



ADVANCED METHODS FOR THE SYNTHESIS AND PREPARATION OF NANOSPONGES: A COMPREHENSIVE REVIEW

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Abstract :

A review is presented on the development and some different preparation method for Nanosponges. In this review we focused on basic material use in preparation method. And proving details about Nanosponges, how much methods of it's, Etc. Provide properties and Classification of preparation method of Nanosponges. A wide variety of drugs, both the lipophilic as well as hydrophilic can be loaded into Nanosponges for targeting drug delivery and ultimately improve solubility and bioavailability of the same drug. Nanosponges can circulate around the whole body until they interact with the specific target site and stick on the surface and begin to release the drug in a controlled manner. There are different methods available for the synthesis of these NF as well as loading the drugs inside them.

Keywords –Nanosponges, Silica-Based Nanosponges, Polymeric Nanosponges

Introduction: -

The Nanosponges are synthesized using various. Methods, each tailored to achieve specific properties such as particle size, The preparation of nanosponges involves several key methods, each designed to produce materials with specific characteristics suitable for different applications. The preparation of nanosponges involves several key methods, each designed to produce materials with specific characteristics suitable for different applications. Nanosponges have a large surface area due to their porous structure, which allows for high drug loading capacity. Nanosponges are often composed of materials like cyclodextrins, which are biocompatible and safe for use in pharmaceutical applications. The nanosponges are made up of several voids in their core structures that provide the free movement of the drug component. Nanosponges can encapsulate drugs within their porous structure, allowing for controlled and sustained release of the drug over time

Properties:

some properties about Nanosponges possess unique Nanosponges have large type surface area.

Properties that make them particularly valuable in applications, in drug delivery, environmental cleanup, and chemical engineering. Below are the key properties of nanosponges.

High Surface Area : Nanosponges have a large surface area due to their porous structure which allows for drug loading capacity. This makes them efficient carriers for various drugs and other molecules. High surface area makes high capacity of drug loading[1].

Biocompatibility : Nanosponges are often composed of materials like cyclodextrins, which are biocompatible and safe for use in pharmaceutical applications. This property makes them suitable for drug delivery systems[2]

Controlled Release : Nanosponges can encapsulate drugs within their porous structure, allowing for controlled and sustained release of the drug over time. This property is particularly useful for enhancing the therapeutic efficacy and reducing dosing frequency[3].

Porous Structure : Nanosponges are characterized by their highly porous structure, which provides a large surface area for adsorption and encapsulation. The pores can trap substances like drugs, toxins, or pollutants.(4)

Environmental Applications : Nanosponges are effective in environmental remediation due to their ability to absorb contaminants from water or air, acting as nanocleaners. They are applied in cleaning oil spills and removing toxic substances from water.(5)

Thermal and Chemical Stability : Nanosponges are generally stable under various environmental conditions, including heat and chemical exposure, making them suitable for diverse industrial applications.(6)

Classification of Nanosponges:

Based on Material Composition : Cyclodextrin-Based Nanosponges: These are made from cyclodextrins (cyclic oligosaccharides) crosslinked with different agents. They are highly versatile and can encapsulate both hydrophobic and hydrophilic molecules[7]. They can be classified based on various criteria.

- **Polymeric Nanosponges:** Made from synthetic polymers like polyesters, polyamides, and polystyrene, these nanosponges offer tailored properties like biodegradability and specific pore size[8]. Nanosponges are porous, nanoscale structure.

- **Carbon-Based Nanosponges:** These consist of carbon-based materials such as carbon nanotubes, graphene, or fullerenes, often used for environmental applications like water purification due to their high adsorption capacity[9]. They have gained attention in drug delivery.

- **Silica-Based Nanosponges:** Silica nanosponges are made from silica and are known for their high thermal stability and large surface area. They are used in catalysis and drug delivery[10].

Based on Structural Characteristics:

- **Amorphous Nanosponges:** These lack a well-defined crystalline structure and are often used for encapsulating poorly soluble drugs to enhance their solubility and bioavailability[11]. Amorphous Nanosponge they have crystalline structure and encapsulate.

-**Crystalline Nanosponges:** These have a well-ordered structure and are used in applications where controlled release of the encapsulated substance is desired[12]. The type of Materials used, Structural Characteristics and intended Applications.

