International Journal of Science, Strategic Management and Technology
Volume **02** Issue **03** March-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Polymeric Microsponges: Synthesis, Characterization, and Pharmaceutical Applications

1) Mrunmayi Vinod Nikam[1*]
Department of Pharmaceutics, SMBT College of Pharmacy, Dhamangaon, Nashik, Maharashtra, India-422403. Affiliated with Savitribai Phule Pune University.
eMail: mrunmayinikam76@gmail.com
2) Suvarna J. Shelke[2]

Department of Pharmaceutics, SMBT College of Pharmacy, Dhamangaon, Nashik, Maharashtra, India-422403. Affiliated with Savitribai Phule Pune University.
eMail: suvarnashelke43@gmail.com
3) Kedar R. Rajapure[3]

Department of Pharmaceutics, SMBT College of Pharmacy, Dhamangaon, Nashik, Maharashtra, India-422403. Affiliated with Savitribai Phule Pune University.

eMail: kedarrajapure@gmail.com

ORCID: 0009-0005-8573-6686
4) Krishna A. Shahane[4]

Department of Pharmaceutics, SMBT College of Pharmacy, Dhamangaon, Nashik, Maharashtra, India-422403. Affiliated with Savitribai Phule Pune University.

eMail: krishnashahane2005@gmail.com

ORCID: 0009-0004-6671-0483

https://doi.org/10.55041/ijsmt.v2i3.251

Cite this Article: Nikam, M. V., Shelke, S. J., Rajapure, K. R. & Shahane, K. A. (2026). Polymeric Microsponges: Synthesis, Characterization, and Pharmaceutical Applications. International Journal of Science, Strategic Management and Technology, *02*(03). https://doi.org/10.55041/ijsmt.v2i3.251

Abstract

Polymeric microsponges are a way to deliver drugs to the body. These microsponges are porous and interlinked in a special way. They come in sizes from very small to a bit bigger like 5 to 300 µm. Entrapped API within the porous polymeric network and release in a controlled manner.

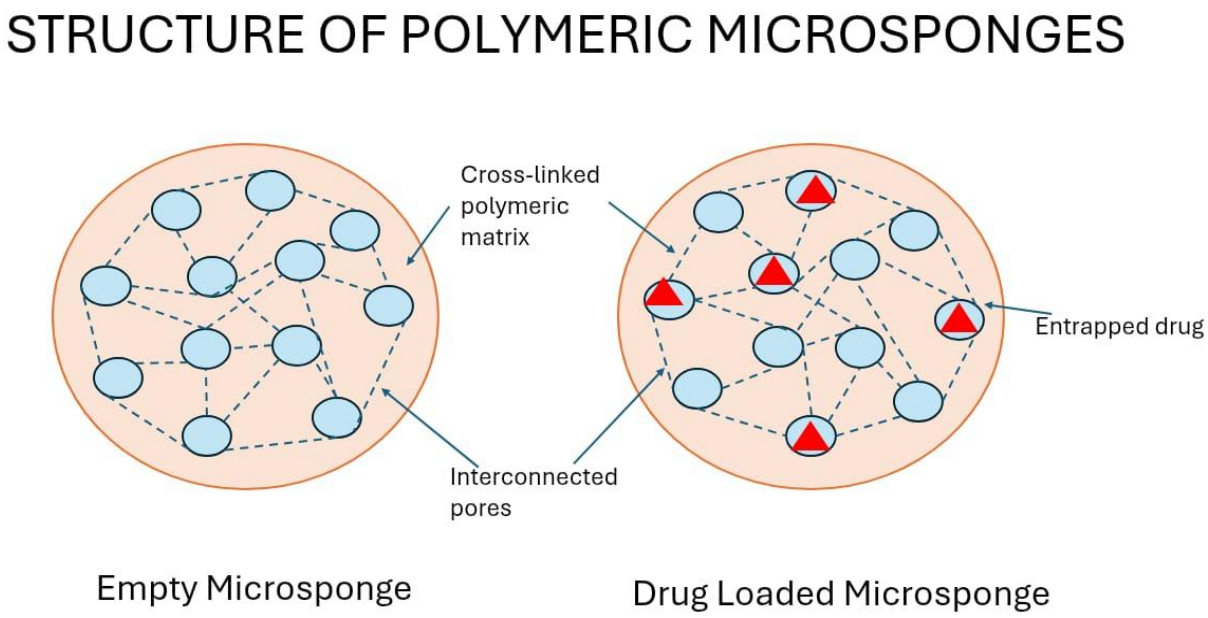
Polymeric microsponges enhance the physicochemical and chemical stability of labile drugs by protecting them from photodegradation , oxidation and reduction. They also reduce the effects that some medicines can have. The significance is that polymeric microsponges can deliver the medicine right where it is needed especially when we use them in creams or for oral administration. This review examines their historical development, fabrication techniques, characterization methods, drug loading and release mechanisms, diverse applications, advantages, limitations, regulatory considerations, and emerging trends, drawing on recent advancements to highlight their potential in pharmaceutical sciences.[4][5]

