World Journal of Pharmaceutical Science and Research

www.wjpsronline.com

Review Article

ISSN: 2583-6579
SJIF Impact Factor: 6.916
Year - 2026
Volume: 5; Issue: 2
Page: 44-55

REVIEW ON NANOSPONGES: A NOVEL DRUG DELIVERY SYSTEM

Varsha Ghotkule[1*], Kadambari Ghatpande[2], Diya Gawade[3], Manish Madli[4]

[1,3,4]Student of IVM's Krishnarao Bhegade Institute of Pharmaceutical Education and Research.

[2]Associate Professor of Department of Pharmaceutical Chemistry, IVM's Krishnarao Bhegade Institute of Pharmaceutical Education and Research.

Article Received: 03 December 2025 | | ***Article Revised: 24 December 2025*** | | ***Article Accepted: 13 January 2026***

***Corresponding Author: Varsha Ghotkule**
Student of IVM's Krishnarao Bhegade Institute of Pharmaceutical Education and Research.
DOI: https://doi.org/10.5281/zenodo.18438423

How to cite this Article: Varsha Ghotkule, Kadambari Ghatpande, Diya Gawade, Manish Madli (2026) REVIEW ON NANOSPONGES: A NOVEL DRUG DELIVERY SYSTEM. World Journal of Pharmaceutical Science and Research, 5(2), 44-55. https://doi.org/10.5281/zenodo.18438423

ABSTRACT

By providing innovative methods for enhancing the effectiveness, safety, and patient compliance of therapeutic drugs, nanotechnology has completely transformed the field of pharmaceutical sciences. Nanosponges are one of the new nanocarriers that have garnered a lot of interest as a novel drug delivery method that can improve the solubility, stability, and controlled release of both hydrophilic and lipophilic medications. By encasing active medicinal ingredients within their three-dimensional network, nanosponges—porous, nanosized polymeric structures—can prevent degradation and enable controlled, prolonged drug release. Polymers like β-cyclodextrin, ethyl cellulose, or polyvinyl alcohol can be used to create these systems utilizing techniques including solvent evaporation, ultrasound-assisted synthesis, or emulsion solvent diffusion. Nanosponges have demonstrated promise uses in topical, oral, and parenteral formulations for the administration of antifungal, anti-inflammatory, and anticancer drugs. They could serve as a platform for upcoming drug delivery advances due to their high loading capacity, biocompatibility, and capacity to increase bioavailability. The design, manufacture, characterisation, and therapeutic usage of nanosponges as an innovative and adaptable drug delivery method are the main topics of this review.

KEYWORDS: Nanosponges, Novel Drug Delivery System, Cyclodextrin-Based Nanosponges Controlled Drug Release, Targeted Drug Delivery.

INTRODUCTION

Nanosponges are tiny, mesh-like structures that can contain a wide range of materials and drug compounds. They have a spherical colloidal structure and improve the solubilization ability of both water-soluble and lipid-soluble medicines. With extended drug release, they improve the bioavailability of medications. The amphiphile nature of nanosponges allows them to transport both hydrophilic and hydrophobic therapeutic compounds due to their external hydrophilic

branching and internal hydrophobic chambers. With a backbone of long-chain polyesters in the solution and crosslinkers connecting various polymer components, they resemble a three-dimensional network.[1] For example, cyclodextrin-based nanosponges offer a therapeutic vehicle that effectively transfers medicines with low bioavailability by producing inclusion and non-inclusion complexes with a variety of pharmaceuticals/active molecules. The medication and cyclodextrin molecule combine to produce an inclusion complex in inclusion complex nanosponges. On the other hand, the drug molecule becomes trapped or absorbed into the porous nanostructures of non-inclusive complex nanosponges. Cyclodextrin-based nanosponges have been extensively investigated for drug delivery, cleanup, sensing, and catalytic uses.Hydrophobic molecules can be added to the cavity of nanosponges, while less lipophilic molecules can be accommodated by the more hydrophilic outer polymeric network. It has been discovered that incorporating the medications into the nanosponges can improve their solubility and degradability, increasing their bioavailability. For instance, nanosponges have been developed to improve the anticancer drug's solubility and absorption while lowering its oral dosage.[2]

HISTORICAL BACKGROUND

In 1965, Solms and Egli published a study on the synthesis and inclusion properties of novel network polymers composed of CDs crosslinked with epichlorohydrin (EPI), which marked the beginning of the history of crosslinked insoluble CD polymers. First, a hot solution of sodium hydroxide and sodium borohydride were used to activate CDs dissolved in water. Next, EPI was added as a crosslinker. The binding characteristics of this new material were examined by the authors in relation to EPI-dextran network polymers. Iodine and a number of chemical molecules, such as aniline, pyridine, benzaldehyde, butyric acid, and p- and o-nitrophenol, were among them.The separation of p-nitrophenol from o-nitrophenol and variations in their inclusion behavior are two examples of how the inclusion ability may be helpful in separation methods based on both size and shape. In order to create new stationary phases for nucleic acids and derivatives of mandelic acid, this concept was expanded upon in the 1970s.[3] The term "cyclodextrin nanosponges" was first used by DeQuan Li and Min Ma in 1998 to refer to a cross-linked β-cyclodextrin with organic diisocyanates that resulted in an insoluble network that demonstrated a very high inclusion constant with several organic pollutants, even though insoluble crosslinked cyclodextrin polymers were first reported long ago by reacting the parent cyclodextrin with dialdehydes, epoxides, diacyl chlorides, etc.

DEFINITION OF NANOSPONGES

A nanosponge is a nanoscale, three-dimensional, highly porous polymeric carrier system that can encapsulate a wide range of drugs (both hydrophilic and lipophilic), protect them from degradation, increase their solubility and bioavailability, and deliver them to particular body sites in a controlled and targeted manner.[5] It is typically made of cross-linked polymers like cyclodextrins.

