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Polymer Hydrogels in Biomedical Applications: A Short Review

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Abstract

Polymer-based hydrogels are materials that love water and are made from long chains of molecules linked together. They are used in transportation for carrying large amounts of water and natural materials, and for controlling the gentle release of liquids based on their unique physical and chemical traits. Recent trends in hydrogel drug delivery systems include releasing medicines in response to triggers like pH levels, temperature, or proteins to ensure controlled delivery and reduce potential harm. Injectable hydrogels that are easy to use and long-lasting are gaining interest. Combining nano hydrogels with other materials is being explored to improve the effectiveness of medicine delivery. Advanced hydrogels with enhanced properties and controlled release capabilities are being developed, with a focus on biocompatibility. These advancements are paving the way for more complex medicine delivery systems that combine multiple drugs for improved treatment. The growing use of polymer-based hydrogels in personalized medicine is focused on creating tailored solutions for specific needs and improving disease treatment effectiveness for accessible healthcare. The use of hydrogels is rapidly evolving and becoming more effective, with potential to enhance transportation systems in the future.

Keywords: polymer hydrogels; ionic charge; pore size; crosslinking; drug delivery systems

Introduction

Drug Delivery Systems (DDSs) are essential for improving solutions by addressing issues such as low retention and poor dissolution. Controlled drug delivery systems, such as hydrogels made from polymers, slowly release medication [1]. This maintains consistent drug levels in the body and reduces the frequency of dosing for patients. DDS can target specific body parts, reducing side effects and enhancing effectiveness. Hydrogels made from polymers have the ability to retain and release various types of drugs, making them valuable for research and medical purposes [2]. These hydrogels consist of water-attracting materials that can absorb and retain water, mimicking the properties of natural tissues. This capability makes them particularly suitable for applications in drug delivery, tissue engineering, and wound healing. They have the ability to regulate drug release by modifying their swelling behavior, which can prolong the medication's effectiveness and improve patient adherence to treatment regimens [3-5]. Additionally, these hydrogels can respond to specific stimuli, allowing for targeted medication delivery to affected areas, thereby minimizing side effects and boosting treatment efficacy [6]. Polymer-based hydrogels are biocompatible and hydrophilic, resembling living tissues, and they can serve as scaffolds for cell growth and tissue repair. Furthermore, they are employed in biosensing to monitor environmental changes for medical testing and drug delivery. Overall, advancements in hydrogel technology hold great potential for improving drug delivery, tissue engineering, and environmental sensing across a variety of medical applications [8]. The article explores recent developments in polymer-based hydrogels for drug delivery, presenting innovative ideas and strategies to propel this field forward. The article discusses three significant concerns regarding bio-hydrogels and offers brief insights on them (Fig.1).

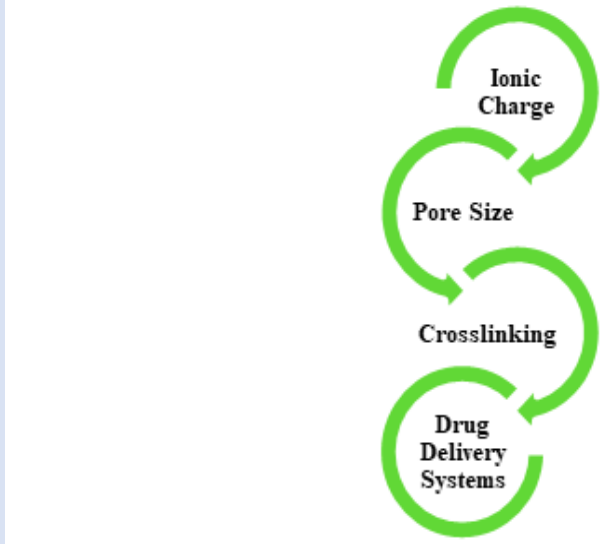

Figure1: Key considerations when utilizing polymer hydrogels in the field of biotechnology

Ionic Charge-Based Polymer Hydrogels

Hydrogels derived from polymers can be categorized into three types based on their ionic charge: neutral, ionic, and ampholytic [9]. Neutral hydrogels lack any ionic charge, making them biocompatible and non-toxic, which enables the fine-tuning of their mechanical properties for a variety of biomedical applications. Ionic polymer hydrogels, on the other hand, contain charged functional groups that allow for interactions with oppositely charged molecules, including both cationic and anionic variants that are beneficial in drug delivery and tissue engineering [10]. Ampholytic hydrogels possess both positive and negative charged groups, allowing their properties to change in response to pH variations. This adaptability makes them particularly suitable for drug delivery and biosensing applications. Compared to ionic hydrogels, ampholytic hydrogels provide enhanced stability and biocompatibility, along with the capability for precise property modulation, catering to a range of biomedical uses [11-13].

