moreover, composite hydrogels can be engineered to incorporate materials that prevent the adhesion and growth of microorganisms on their surface. The integration of materials such as chitosan, a naturally occurring antimicrobial polysaccharide, or Graphene oxide, known for its antibacterial properties, can enhance the hydrogel's ability to combat microbial infections[3].

Inherent hydrogels, as the name suggests, are hydrogels that possess intrinsic antimicrobial properties without the need for additional antimicrobial agents or nanoparticles. These hydrogels typically rely on the chemical composition of the polymer used to form the hydrogel, and some natural polymers have been shown to exhibit antimicrobial activity [4]. For example, natural polymers such as chitosan, alginate, and hyaluronic acid have inherent antimicrobial properties that can be exploited in the development of hydrogels for infection control. Chitosan, derived from chitin, is particularly notable for its ability to inhibit the growth of a wide range of microorganisms, including bacteria, fungi, and viruses. Its antimicrobial activity is thought to result from its positive charge, which can interact with the negatively charged bacterial cell membranes, disrupting their integrity and leading to cell death. Chitosan-based hydrogels have been studied extensively for use in wound dressings and other infection control applications. Similarly, alginate, a polysaccharide derived from brown algae, has been shown to have mild antimicrobial effects, particularly against gram-positive bacteria. Hyaluronic acid, a naturally occurring substance in human connective tissue, has been reported to possess anti-inflammatory and antimicrobial properties as well, making it a valuable material for the development of hydrogels for wound healing [5].

Conclusion

Composite and inherent hydrogels represent promising materials in the fight against antimicrobial resistance. Their ability to provide sustained release of antimicrobial agents, prevent microbial colonization, and reduce the overuse of antibiotics positions them as valuable tools in modern medicine. Furthermore, the versatility of these hydrogels—whether through the incorporation of bioactive agents or by utilizing natural antimicrobial properties—offers a wide range of applications in wound care, implantable devices, and drug delivery systems. As research continues to advance, it is likely that hydrogels will play an increasingly significant role in reducing AMR, helping to curb the spread of resistant infections and ultimately improving patient outcomes. By combining the therapeutic potential of hydrogels with innovative approaches to drug resistance, these materials could offer a transformative solution to one of the most challenging global health threats of our time.

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Conflict of Interest

None.

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