Table No. 1: Ideal Characteristics of Nanosponges:-The table below summarizes the ideal physicochemical and biological characteristics that make nanosponges effective drug delivery carriers.

Sr. No.	Characteristic	Description & Importance
1	Nano-sized & porous 3D structure	Effective drug loading and improved cellular absorption are made possible by nanosponges, which are nanoscale particles with a porous three-dimensional network.[2–6]
2	High entrapment/loading efficiency	Enables decreased dosage frequency, enhanced bioavailability, and high payload delivery.[7]
3	Ability to carry both hydrophilic and lipophilic drugs	Versatility in loading drugs of varying solubility expands their use in multiple drug types.[8]

4	Controlled/sustained release capability	The porous structure and tunable cross-linking allow adjusting drug release kinetics.[9]
5	Stability & biocompatibility/ biodegradability	Stable under physiological conditions, non-toxic, biocompatible and safely degradable.[6,2]
6	Scalable and reproducible synthesis	Should allow reproducible synthesis and control over particle size for industrial feasibility.[10]
7	Suitable drug properties for loading	Optimal drug characteristics: MW 100–400 Da, solubility <10 mg/mL, melting point <250 °C.[11]
8	Surface modifiability/targeting potential	Can be functionalized for targeted delivery, e.g., in cancer therapy.[6,2]

MECHANISM OF DRUG RELEASE FROM NANOSPONGES

The three-dimensional structure of cross-linking polymers is made up of nanosponges. The amount of cross-linking polymer added to the formulation can alter the entrapment and solubilizing efficiencies of nanosponges. Because of their toroidal form, nanosponges have an internal chamber that can accommodate different kinds of drug molecules. Because of this kind of structure, they can serve as drug carriers for a variety of medications; the drug will release at the target site as long as the active ingredient is compatible with the geometry and polarity of the cavity. The structure of the nanosponge, which may be altered based on the needs of drug release, is a key factor in determining when these active chemicals will be released. To direct the molecules to different parts of the body, a number of ligands or carriers can be affixed to the nanosponge's surface.[12]

METHODS OF PREPARATION

1. Solvent method

The procedure made use of appropriate solvents, such as polar aprotic solvents like dimethyl sulfoxide and dimethylformamide. Polymer was added to this and thoroughly mixed. The aforesaid mixture was mixed to an optimal crosslinker/polymer ratio of 8:2. After the aforementioned mixing, the mixture was allowed to react for 48 hours at a temperature between 10 °C and the solvent's reflux temperature. The solution was cooled to room temperature when the reaction was finished.[13] The product was extracted from the above-cooled solution by adding an excess of bi-distilled water, and it was recovered using vacuum filtering (Fig. 1).

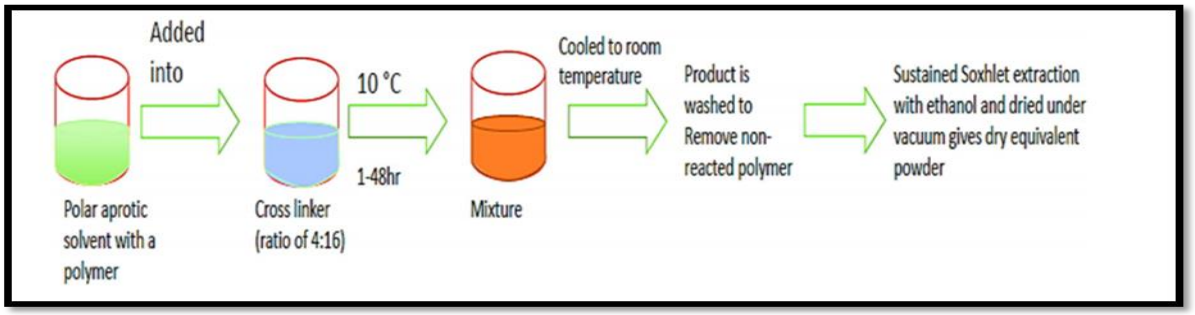


Fig. 1: Solvent Method.

2. Ultrasound-assisted method

The polymer ultrasonics junction is used in the ultrasound-assisted synthesis process. Ultrasonic waves cause polymer crosslinking, which is accomplished without the use of a solvent. Polymer and crosslinker were mixed in a flask at a suitable molar ratio. The flask was placed in an ultrasound bath set at 90 °C for five hours throughout the ultrasonication procedure. After sonication, the temperature of the collected mixture was lowered. The result was then violently split and cleaned to remove unreacted polymer and reagents using an excess amount of water.[13] Soxhlet

extraction was used to purify the cleaned solid using ethyl alcohol. The obtained filtered NSs were vacuum-dried and properly treated before additional drug loading (Fig. 2).