Key Words: Polymeric microsponges, drug delivery system, porou polymeric carrier, polymer cross-linking.

Introduction

Polymeric microsponges were introduced as an innovative drug delivery method in the late 1980s, patented by Won, and initially aimed at topical applications to address the shortcomings of traditional formulations such as rapid evaporation and irritation.[1][6] Composed of biocompatible polymers such as Eudragit, ethylcellulose, or polyacrylates, these sponge-like particles possess interconnected pores that allow high drug payloads, often up to the particle's weight equivalent.[1][7] Their versatility stems from responsiveness to stimuli like pH, temperature, or mechanical rubbing, facilitating programmable release profiles.[8] This review synthesizes current knowledge on polymeric microsponges, focusing on synthesis, characterization, mechanisms, applications, challenges, and future directions to guide researchers in leveraging this technology for improved therapeutic outcomes.[2][3]

Fig 1 – Structure of Polymeric Microsponges



History and Background

Polymeric microsponges originated in 1987 when Won developed the foundational technology and assigned patents to Advanced Polymer Systems for topical drug delivery.
[9][10][6] Early innovations addressed issues in skin care products, such as benzoyl peroxide instability in acne treatments, by enabling sustained release and reduced irritation.[1] By the 1990s, the system expanded to commercial products like Retin-A Micro, incorporating tretinoin for acne management.[1] Subsequent research in the 2000s shifted toward oral and colon-specific delivery
using pH-sensitive polymers like Eudragit S-100.[11] Recent decades have seen diversification into biomedical uses, including anticancer and antifungal therapies, driven by advances in polymer chemistry and nanotechnology.[2][3] This evolution reflects a progression from simple topical carriers to sophisticated, stimuli-responsive platforms.[5]

Methods of Fabrication

Method	Key components	Advantages	Typical yield
Suspension Polymerization	Monomer, cross-linker (divinylbenzene), porogen (toluene)	High porosity, simple	50-80%
Quasi-emulsion solvent diffusion	Eudragit, ethanol, PVA	Reproducible, spherical	70-90%
Spray Drying	Cellulose Derivative	Scalable, solvent evaporation	Variable

Suspension Polymerization is better suited for industrial scale but involves toxic monomers. On the other hand Quasi-emulsion Solvent Diffusion Method uses ready-made polymers such as Eudragit and is therefore preferred in academic formulations. Fabrication of polymeric microsponges primarily employs emulsion-based techniques to achieve porous structures.

Suspension Polymerization

Liquid-liquid suspension polymerization entails the dissolution of monomers (e.g., styrene, Eudragit) and pharmaceuticals in an organic solvent, followed by dispersion into an aqueous phase containing surfactants, and the initiation of polymerization through heat or catalysts.
[4][1] This one-step process yields grape-like clusters of microspheres with interconnecting pores.[1]