Hydrogels Made from Polymers with Varying Pore Sizes

Polymer-based hydrogels exhibit a range of pore sizes and interstitial spaces. Pore size pertains to the voids that facilitate molecular movement, whereas interstitial spaces refer to the gaps between polymer chains that influence the material's structural integrity [14]. By engineering hydrogels with targeted pore dimensions, one can significantly alter their properties and applications, particularly by improving drug delivery efficacy. Microporous hydrogels, characterized by their large interconnected voids, are especially beneficial for tissue engineering applications [15]. Mesoporous hydrogels contain pores measuring between 2 to 50 nm, yielding a high surface area and unique attributes that are ideal for drug delivery and tissue regeneration purposes. Conversely, microporous hydrogels have pores smaller than 2 nm, enabling efficient fluid absorption and release, which makes them suitable for uses like wound dressings and tissue engineering [16]. Each hydrogel type presents distinct advantages and specific applications. Microporous hydrogels effectively promote cell infiltration and tissue regeneration, while mesoporous hydrogels are particularly adept at controlled drug release and biosensing functions [17]. Microporous hydrogels enhance mechanical strength and can be tailored for targeted drug delivery applications. Altogether, the careful engineering of pore structures in polymer-based hydrogels allows researchers and engineers to fine-tune molecular interactions and diffusion processes, optimizing these materials for a wide array of biomedical applications [18]. Understanding the unique properties of different hydrogels paves the way for advancements in their design for specialized uses.

Polymer-Based Hydrogels Based on Crosslinking Rom polymers can be categorized linking

Hydrogels made from polymers can be categorized based on their crosslinking mechanisms into two primary types: chemical and physical crosslinking [19]. Chemical crosslinking involves creating covalent bonds between polymer chains, with methods like radical polymerization and Michael addition being common. In contrast, physical crosslinking is dependent on reversible interactions among polymer

chains, employing techniques such as temperature-induced gelation and pH-induced gelation [20]. Chemically crosslinked hydrogels are characterized by robust mechanical properties and enhanced stability; however, their production may require harsh conditions or the use of toxic substances. Physically crosslinked hydrogels respond to environmental variations, whereas chemically crosslinked hydrogels are more suitable for load-bearing applications. The selection between the two depends on the required properties: physically crosslinked hydrogels are ideal for drug delivery and tissue engineering [21].

Hydrogels Made from Polymers for Drug Delivery Systems

Polymer-based hydrogels are gaining significance in drug delivery applications due to their exceptional water retention properties, biocompatibility, and responsiveness to various stimuli [22-24]. These hydrogels facilitate controlled drug release by adjusting their swelling characteristics, enabling targeted delivery to specific tissues. They also improve the oral bioavailability of drugs, provide options for transdermal administration, and support the creation of implantable systems for continuous treatment of chronic conditions or prolonged medication release [25-27]. By carefully manipulating the chemical composition or cross-linking density of the hydrogel, the rate of drug release can be accurately regulated. Additionally, incorporating targeting agents such as antibodies or peptides into the hydrogel increases the precision of drug delivery to targeted areas. Implantable drug delivery systems are capable of maintaining a consistent medication release over extended durations, making them particularly suitable for managing chronic illnesses or for use in extended-release formulations [28-31].

Conclusions

Polymer-based hydrogels are a highly promising class of materials for drug delivery systems due to their high-water content, pliable and flexible characteristics, and compatibility with biological tissues. These hydrogels enable prolonged drug release, provide controlled delivery mechanisms, and allow for targeted drug administration through modifications in their properties. Research in recent decades has emphasized the significant impact of polymer-based hydrogels in the biomedical sector, with potential applications in tissue engineering, wound management, and biosensing. These versatile materials can improve treatment outcomes by enhancing drug effectiveness, reducing side effects, and promoting patient adherence to treatment regimens. Polymer-based hydrogels have the potential to revolutionize healthcare and drive advancements in therapeutic science through innovative applications.