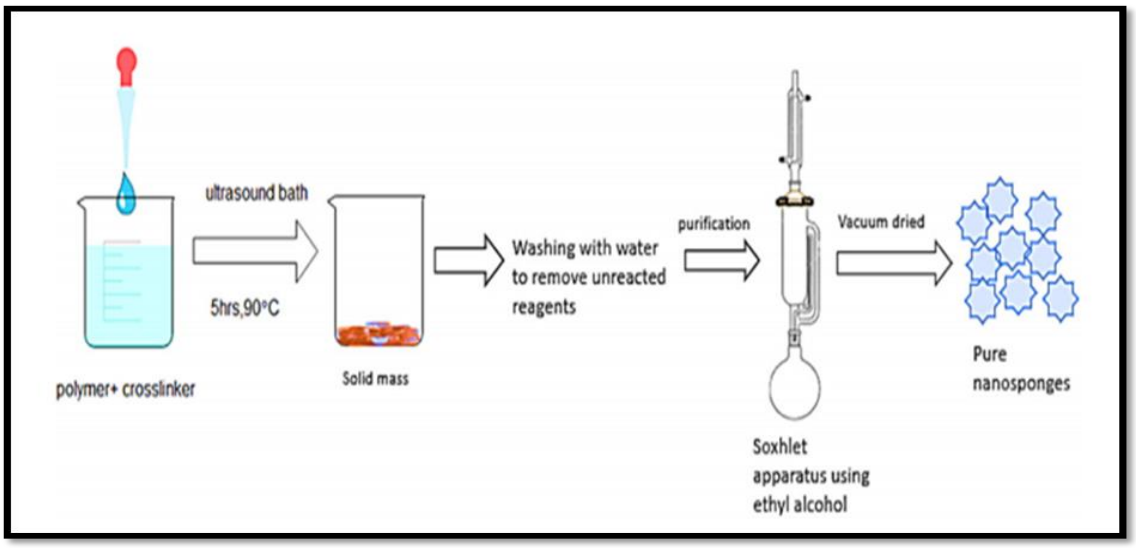


Fig. 2: Ultrasound-assisted method.

3. Emulsion solvent diffusion method

Polyvinyl alcohol (PVA) and ethyl cellulose (EC) can be used to create nanosponges. Dichloromethane (dispersed phase) dissolves ethyl cellulose. Pour this mixture into a polyvinyl alcohol aqueous solution. A magnetic stirrer was used to agitate the reaction mixture for two hours at 1000 rpm. The product is then filtered and dried for a whole day at 40 degrees Celsius in an oven. To guarantee that all remaining solvent was eliminated, dried nanosponges were kept in a vacuum desiccator.[14]

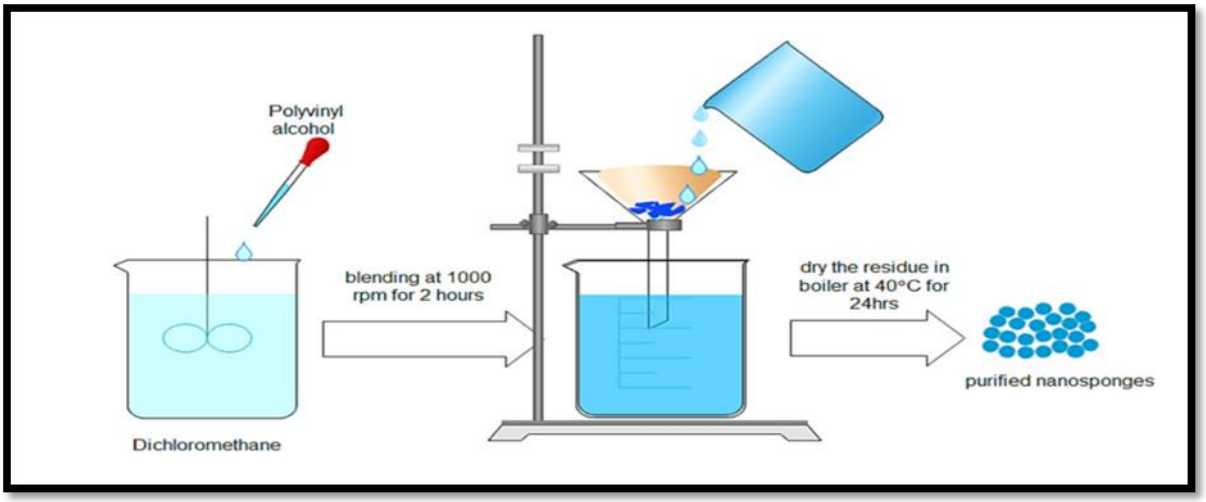


Fig. 3: Emulsion solvent diffusion method.

4. Hyper crosslinked β-cyclodextrin

Cyclodextrin reacts with a cross-linking agent, such as diisocyanates, di-aryl carbonates, dimethyl carbonate, diphenyl carbonate, carbonyl diimidazole, carboxylic acid dianhydrides, and 2, 2-Bis (acrylamido) acetic acid, to produce nanosponges. To connect various molecules, sponges' surface charge density, porosity, and pore size can be adjusted.

Fast drug release is provided via a nano sponge with minimal cross-linking agents. They are used to increase the aqueous solubility of medications that are weakly soluble in water, primarily BCS class II medications.[15]

5. Melt technique

Melt method A appropriate crosslinker, such as dimethyl carbonate, diphenyl carbonate, isocyanates, diaryl carbonates, carbonyldiimidazole (C7H6N40), carboxylic acid anhydrides, and 2, 2-bis (acrylamide) acetic acid, is reacted with cyclodextrin in the melt process.[18] All of the ingredients are carefully combined, heated to 100°C in a 250 mL flask, and the reaction is allowed to proceed for five hours using a magnetic stirrer.[16] After allowing the mixture to cool, the resulting product is broken down and cleaned with an appropriate solvent to remove any remaining excipients [Fig. 4].