Quasi-emulsion solvent diffusion

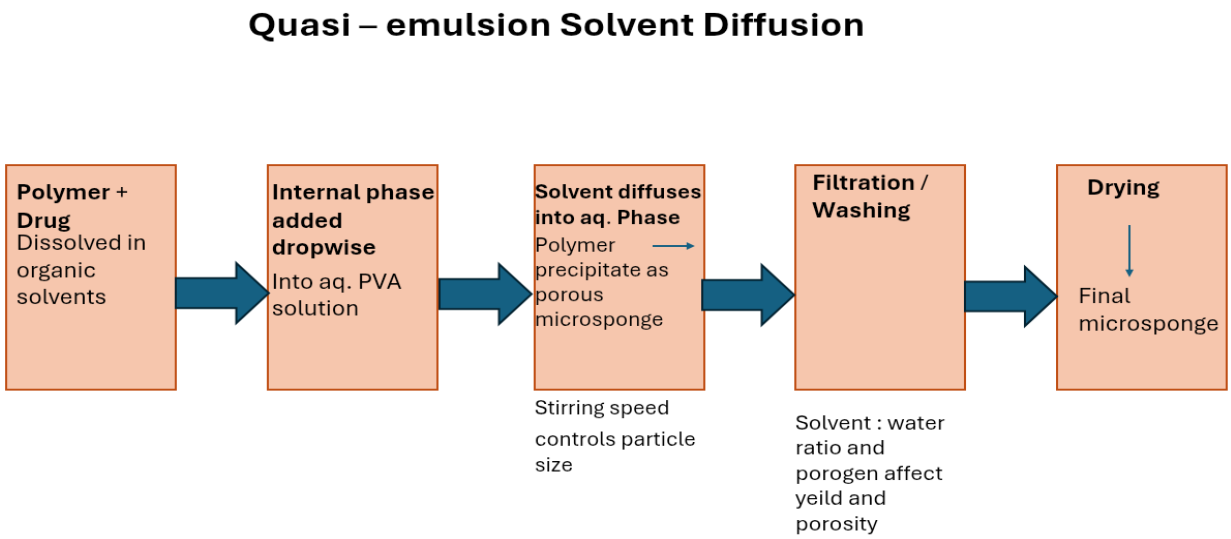


Fig 2 – Quasi-emulsion solvent diffusion Method diffusion Method

This method involves dissolving the polymer and drug in an organic phase (e.g., ethanol), which is then introduced into an aqueous polyvinyl alcohol solution, followed by stirring, filtering, and drying.[1][7] Parameters like drug:polymer ratio (1:1 to 1:3) and stirring speed influence yield (20-72%) and size (1-18 µm).[12]

Other techniques

For certain polymers, scalability is provided by oil-in-oil emulsion and spray-drying techniques employing TEMPO-oxidized cellulose.[13] Hydrophilic medications work well in water-in-oil-in-water emulsions.[14] Particle size and entrapment are improved through Box-Behnken design optimization.[15]

Physiochemical Characterization

Microsponge performance and quality are guaranteed by thorough characterization. Release kinetics are affected by particle size (5-300 μm), which is measured using laser diffraction or Mastersizer.[7] Rigid shells and a spherical, porous morphology are revealed by scanning electron microscopy (SEM).[7][12] While differential scanning calorimetry (DSC) identifies interactions, Fourier-transform infrared spectroscopy (FTIR) verifies drug-polymer compatibility.[7] BET analysis or mercury porosimetry are used to measure the diameter and volume of pores.[1] Production yield is 50-80%, and entrapment efficiency (EE = actual/theoretical drug × 100) is 70-90%.[12] Stability is guaranteed by zeta potential (e.g., -38 mV).[15] In vitro release is biphasic, with a burst and a sustained phase, according to Higuchi kinetics.[11]

Mechanism of drug loading and release

Drug loading occurs physically via adsorption into pores or chemically during polymerization, accommodating hydrophobic/hydrophilic actives.[1][2] Equilibrium partitioning governs release: actives diffuse out upon stimuli, maintaining vehicle saturation.[1]