Declarations

Credit authorship contribution statement

Mohammad Hossein Karami: Supervision, Validation, Formal analysis, Data curation, Investigation, Resources, Writing – original draft, Writing - review & editing, Visualization, Project administration, Methodology. Majid Abdouss: Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Arnold, M.; Morgan, E.; Rumgay, H.; Mafra, A.; Singh, D.; Laversanne, M.; Vignat, J.; Gralow, J.R.; Cardoso, F.; Siesling, S.; et al. (2022). Current and future burden of breast cancer: Global statistics for 2020 and 2040. *Breast*, 66:15-23.
2. Li, S.; Silvestri, V.; Leslie, G.; Rebbeck, T.R.; Neuhausen, S.L.; Hopper, J.L.; Nielsen, H.R.; Lee, A.; Yang, X.; McGuffog, L.; et al. (2022). Cancer Risks Associated with BRCA1 and BRCA2 Pathogenic Variants. *J. Clin. Oncol*, 40:1529-1541.
3. Mundekkad, D.; Cho,W.C. (2022): Nanoparticles in Clinical Translation for Cancer Therapy. *Int. J. Mol. Sci*, 23:1685.
4. Rej, R.K.; Roy, J.; Allu, S.R. (2024). Therapies for the Treatment of Advanced/Metastatic Estrogen Receptor-Positive Breast Cancer: Current Situation and Future Directions. **Cancers**, 16:552.
5. Karami,M, H.; Abdouss,M. (2024). Cutting-edge tumor nanotherapy: Advancements in 5-fluorouracil Drug-loaded chitosan nanoparticles, Inorg. Chem Commun, 164, 112430.
6. Yao, Y.; Zhou, Y.; Liu, L.; Xu, Y.; Chen, Q.;Wang, Y.;Wu, S.; Deng, Y.; Zhang, J.; Shao, A. (2020). Nanoparticle-Based Drug Delivery in Cancer