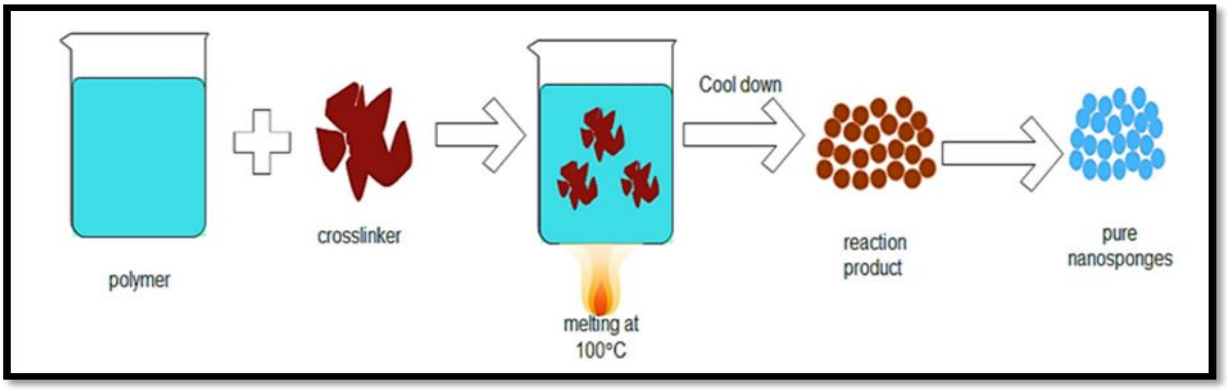


Fig. 4: Melt method.

6. Bubble electrospinning

The main components of a standard and conventional electrospinning setup are a syringe, a grounded collector, a high-voltage power source, and a syringe pump, as described in several publications. However, the quantity of nanofiber output is one of the main constraints that restricts their applicability. Polyvinyl alcohol can also be utilized as a polymer in bubble electrospinning. The 10% polymer solution was organized by adding distilled water, and it was then heated to 80–90 °C for two hours to produce a one-phase mixture. The polymer solution was then allowed to reach room temperature before being utilized to create nanoporous fibers.[13]

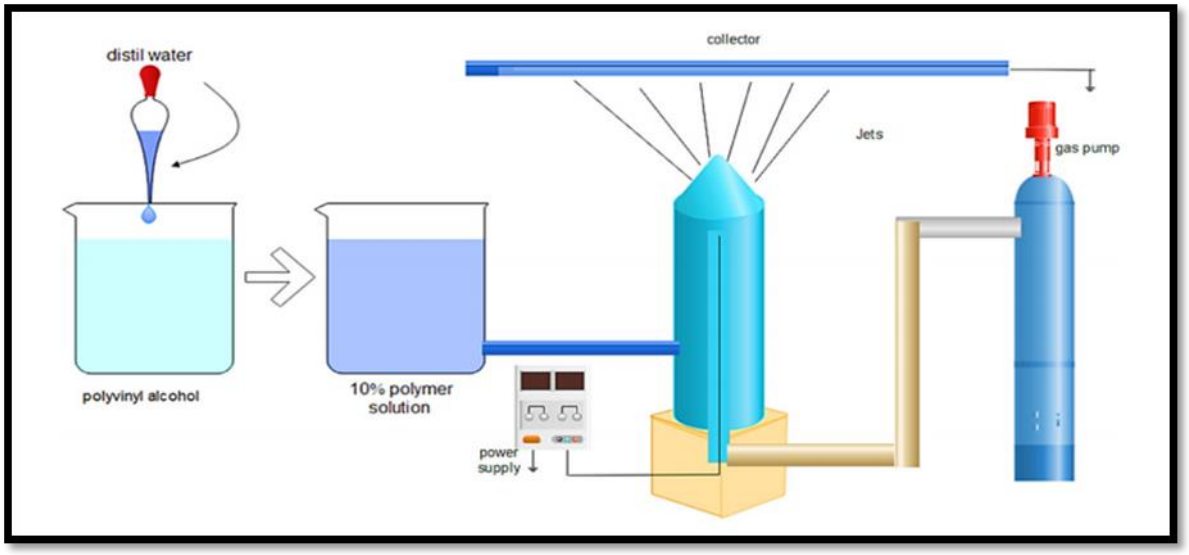
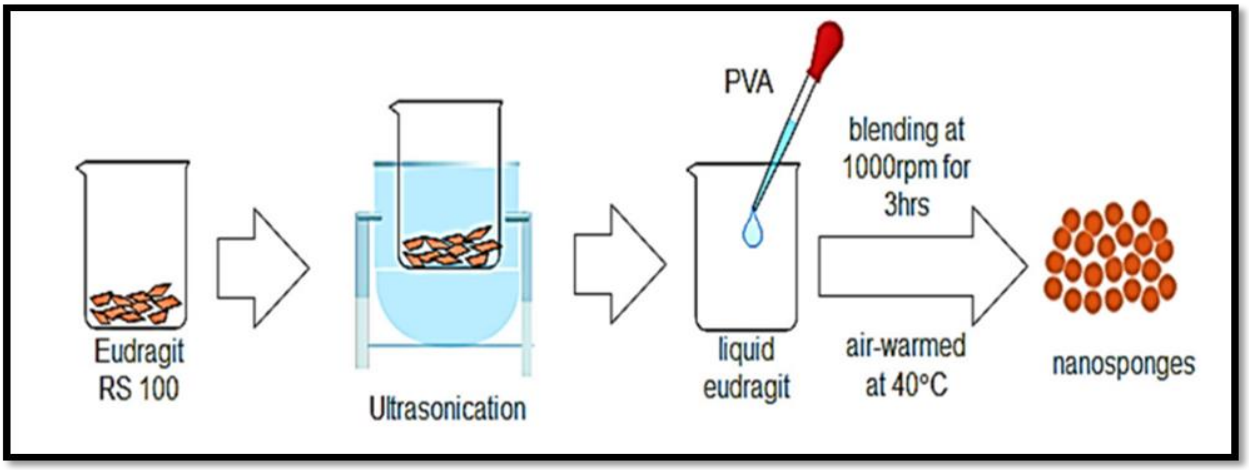


Fig. 5: Bubble electrospinning.

