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Commentary

Eco-biomaterials: Sustainable drug delivery platforms from natural polymers and waste derivatives

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ABSTRACT

The increasing demand for sustainable and eco-friendly drug delivery systems has driven significant interest in the development of eco-biomaterials derived from natural polymers and waste derivatives. This paper explores the potential of these renewable resources as versatile platforms for controlled and targeted drug delivery applications. Natural polymers along with bio-waste derivatives, offer unique advantages including biocompatibility, biodegradability, and cost-effectiveness. Additionally, the environmental benefits of utilizing waste-derived biomaterials are highlighted, showcasing a circular economy approach that reduces environmental impact while enhancing healthcare outcomes. This article underscores the promise of eco-biomaterials as sustainable alternatives to conventional synthetic carriers, paving the way for greener pharmaceutical technologies and improved patient care.

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In recent years, the field of drug delivery has witnessed a paradigm shift towards sustainability and environmental responsibility [1]. Traditional synthetic materials, often derived from non-renewable resources and associated with environmental toxicity, are increasingly being replaced by eco-biomaterials . These materials, sourced from natural polymers and waste derivatives, offer a promising route to develop sustainable drug delivery platforms that align with green chemistry principles and circular economy concepts [2]. Natural polymers such as chitosan, alginate, cellulose, starch, and gelatin have gained significant attention due to their biocompatibility, biodegradability, and non-toxic nature [3-5]. These polymers are abundant in nature and can be extracted from renewable resources like crustacean shells, seaweed, plants, and animal tissues. Their inherent properties allow for the fabrication of versatile drug delivery systems including hydrogels, nanoparticles, films, and microspheres that can provide controlled and targeted release of therapeutic agents [6, 7]. Moreover, the functional groups present in natural polymers facilitate chemical modifications, enabling fine-tuning of drug release kinetics and enhancing interaction with biological tissues [8]. Incorporating waste-derived biomaterials into drug delivery platforms supports waste valorization and reduces dependency on virgin raw materials. The application of eco-biomaterials in drug delivery offers multiple advantages beyond sustainability. Their biodegradability minimizes long-term accumulation in the body and environment, reducing the risk of chronic toxicity [9]. Additionally, many natural polymers exhibit inherent bioactivity, such as antimicrobial or wound-healing properties, which can synergistically enhance therapeutic outcomes [10, 11]. The mild processing conditions required for natural polymers also preserve the stability and activity of sensitive drugs, making them suitable for delivering proteins, peptides, and nucleic acids [12]. Despite these benefits, challenges remain in standardizing the quality and performance of eco-biomaterials due to variability in natural sources and extraction processes. Advances in characterization techniques and scalable manufacturing methods are essential to ensure reproducibility and regulatory compliance [13, 14]. Furthermore, interdisciplinary research combining materials science, pharmacology, and environmental science is crucial to optimize these platforms for clinical translation [15].

Generally, eco-biomaterials derived from natural polymers and waste derivatives represent a sustainable and innovative frontier in drug delivery technology. By connecting renewable resources and promoting circular economy principles, these platforms not only address environmental concerns but also enhance therapeutic efficacy and patient safety. Further research and development in this area hold great promise for creating greener, safer, and more effective drug delivery systems for the future.

Author Contributions

Bahram Rezazadeh Moghaddam: Conceptualization, Writing – original draft, Writing – review & editing; **Mahsa Hojjati:** Writing – original draft, Writing – review & editing. All authors read and approved the final version of manuscript.

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.

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Data Availability

No data is available.

Ethical issues

The authors confirm full adherence to all ethical guidelines, including the prevention of plagiarism, data fabrication, and double publication.

References

[1] Shetty Y, Prabhu P, Prabhakar B. Emerging vistas in theranostic medicine. International journal of pharmaceutics. 2019;558:29-42. DOI: https://doi.org/10.1016/j.ijpharm.2018.12.068.