3. Based on Application Drug Delivery :

--**Nano sponges:** Specifically designed to improve the solubility, stability, and bioavailability of drugs. These nanosponges can encapsulate drugs within their porous structure, allowing for

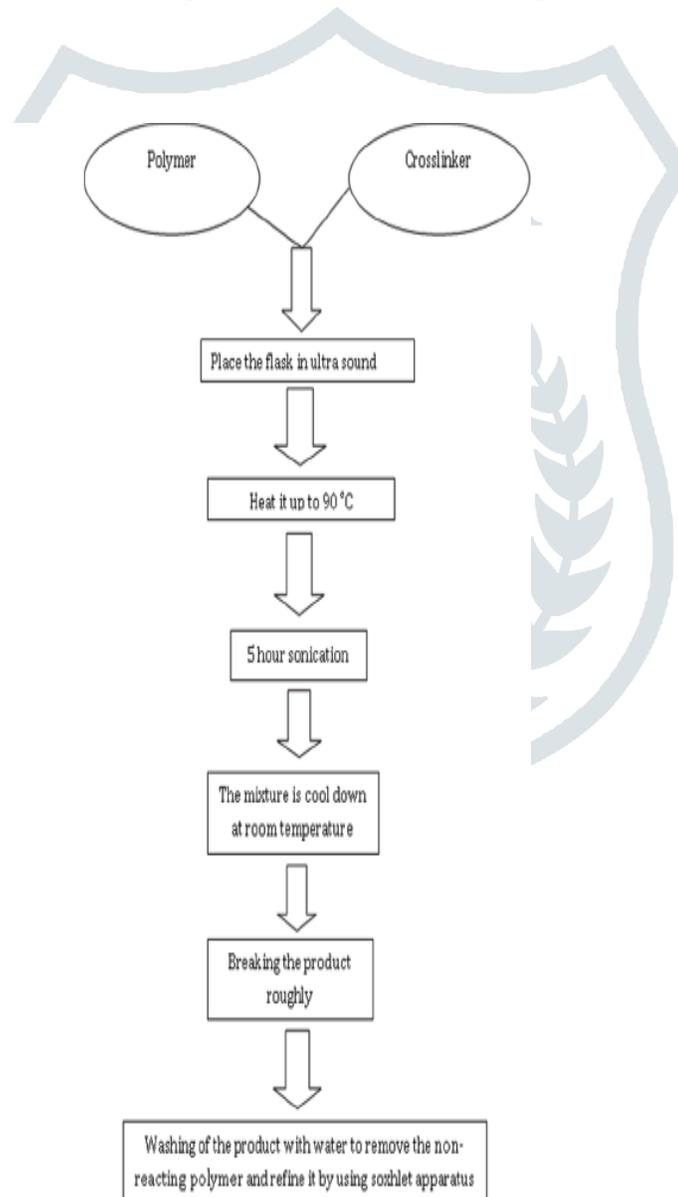


Fig. 2: Flow diagram for the preparation of nanosponges by ultrasound-assisted method

controlled release[13].Nanosponge based on application drugdelivery system this is encapsulate drugs.

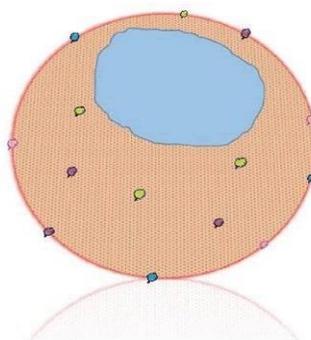


Fig. 1: Structure of a nanosponge

Fig: structure of nanosponge.

Importance of Nanospnges :

1. Drug Delivery and Medicine:

Targeted Drug Delivery: Nanosponges are porous, Nano-sized particles that can encapsulate drugs, improving their solubility and stability. They can deliver drugs to specific sites in the body, reducing side effects and improving therapeutic efficacy[14]

2. Environmental Applications:

Pollutant Removal: Nanosponges can be used to remove pollutants from water and air due to their high surface area and porosity.
Oil Spill Cleanup: In environmental cleanup efforts, nanosponges have shown promise in absorbing oil from water, offering a potential solution for mitigating the effects of oil spills.(15)

3. Materials Science:

Catalysis: Nanosponges can serve as supports for catalytic reactions, improving reaction rates and product selectivity due to their high surface area and ability to stabilize catalytic particles.
Self-Healing Materials: In advanced

materials, nanosponges have been incorporated into polymers to create self-healing materials. [16]

