Research & Reviews: Journal of Pharmaceutics and Nanotechnology

e-ISSN:2347-7857

PH-Sensitive Drug Delivery: Targeted Therapy Through Smart Nanocarriers

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Editorial

Received: 01-Dec-2025, Manuscript No. jpn-25-177954; **Editor assigned:** 03-Dec-2025, Pre-QC No. jpn-25-177954 (PQ); **Reviewed:** 17-Dec-2025, QC No. jpn-25-177954; **Revised:** 22-Dec-2025, Manuscript No. jpn-25-177954 (R); **Published:** 29-Dec-2025, DOI: 10.4172/2347-7857.13.010

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Citation: Nurul A. Rahman, PH-Sensitive Drug Delivery: Targeted Therapy Through Smart Nanocarriers. J Pharm Anal. 2025.13.010.

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Introduction

pH-sensitive drug delivery systems are an innovative approach in pharmaceutical science that exploit variations in pH within the body to achieve site-specific drug release. These systems are particularly useful for targeting tissues or cellular compartments with abnormal pH, such as tumors, inflamed tissues, or the gastrointestinal tract. By releasing drugs selectively at the intended site, pH-sensitive formulations enhance therapeutic efficacy, minimize systemic side effects, and improve patient compliance [1].

Discussion

The principle of pH-sensitive drug delivery relies on materials that respond to changes in acidity or alkalinity. Polymers, liposomes, micelles, and nanoparticles can be engineered to remain stable at physiological pH (around 7.4) and undergo structural changes, swelling, or degradation in acidic or basic environments. For instance, many solid tumors exhibit a slightly acidic extracellular pH (6.5–7.0), and endosomal/lysosomal compartments within cells have a pH of 4.5–5.5. pH-responsive carriers exploit these differences to release encapsulated drugs precisely where needed [2].

Various strategies are used to design pH-sensitive systems. Polymers with acid-labile bonds, such as hydrazone or imine linkages, release drugs upon hydrolysis in acidic conditions. Polyelectrolyte-coated nanoparticles can swell or collapse in response to pH shifts, controlling drug diffusion. Liposomes with pH-sensitive phospholipids destabilize in acidic environments, facilitating intracellular drug delivery. These approaches have been successfully applied in anticancer therapy, gene delivery, and treatment of gastrointestinal disorders [3,4].

The advantages of pH-sensitive drug delivery include reduced off-target toxicity, enhanced bioavailability, and the ability to deliver sensitive molecules such as peptides, proteins, or nucleic acids. Moreover, combining pH sensitivity with other stimuli-responsive features, such as temperature or enzyme responsiveness, can create multifunctional delivery platforms for precision therapy. However, challenges remain, including ensuring stability during circulation, achieving rapid and complete drug release at the target site, and scaling up manufacturing for clinical use [5].

Conclusion

pH-sensitive drug delivery represents a promising strategy for targeted and controlled therapy. By exploiting natural pH variations in the body, these systems improve drug efficacy, reduce side effects, and enable precision treatment of complex diseases. Ongoing research on novel materials, carrier design, and combination strategies will continue to advance the clinical translation and effectiveness of pH-responsive drug delivery systems.

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e-ISSN:2347-7857