7. Quasi emulsion solvent method

The polymer was used to assemble the NSs in various sums. The inner stage is prepared and applied to a very dissolvable stage using Eudragit RS 100. Under ultrasonication, the medication caused a reaction and disintegrated at 35 °C. This internal activity functions as an emulsifying operator in the polyvinyl alcohol containing external phase. The mixture is blended at ambient temperature for three hours at 1000–2000 rpm and dried for twelve hours at 40 °C in an air-heated oven[13] (Fig. 6)



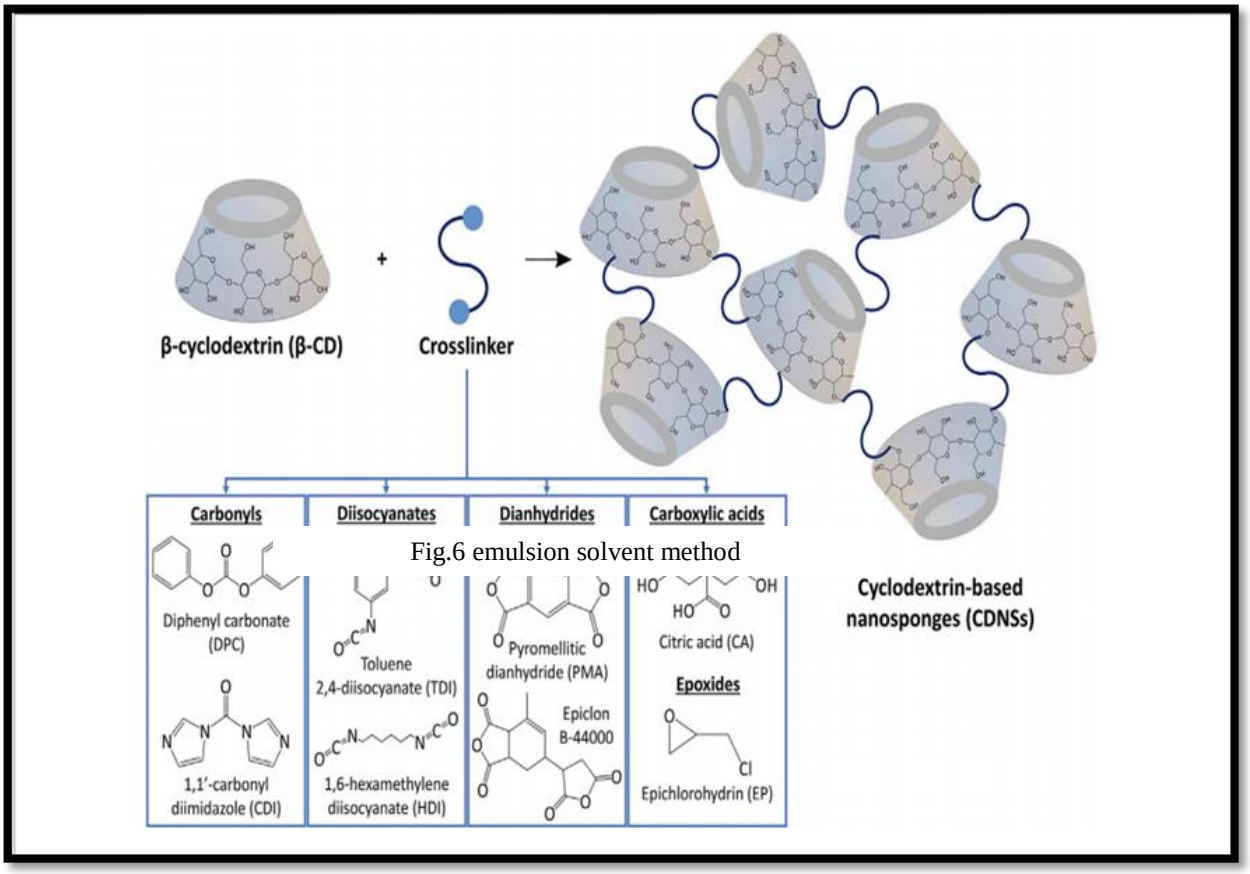


Fig.6 emulsion solvent method

Fig. 7: Synthesis of CDNSs through the reaction between β-cyclodextrin and a crosslinker, being carbonyls, diisocyanates, dianhydrides, carboxylic acids and epoxides the most common.[17]

ADVANTAGES

1) The porous, three-dimensional network of nanosponges can encapsulate poorly soluble drugs and improve their aqueous solubility and dissolution.[18]
2) By improving solubility and protecting the drug, nanosponges boost the fraction of the drug that becomes available to the body.[13]
3) Because of their porous and cross-linked structure, nanosponges can entrap both water-loving and water-hating molecules.[19]
4) Nanosponges allow the drug to release over time in a predictable manner, which can reduce dosing frequency and improve therapeutic profiles.[13]
5) These carriers can be formulated for oral, topical, parenteral (injection), inhalational, etc.[20]
6) Encapsulation within nanosponges can protect sensitive drugs from degradation (light, heat, enzymatic) and improve stability.[21]
7) Because of their nanoscale size and modifiable surface, nanosponges can accumulate or be directed (via ligands) to specific tissues or cells.[13]
8) By limiting off-target release and by controlling dose/exposure, nanosponges can reduce adverse effects.[20]
9) Their architecture allows a relatively large amount of drug to be loaded (especially compared to some simpler carriers).[22]
10) Nanosponges can be incorporated into tablets, capsules, gels, creams, etc., offering formulation flexibility.[18]
11) Some studies show nanosponges being used for proteins, enzymes, or in advanced therapeutic systems (beyond small molecule drugs).[23]
12) Because the delivery can be sustained, dose frequency reduced, side-effects reduced — all factors improving how well patients stick to therapy. (Implied across multiple sources).[13]