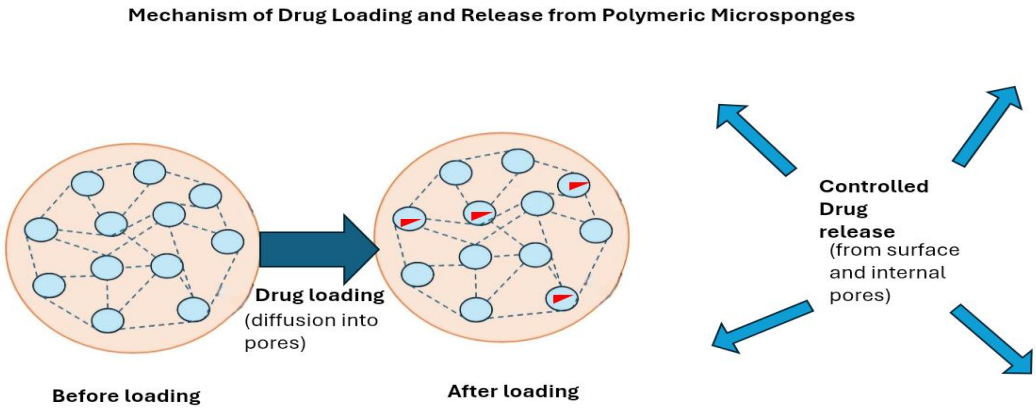


Fig 3 – Mechanism of Drug Loading and Release from Polymeric Microsponges

Release mechanisms include diffusion through pores, polymer erosion, or stimuli-response (pH > 7 for Eudragit S-100 in colon).[11] Factors like polymer ratio and porogen volume dictate kinetics: higher cross-linking slows release.[4][12] Biphasic profiles show 17-31% initial burst, 50-90% over 8 hours.[11]

Pharmaceutical and Biomedical Application

1) Topical Delivery

In dermatology, microsponges—such as fluconazole gels for antifungal action with extended skin retention—perform exceptionally well.[7] Formulations containing tretinoin and benzoyl peroxide lessen irritation.[1]

2) Oral and colon specific
Dicyclomine can be targeted to the colon using Eudragit microsponges coated with pectin.[11] Microsponges of valsartan improve bioavailability.[16]

3) Other uses
Stability and elegance are advantageous for cosmetics, bone substitutes, and site-specific anticancer treatments.[2] Mupirocin for skin infections is covered by recent patents.[17]

Advantages And Limitations
High payload, pH stability, fewer adverse effects, and vehicle compatibility are among the benefits.[1][2] Without the use of preservatives, they enhance bioavailability, patient compliance, and elegance.[18] Limitations include the use of organic solvents (flammable, environmental risks), the toxicity of residual monomers, difficulties scaling up, and payload/release optimization requirements.[19] [20]
These features make microsponges particularly relevant for anti-acne preparations, once daily anti-fungal and colon specific anti- spasmodic.

Regulatory And Safety Aspects
Microsponges use FDA-approved polymers that are non-irritating and non-mutagenic.[1][21] Safety is evaluated through tests for rabbit skin and eye irritation, rat oral toxicity, guinea pig allergenicity, and bacterial mutagenicity.[22][18] The pore size, which is less than 0.2 μm, prevents bacteria from entering. [1]Commercial products such as Retin-A Micro meet over-the-counter and prescription standards, while patents guide new filings.[3]Residual solvent limits from ICH Q3C apply.[19]

Future Prospects and Trends
Current trends include the combination of microsponges and nanotechnology for combination therapy, biodegradable polymers for oral sustained delivery, and 3D printing for customized delivery.[2][3] AI-optimized designs using BBD hold promise for precision.[15] Future applications include transdermal patches, implants, and gene therapy for poorly soluble drugs due to the increasing incidence of chronic diseases.[5][8] Translation to clinical practice needs improvements in biocompatibility and green synthesis.[13]

Conclusion
Polymeric microsponges provide a versatile platform for controlled delivery, and their efficacy and safety are well balanced. Innovations in the preparation and responsiveness of polymeric microsponges will continue to open up new avenues in the pharmaceutical industry.