Therapy and Its Role in Overcoming Drug Resistance. *Front. Mol. Biosci*, 7:193.
7. Kong, X.; Qi, Y.; Wang, X.; Jiang, R.; Wang, J.; Fang, Y.; Gao, J.; Chu Hwang, K. (2023). Nanoparticle drug delivery systems and their applications as targeted therapies for triple negative breast cancer. *Prog. Mater. Sci*, 134:101070.
8. Ajith, S.; Almomani, F.; Elhissi, A.; Husseini, G.A. (2023). Nanoparticle-based materials in anticancer drug delivery: Current and future prospects. Heliyon, 9: e21227.
9. Rethi, L.; Mutalik, C.; Anurogo, D.; Lu, L.S.; Chu, H.Y.; Yougbaré, S.; Kuo, T.R.; Cheng, T.M.; Chen, F.L. (2022). Lipid-Based Nanomaterials for Drug Delivery Systems in Breast Cancer Therapy. *Nanomaterials*, 12:2948.
10. Bourang, S.; Noruzpour, M.; Jahanbakhsh Godekahriz, S.; Ebrahimi, H.A.C.; Amani, A.; Asghari Zakaria, R.; Yaghoubi, H. (2024). Application of nanoparticles in breast cancer treatment: A systematic review. Naunyn. Schmiedebergs Arch. *Pharmacol*, 1-47.
11. Sartaj, A.; Qamar, Z.; Qizilbash, F.F.; Annu; Md, S.; Alhakamy, N.A.; Baboota, S.; Ali, J. (2021). Polymeric Nanoparticles: Exploring the Current Drug Development and Therapeutic Insight of Breast Cancer Treatment and Recommendations. *Polymers*, 134400.
12. Liu, Y.; Guo, K.; Ding, M.; Zhang, B.; Xiao, N.; Tang, Z.; Wang, Z.; Zhang, C.; Shubhra, Q.T.H. (2022). Engineered Magnetic Polymer Nanoparticles Can Ameliorate Breast Cancer Treatment Inducing Pyroptosis–Starvation along with Chemotherapy. ACS Appl. Mater. *Interfaces*,14:42541-42557.
13. Długosz, O.; Matyjasik, W.; Hodacka, G.; Szostak, K.; Matysik, J.; Krawczyk, P.; Piasek, A.; Pulit-Prociak, J.; Banach, M. (2023). Inorganic Nanomaterials Used in Anti-Cancer Therapies:Further Developments. *Nanomaterials*, 13:1130.
14. Karami,M, H.; Abdouss,M.; Maleki,B. (2024). The state-of-the-art metal nanoparticles in drug delivery systems: A comprehensive review. *Nanomed J*, 11(3):222-249.
15. Karami,M, H.; Aghabarari,B. (2024). The advancement of molybdenum disulfide quantum dots nanoparticles as nanocarrier for drug delivery systems: Cutting-edge in dual therapeutic roles, *J. Mol. Struct*, 1318(1):139149.
16. Saif, A.; Anjum, L.; Faisal, Z.; Akram, N.; Shah, Y.A.; Irfan, R.; Saeed, F.; Afzaal, M.; Asif Shah, M. (2023). Recent advances in protein-based nanoparticles and their applications in the delivery of bioactive compounds. *Int. J. Food Prop*. 26:2866-2880.
17. Mohan, H.; Fagan, A.; Giordani, S. (2023). Carbon Nanomaterials (CNMs) in Cancer Therapy: A Database of CNM-Based Nanocarrier Systems. *Pharmaceutics*,15:1545.
18. Rajana, N.; Mounika, A.; Chary, P.S.; Bhavana, V.; Urati, A.; Khatri, D.; Singh, S.B.; Mehra, N.K. (2022). Multifunctional hybrid nanoparticles in diagnosis and therapy of breast cancer. *J. Control. Release*, 352:1024-1047.
19. Marshall, S.K.; Angsantikul, P.; Pang, Z.; Nasongkla, N.; Hussen, R.S.D.; Thamphiwatana, S.D. (2022). Biomimetic Targeted Theranostic Nanoparticles for Breast Cancer Treatment. *Molecules*, 27:6473.
20. Araújo, J.L.; Vieira, J.A.; Dos Santos Silva, M.; Lima, A.K.O.; da Silva Luz, G.V.; Carneiro, M.L.B.; Azevedo, R.B. (2023). Benefits of using polymeric nanoparticles in breast cancer treatment: A systematic review. *3 Biotech*, 13:357.
21. Dheyab, M.A.; Aziz, A.A.; Khaniabadi, P.M.; Jameel, M.S.; Oladzadabbasabadi, N.; Rahman, A.A.; Braim, F.S.; Mehrdel, B. (2023). Gold nanoparticles-based photothermal therapy for breast cancer. Photodiagnosis Photodyn. Ther, 42:103312.
22. Rahimkhoei, V.; Alzaidy, A.H.; Abed, M.J.; Rashki, S.; Salavati-Niasari, M. (2024). Advances in inorganic nanoparticles-based drug delivery in targeted breast cancer theranostics. Adv. Colloid. *Interface Sci*, 329:103204.
23. Mal, S.; Chakraborty, S.; Mahapatra, M.; Pakeeraiah, K.; Das, S.; Paidesetty, S.K.; Roy, P. (2024). Tackling breast cancer with gold nanoparticles: Twinning synthesis and particle engineering with efficacy. *Nanoscale Adv*, 6:2766-2812.
24. Kumar, P.P.P.; Lim, D.K. (2023). Photothermal Effect of Gold Nanoparticles as a Nanomedicine for Diagnosis and Therapeutics. *Pharmaceutics*, 15:2349.
25. Zhao, L.; Zhou, Y.; Zhang, J.; Liang, H.; Chen, X.; Tan, H. (2023). Natural Polymer-Based Hydrogels: From Polymer to Biomedical Applications. *Pharmaceutics*, 15:2514.

26. Tai, J.; Fan, S.; Ding, S.; Ren, L. (2022). Gold Nanoparticles Based Optical Biosensors for Cancer Biomarker Proteins: A Review of the Current Practices. Front. Bioeng. *Biotechnol*, 10:877193.
27. Karami, M, H.; Abdouss,M. (2024). Recent advances of carbon quantum dots in tumor imaging. *Nanomed J,* 11(1):13-35.
28. Prasad, A.; Bakr, M.M.; ElMeshad, A.N. (2024). Surface-functionalised polymeric nanoparticles for breast cancer treatment: Processes and advances. *J. Drug Target.* 1-15.
29. Karami, MH.; Abdouss, M. (2024). A General Evaluation of the Cellular Role in Drug Release: A Clinical Review Study. *Clin J Obstet Gynecol*. 7:042-050.
30. Karami, MH.; Abdouss, M, Karami, M. (2023). Evaluation of In vitro and Ex vivo Models for Studying the Effectiveness of Vaginal Drug Systems in Controlling Microbe Infections: A Systematic Review. *Clin J Obstet Gynecol*. 6:201-215.
31. Falagan-Lotsch, P.; Grzincic, E.M.; Murphy, C.J. (2017). New Advances in Nanotechnology-Based Diagnosis and Therapeutics for Breast Cancer: An Assessment of Active-Targeting Inorganic Nanoplatforms. Bioconjug. *Chem*, 28:135-152.

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