DISADVANTAGES

1) Nanosponges are generally suitable only for small-sized molecules; large biomolecules (like peptides and proteins) show poor encapsulation.[6]
2) The drug loading and release behavior depend heavily on the degree of cross-linking and void size; too much or too little cross-linking alters performance.[13]
3) Uncontrolled or early dissolution of cross-linkers may lead to rapid drug release or dose dumping.[13]
4) Maintaining uniform nanosponge size, porosity, and drug loading at industrial scale is challenging and costly.[6]
5) Cross-linkers such as diphenyl carbonate or carbonyl diimidazole may be toxic if residues remain in the final formulation.[24]
6) Nanosponges may aggregate or degrade during storage or in biological fluids, affecting drug release and shelf life.[6]
7) Long-term safety, biodegradability, and clinical approval data are still limited for nanosponge-based systems.[6]
8) Some drugs with high melting points or large structures show low binding or poor inclusion complex formation with nanosponges.[13]

APPLICATIONS OF NANOSPONGES

A sophisticated family of nanomaterials with a highly porous structure, nanosponges are perfect for a range of industrial and biological uses. They are widely used in medicine delivery, water purification, catalysis, and other fields because to their capacity to encapsulate, protect, and release active molecules in a controlled manner.

1. Pharmaceutical and Drug Delivery Applications

a. Controlled and Targeted Drug Delivery[4]

Nanosponges are useful for medications that are poorly soluble in water because they increase drug solubility, stability, and bioavailability. Because of their porous structure, they can release drugs in a regulated or continuous manner, which lessens adverse effects and increases patient compliance.

b. Cancer Therapy[25]

Targeted chemotherapy is made possible by nanosponges, which lessen toxicity to healthy cells. can be altered to target particular cancer cells using ligands (antibodies, peptides, or folic acid). For instance, cyclodextrin nanosponges loaded with doxorubicin have demonstrated improved tumor penetration and effectiveness.

c. Antimicrobial Drug Delivery[26]

Antibiotics, antifungals, and antivirals can be encapsulated by nanosponges to increase their stability and lower resistance. For instance, nanosponges filled with silver nanoparticles have strong antibacterial qualities against germs that are resistant to drugs.

2. Water Purification and Environmental Applications

When it comes to eliminating organic pollutants from water, cyclodextrin nanoparticles are very successful. Among these, β-Cyclodextrin Nanosponges are especially helpful since they can encapsulate contaminants without dissolving in water. These nanosponges can be added to ceramic porous filters to create organic/inorganic hybrid filter modules, which have been shown to effectively remove a range of water pollutants.[27] Nanosponges based on cyclodextrin and maltodextrin have both shown remarkable adsorption capacities in removing toxic materials from water and wastewater. These bio-based materials are becoming more and more well-known in the market since they provide an affordable and sustainable option.[28] Nanoporous cyclodextrin (CD) polyurethane, one extensively researched nanosponge, has been effectively employed for regular water filtration.Organic molecules are bound to the surface of the nanosponge through the adsorption mechanism, where the CD polymer creates guest-host inclusion complexes. Cyclodextrin-based nanosponges are a potential solution for environmental water treatment since these complexes efficiently capture and hold a variety of chemical contaminants.[29]

3. Nanosponge as Chemical Sensors

Because of its capacity to detect and quantify a wide range of analytes, including hazardous gases, heavy metals, organic pollutants, and biomolecules, nanosponges—which are characterized by their porous architecture and vast surface area—have attracted a lot of interest as chemical sensors. For the purpose of detecting gases like hydrogen, metal oxide nanosponges like titania have been created. These sensors are appropriate for industrial safety applications because of their high sensitivity and quick reaction times.[30]

Nanosponges based on cyclodextrin have shown remarkable adsorption capacities for eliminating hazardous materials, such as heavy metals, from water and wastewater. Because they are bio-based, they provide an inexpensive way to clean up the environment.[31] In the biomedical field, nanosponges have been investigated for uses like biosensing and protein delivery. They have the potential to be used in disease diagnostics because of their capacity to form inclusion complexes with a wide range of molecules, which makes them appropriate for biomolecule detection.[32]

4. Applications in Dermatology and Cosmetics

An inventive method for the controlled release of topical pharmaceuticals that provides delayed drug release and extended skin retention is the nanosponge-based delivery system. Benzoyl peroxide, salicylic acid, and retinoids are administered via nanosponges to treat acne. For instance, compared to traditional creams, a nanosponge formulation loaded with benzoyl peroxide demonstrated greater drug retention and reduced skin irritation.[33] Zinc oxide nanosponges and titanium dioxide (TiO_2) improve UV protection in sunscreens while lessening skin irritation. Nanosponges based on cyclodextrin increase the stability of photoprotective chemicals and stop them from degrading.[34]

Antibiotics and antibacterial substances can be encapsulated in nanosponges to aid with wound healing. For instance, nanosponges coated with silver nanoparticles showed improved antibacterial activity in infected wounds. Econazole nitrate nanosponges were created and then incorporated into a hydrogel, serving as a local depot for prolonged drug release. Econazole nitrate is a powerful antifungal compound that is applied topically to treat conditions like dermatophytosis, tinea versicolor, superficial candidiasis, and other skin infections.[35]

FUTURE DIRECTIONS

In addition to providing focused therapy and improved medication availability, the nanosponges' delivery method aids in controlling drug release. Future scientific research should focus on functionalization methods that improve specificity, reduce toxicity, and boost biocompatibility. Fluorescent probes and magnetite nanoparticles combined with biomolecular ligands provide real-time imaging and targeted medication administration. 3D printing technology can help with large-scale product production. Scientific research on the possibilities of utilizing proteins and peptides orally is still in its infancy. β-cyclodextrin nanosponges have been shown to deliver insulin with pH-triggered drug release features and improved permeability for peptide therapeutic applications. For medical adaption to be effective, more clinical studies should assess stability in addition to immunogenicity and safety factors.[23]