4. Detoxification:

Toxin Neutralization: In biomedical applications, nanosponges can neutralize bacterial toxins in the bloodstream, offering a potential treatment for bacterial infections that involve toxin release, such as sepsis. [17]

General Tips of Nanosponges:

Application-Specific Design:

Safety and Biocompatibility:

Toxicity Assessment: It is essential to thoroughly assess the toxicity and biocompatibility of nanosponges, particularly in medical applications. [20]

Regulatory Compliance: Ensure that nanosponges meet all necessary regulatory requirements, particularly in terms of safety and environmental impact, before commercialization. [21]

Preparation methods of Nanosponges:

1) Polymer-Based Nanosponges Materials:

Commonly used polymers include polyesters like poly(lactide-co-glycolide) (PLGA), hyper-crosslinked polystyrene, cyclodextrins, and other cross-linkable polymers. **Preparation Method: Crosslinking Process:** Cyclodextrins are typically used due to their ability to form inclusion complexes with guest molecules. Cyclodextrin nanosponges can be prepared by crosslinking β -cyclodextrin with a cross-linker like diphenyl carbonate, pyromellitic dianhydride, or carbonyldiimidazole. **Mixing and Heating:** The polymer and crosslinker are dissolved in a suitable solvent. The mixture is heated to promote the crosslinking reaction, forming a gel-like

structure. **Purification:** The formed nanosponges are washed with distilled water or other solvents to remove unreacted crosslinkers and other impurities. **Drying and Milling:** The nanosponges are then dried and ground into fine powders [22].

2) Emulsion Solvent Diffusion Method Materials:

Polymers like ethyl cellulose and polyvinyl alcohol (PVA), organic solvents like dichloromethane, and stabilizers. **Preparation Method: Emulsification:** The polymer is dissolved in a volatile organic solvent (e.g., dichloromethane) to create a polymer

solution, which is then emulsified in an aqueous phase containing a surfactant like PVA. **Solvent Diffusion:** The solvent gradually diffuses out into the aqueous phase, leading to the formation of porous nanoparticles or nanosponges. **Collection and Drying:** The formed nanosponges are separated by filtration or centrifugation, followed by drying. [23]

3) Microwave-Assisted Synthesis Materials:

Similar to the polymer-based method but involves using microwaves to accelerate the crosslinking reaction. Preparation Method: Microwave Irradiation: The polymer and crosslinker mixture is exposed to microwave irradiation, which rapidly heats the mixture and promotes the crosslinking reaction. Purification: After the reaction, the product is purified by washing and drying. (24)

Cyclodextrins, crosslinkers (e.g., carbonyl diimidazole), solvents, and an ultrasound bath. Preparation Method: Ultrasonication: The mixture of cyclodextrin and crosslinker is subjected to ultrasonic waves, which enhance the mixing and crosslinking process by creating localized high temperatures and pressures. Purification: Similar to the previous methods, the product is purified by washing and drying. (25)

3) Thermal Decomposition Method Materials:

Often used with metallic or ceramic nanosponges, involving precursors like metal alkoxides. Preparation Method: Precursor Preparation: A solution of the metal precursor is prepared. Thermal Decomposition: The solution is subjected to high temperatures, leading to the decomposition of the precursor and formation of porous structures. Purification and Drying: The product is washed to remove byproducts and then dried. (26)

4) Ultrasound-Assisted Synthesis Materials:

Conclusion :

The preparation methods and Properties of Nanosponge are critical in determining their suitability for specific applications. The choice of preparation method directly influences the nanosponges structure. This review Reports on the provide information about Nanosponges, preparation method , Properties, classifications and various different methods about preparation of Nanosponges is use in pharmacy field to make Nanosponges.

Their ability to absorb transport, and release substances at the nanoscale makes them crucial in developing new treatment. Nanosponges have emerged as promising drug delivery systems due to their ability to encapsulate both hydrophilic and hydrophobic drugs, protect drugs from degradation, and enable controlled release. Different preparation methods offer varying advantages in terms of encapsulation efficiency, particle size control, and scalability. However, each method has its own.

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stability, cytotoxicity and permeability assessment.” Journal of Drug Delivery Science and Technology, 2011. limitations, particularly regarding the use of solvents and temperature-sensitive processes. Optimizing the preparation method based on the drug’s characteristics and the desired application is crucial for successful nanosponge development.