References

[1] PMC. Microsponges: A novel strategy for drug delivery system. https://pmc.ncbi.nlm.nih.gov/articles/PMC3255415/ DOI: 10.4103/0973-8398.94037 (approx., inferred)

[2] PubMed. Microsponges as Drug Delivery System: Past, Present, and Future... PMID: 37013425 DOI: 10.2174/9789815040408123010008 (bentham)

[3] Liebertpub. Microsponges: Development, Characterization, and Key... DOI: 10.1089/adt.2023.052 [3]

[4] GSCBPS. Design development and evaluation of controlled release micro... https://gsconlinepress.com/journals/gscbps/sites/default/files/GSCBPS-2025-0178.pdf

[5] Taylor & Francis. Polymeric microsponges: an emerging prospect in topical delivery... DOI: 10.1080/00914037.2023.2235872

[6] Pharmajournal. A brief review of microsponges: An update. https://www.thepharmajournal.com/archives/2017/vol6issue5/PartC/6-5-15-269.pdf

[7] PMC. Fabrication, characterization, and evaluation of microsponge... https://pmc.ncbi.nlm.nih.gov/articles/PMC4804404/ DOI: 10.4103/2231-4040.172655 (approx.)

[9] TURCOMAT. A Review On Different Methods Development Approaches Of Micro... https://turcomat.org/index.php/turkbilmat/article/download/11297/8357

[10] IAJPR. MICROSPONGES – A COMPREHENSIVE REVIEW. https://iajpr.com/iajprfiles/uploaddir/190604_DOI.pdf

[12] JPRI. Formulation and Evaluation of Eudragit Rl100 Polymeric Drug... https://journaljpri.com/index.php/JPRI/article/view/2263 DOI: 10.9734/jpri/2019/v21i330140

[14] IndJPhaEdRes. A Novel Approach on Micro Sponges Drug Delivery System. https://www.ijper.org/sites/default/files/IndJPhaEdRes-58-1-45.pdf

[17] JDDT. MICROSPONGES FOR TOPICAL DRUG DELIVERY. DOI: 10.22270/jddt.v5i3.1885

[18] Derpharmachemica. Microsponge: An Innovative... (2024) https://www.derpharmachemica.com/pharma-chemica/microsponge-an-innovative-and-novel-strategy-for-drug-delivery-system-104528.htm

[19] IjRTI. REVIEW ON MICROSPONGE DRUG DELIVERY SYSTEM. https://www.ijrti.org/papers/IJRTI2006006.pdf

[20] IJPP. Recent Trends on Microsponges... https://ijppr.humanjournals.com/wp-content/uploads/2023/07/34.Vaibhav-Sisodia-Shaffi-K.-Tangri-Himanshu-Rana.pdf

[21] Crimson. An Overview of Microsponge as a Novel Tool in Drug Delivery. DOI: 10.31031/MADD.2018.01.000537

[22] Derpharmachemica. Microsponge: An Innovative and Novel Strategy... https://www.derpharmachemica.com/pharma-chemica/microsponge-an-innovative-and-novel-strategy-for-drug-delivery-system.pdf

[23] WJBPHS. Unveiling the potential of microsponges: Enhancing oral bioavailability. https://wjbphs.com/sites/default/files/WJBPHS-2024-0085.pdf

[24] IJPSR. microsponges drug delivery system. https://ijpsr.com/?action=download_pdf&postid=77520

[25] JSIR. Microsponge Delivery System: An updated review... http://www.jsirjournal.com/Vol2Issue6019.pdf

[26] JPTCP. DEVELOPMENT AND CHARACTERIZATION OF... DOI: 10.5281/zenodo.11494455

[27] RJTC. Microsponge for Skin Treatment: An Updated Review.

[28] IJPSN. Microsponges as Innovative Drug Delivery Systems. DOI: 10.36468/pharmaceutical-sciences.spl.202

[29] JDDT. Microsponge: A Review. DOI: 10.22270/jddt.v14i1.6620

[30] IJRPS. A Brief Review on Microsponge Drug Delivery Systems. DOI: not listed

[31] IJPR. A Review on Microsponges Drug Delivery System. https://ijprajournal.com/issue_dcp/A%20Review%20on%20Microsponges%20Drug%20Delivery%20System.pdf

[32] IJPS. Microsponge: A Stable Microscopic Polymeric Delivery System. https://www.ijpsjournal.com/article/Microsponge+A+Stable+Microscopic+Polymeric+Delivery+System+