CONCLUSION

Finally, it was determined that the NSs are tiny, mesh-like structures that may be used to treat a variety of diseases and that this nanotechnology is four to five times more effective in delivering medications than the traditional approach. They can be added to a variety of formulations, including parenteral, aerosol, topical, tablets, and capsules, because of their small size. Because NSs are nanoscale colloidal bearers, they can penetrate the skin with ease. They advise ingesting both hydrophilic and lipophilic medications and releasing them at the intended location in a regulated and predictable way. The poorly soluble drug's solubility is improved by this nanotechnology.

REFERENCES

1. Garg A, Lai WC, Chopra H, Agrawal R, Singh T, Chaudhary R, Dubey BN. Nanosponge: A promising and intriguing strategy in medical and pharmaceutical Science. Heliyon, 2023 Dec 6; 10(1): e23303. doi: 10.1016/j.heliyon.2023.e23303. PMID: 38163139; PMCID: PMC10757015.
2. Iravani S, Varma RS. Nanosponges for Drug Delivery and Cancer Therapy: Recent Advances. Nanomaterials (Basel), 2022 Jul 16; 12(14): 2440. doi: 10.3390/nano12142440. PMID: 35889665; PMCID: PMC9323080.
3. AMA Style Krabicová I, Appleton SL, Tannous M, Hoti G, Caldera F, Rubin Pedrazzo A, Cecone C, Cavalli R, Trotta F. History of Cyclodextrin Nanosponges. *Polymers*, 2020; 12(5): 1122. https://doi.org/10.3390/polym12051122.
4. Trotta F, Zanetti M, Cavalli R. Cyclodextrin-based nanosponges as drug carriers. Beilstein J Org Chem, 2012; 8: 2091-9. doi: 10.3762/bjoc.8.235. Epub 2012 Nov 29. PMID: 23243470; PMCID: PMC3520565.
5. S, S., S, A., Krishnamoorthy, K., & Rajappan, M., Nanosponges: A Novel Class of Drug Delivery System - Review. *Journal of Pharmacy & Pharmaceutical Sciences*, 2012; *15*(1): 103–111. https://doi.org/10.18433/J3K308.
6. MDPI and ACS Style Iravani, S.; Varma, R.S. Nanosponges for Drug Delivery and Cancer Therapy: Recent Advances. *Nanomaterials*, 2022; *12:* 2440. https://doi.org/10.3390/nano12142440.
7. Singh & Monika (2022), Sys Rev Pharm. https://www.sysrevpharm.org/articles/nanosponges-as-emerging-carriers-for-drug-delivery.pdf
8. Kaur & Kumar (2019), Asian J Pharm Clin Res. https://journals.innovareacademics.in/index.php/ajpcr/article/view/33879
9. Bhowmik et al. (2018), Int J Appl Pharm. https://journals.innovareacademics.in/index.php/ijap/article/view/25026
10. J Mater Sci Med. https://link.springer.com/article/10.1007/s10856-022-06652-9
11. IJDDT 2022, Impactfactor.org. https://impactfactor.org/PDF/IJDDT/14/IJDDT%2CVol14%2CIssue3%2CArticle72.pdf
12. Singh S, Monika K, Nanosponges as Emerging Carriers for Drug Delivery, Sys Rev Pharm, 2022; 13(1): 55-62.
13. Tiwari K, Bhattacharya S. The ascension of nanosponges as a drug delivery carrier: preparation, characterization, and applications. J Mater Sci Mater Med., 2022 Mar 4; 33(3): 28. doi: 10.1007/s10856-022-06652-9. PMID: 35244808; PMCID: PMC8897344.
14. Patil Tukaram S. et al; International Journal of Advance Research and Development. © 2017, www.IJARND.com All Rights Reserved Page, 2(4): 55 Nanosponges: A Novel Targeted Drug Delivery for Cancer Treatment Tukaram S. Patil* , Nishigandha A. Nalawade, Vidya K. Kakade, Sumedha N. Kale Dept. of Pharmaceutics, Bharati Vidyapeeth college of Pharmacy, Dept. of Pharmaceutical Chemistry, Bharati Vidyapeeth college of Pharmacy, Near Chitranagari, Kolhapur (M.S), India.
15. Harshit Srivastava, Vivek Kumar Pandey, Dr. Manju Pandey*, Mukesh Kumar Shukla, Sanjeev Kumar Dubey, Sarita Singh, Reema Yadav, Basant Lal, Rukhsar Bano., A REVIEW ON NANOSPONGES: A REVOLUTIONIZING DRUG DELIVERY SYSTEM. *JOURNAL OF PHARMACEUTICAL ANALYSIS*, 2024; *14*(2): 196–205. Retrieved from https://www.journalsofpharmaceuticalanalysis.com/index.php/jpa/article/view/168
16. simranjot kaur, and sandeep kumar. “the nanosponges: an innovative drug delivery system: nanosponges: an innovative drug delivery system”. *asian journal of pharmaceutical and clinical research*, July 2019; 12(7): 60-67, doi: 10.22159/ajpcr.2019.v12i7.33879.