[2] Zuppolini S, Salama A, Cruz-Maya I, Guarino V, Borriello A. Cellulose amphiphilic materials: chemistry, process and applications. Pharmaceutics. 2022;14(2):386. DOI: https://doi.org/10.3390/pharmaceutics14020386.

[3] Martau G, Mihai M, Vodnar D. Review: the use of Chitosan. Alginate and Pectin in the Biomedical and Food Sector-Biocompatibility, Bio adhesiveness and Biodegradability Polymer. 1837;11:1-28. DOI: https://doi.org/10.3390/polym11111837.

[4] Shirbacheh A, Shirbache K, Karbalaee M. Natural Biomaterial Composites for Tissue Engineering: Challenges and Opportunities. Journal of Composites and Compounds. 2024;6(20). DOI: https://doi.org/10.61186/jcc.6.3.4.

[5] Salehi M, Mirhaj M, Banitorfi Hoveizavi N, Tavakoli M, Mahheidari N. Advancements in Wound Dressings: The Role of Chitin/Chitosan-based Biocomposites. Journal of Composites and Compounds. 2025;7(23). DOI: https://doi.org/10.61186/jcc.7.2.2.

[6] Alkekhia D, Hammond PT, Shukla A. Layer-by-layer biomaterials for drug delivery. Annual review of biomedical engineering. 2020;22(1):1-24. DOI: https://doi.org/10.1146/annurev-bioeng-060418-052350.

[7] Ertugral-Samgar EG, Ozmen AM, Gok O. Thermo-responsive hydrogels encapsulating targeted core–shell nanoparticles as injectable drug delivery systems. Pharmaceutics. 2023;15(9):2358. DOI: https://doi.org/10.3390/pharmaceutics15092358.

[8] Sanchez-Salvador JL, Balea A, Monte MC, Negro C, Blanco A. Chitosan grafted/cross-linked with biodegradable polymers: a review. International Journal of Biological Macromolecules. 2021;178:325-43. DOI: https://doi.org/10.1016/j.ijbiomac.2021.02.200.

[9] Alizade A, Reich T, Jantschke A. Cellulose from dinoflagellates as a versatile and environmentally friendly platform for the production of functionalised cellulose nanofibres. International Journal of Biological Macromolecules. 2024;272:132804. DOI: https://doi.org/10.1016/j.ijbiomac.2024.132804.

[10] Basu B, Rahaman M, Ghosh S, Dutta S, Kumar A, Mukherjee S, et al. Emerging silk sericin-based formulation fortified with therapeutics in the management of diabetic wound and skin tissue regeneration. Zeitschrift für Naturforschung C. 2025(0). DOI: https://doi.org/10.1515/znc-2024-0198.

[11] Wu J, Huo X, Liu J, Bu F, Zhang P. Multifunctional NIR-II nanoplatform for disrupting biofilm and promoting infected wound healing. Colloids and Surfaces B: Biointerfaces. 2025;245:114330. DOI: https://doi.org/10.1016/j.colsurfb.2024.114330.

[12] Dheer D, Arora D, Jaglan S, Rawal RK, Shankar R. Polysaccharides based nanomaterials for targeted anti-cancer drug delivery. Journal of drug targeting. 2017;25(1):1-16. DOI: https://doi.org/10.3109/1061186x.2016.1172589.

[13] Arrasate A, Bravo I, Lopez-Robles C, Arbelaiz-Sarasola A, Ugalde M, Meijueiro ML, et al. Establishment and Characterization of a Stable Producer Cell Line Generation Platform for the Manufacturing of Clinical-Grade Lentiviral Vectors. Biomedicines. 2024;12(10):2265. DOI: https://doi.org/10.3390/biomedicines12102265.

[14] Izadi M, Bazli L. Eco-friendly composites: developing sustainable solutions for modern engineering. Journal of Composites and Compounds. 2025;7(22). DOI: https://doi.org/10.61186/jcc.7.1.4.

[15] Kaufman JD, Curl CL. Environmental health sciences in a translational research framework: more than benches and bedsides. Environmental Health Perspectives. 2019;127(4):045001. DOI: https://doi.org/10.1289/ehp4067.