17. Morin-Crini, N., Winterton, P., Fourmentin, S., Wilson, L. D., Fenyvesi, É., and Crini, G., Water-insoluble β-cyclodextrin-epichlorohydrin Polymers for Removal of Pollutants from Aqueous Solutions by Sorption Processes Using Batch Studies: A Review of Inclusion Mechanisms. Prog. Polym. Sci., 2018; 78: 1–23.doi: 10.1016/j.progpolymsci.2017.07.004.
18. International Journal of Pharmaceutical Research and Applications, Nov-Dec 2022; 7(6): 1588-1606 www.ijprajournal.com ISSN: 2456-4494 DOI: 10.35629/7781-070615881606 Impact Factor value 7.429 | ISO 9001: 2008 Certified Journal Page 1588 Nanosponges: A Comprehensive Review Pooja Adhikari, Mr. Sanjay Jain, Dr. Vijay Nigam, Muskan Kankane Daksh Institute of Pharmaceutical Science Chhatarpur (M.P.).
19. Nanosponges- A Versatile Approach of Drug Delivery System Alka Singh*, Chetan S Chauhan Bhupal Nobles' Institute of Pharmaceutical Sciences, Bhupal Nobles' University, Udaipur, Rajasthan, India. DOI: 10.25258/ijpqa.14.4.65
20. Shankhadip Nandi* and Poulomi Biswas Department of Pharmaceutics, Eminent College of Pharmaceutical Technology, Kolkata, West Bengal 700126, India DOI: 10.36468/pharmaceutical-sciences.1290
21. Nanosponge: A promising and intriguing strategy in medical and pharmaceutical Science Akash Garg a , Wen-Cheng Lai b, Himansu Chopra a, Rutvi Agrawal a,*, Talever Singh a, Ramkumar Chaudhary a, Braj Nandan Dubey a a Rajiv Academy for Pharmacy, NH-2, Mathura-Delhi Road, P.O Chhatikara, Mathura, Uttar Pradesh, 281001, India b Dept. of Electrical Engineering, Ming Chi University of Technology, Taiwan.
22. An outlook towards nano-sponges: A unique drug delivery system and its application in drug delivery Shruti I Meshram*, Pooja R Hatwar, Ravindra L Bakal and Samiksha B Rotake Department of Pharmaceutics, Shri Swami Samarth Institute of Pharmacy, At Parsodi Dhamangaon Rly- 444709 Maharashtra, India. GSC Biological and Pharmaceutical Sciences, 2024; 29(03): 089–098 Publication history: Received on 28 October 2024; revised on 05 December 2024; accepted on 07 December 2024 Article DOI: https://doi.org/10.30574/gscbps.2024.29.3.0466
23. S K, S J, Ahmed A SA. A Comprehensive Review on Recent Advancements In Nanosponges: Innovations, Biomedical Applications, And Future Perspectives. J Neonatal Surg [Internet]. 2025 May 30 [cited 2025Oct.25]; 14(29S): 223-9. Available from: https://jneonatalsurg.com/index.php/jns/article/view/6764
24. Sys Rev Pharm, 2022; 13(1): 55-62 A multifaceted review journal in the field of pharmacy E-ISSN 0976-2779 P-ISSN 0975-8453 / DOI: 10.31858/0975-8453.13.1.55-62 Nanosponges as Emerging Carriers for Drug Delivery Shiwangi Singh* , Monika K Department of Pharmacy, Noida Institute of Engineering and Technology, Greater Noida, India
25. Narender B, Sridhar P, ―Formulation and Evaluation of Anticancer Drug (Tamoxifen) Loaded Nanosponges,‖ Am J Pharm Heal Res., 2019; 7(12): 39–57.
26. Jung JY, Yoo SD, Lee SH, Kim KH et al. ―Enhanced solubility and dissolution rate of itraconazole by a solid dispersion technique, Int J Pharm., 1999; 187(2): 209–218.
27. Gu H, Zheng R, Liu H, Zhang X, et.al. ―Direct synthesis of a bimodal nanosponge based on FePt and ZnS‖ Small, 2005; 1(4): 402–6.
28. Bellingeri A, Palmaccio GM, Cecone C, Trotta F, Corsi I. Preliminary assessment of environmental safety (ecosafety) of dextrin-based nanosponges for environmental applications. Ecotoxicol Environ Saf., 2024; 273: 116120.

29. Mhlanga, S. D., Mamba, B. B., Krause, R. W., & Malefetse, T. J., Removal of organic contaminants from water using nano sponge cyclodextrin polyurethanes. Journal of Chemical Technology & Biotechnology, 2007; 82(4): 382–388.
30. e CL, WuCC, Chiou HP, Syu CM, HuangCH and Yang CC, Mesoporous platinum nanosponges aselectrocatalysts forthe oxygenreduction reactionin anacidic electrolyte. International Journalof Hydrogen Energy, 2011; 36(11): 6433-6440.
31. Abu Samah Z, Zuruzi N, Moskovits M, Kolmakov A. Metal oxide "nanosponges" as chemical sensors: highly sensitive detection of hydrogen with nanosponge titania. Angew Chem., 2007; 119(24): 4376-4379. doi: 10.1002/ange.200700006.
32. tchaya J, Girigoswami A, Girigoswami K. Versatile applications of nanosponges in biomedical field: a glimpse on SARS-CoV-2 management. BioNanoScience, 2022; 12: 1018-1031. doi: 10.1007/s12668-022-00952-0.
33. Raytthatha N, Shah I, Patel J, Vyas J, Upadhyay U. Development of benzoyl peroxide loaded nanosponges gel. Natl J Pharm Sci., 2021; 1(2): 25-29.
34. Smijs TG, Pavel S. Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness. Nanotechnol Sci Appl, 2011; 4: 95-112.
35. Malve NV, Gadhave MV, Banerjee SK, Gaikwad DD. Nanosponge: A novel approach in drug delivery system. Int J Inst Pharm Life Sci., 2014; 4(2): 1–6.