NANOSPONGES: CARRIER FOR ADVANCED DRUG DELIVER

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Abstract :- Nanosponges are innovative drug delivery systems derived from β-cyclodextrin (β-CD) that address the difficulties associated with low solubility and and many drugs have less bioavailability. Utilizing various synthesis methods, including emulsion solvent diffusion and microwave radiation ,these porous structures not only enable controlled absorption at certain sites, such as tumors or diseased organs, but they also increase the stability and solubility of drugs that are insoluble in water . X-ray diffraction and scanning electron microscopy are two characterisation techniques that validate their efficacy in medicinal applications. including topical dosage forms, tablets, and capsules, particularly for BCS class II drugs. Nanosponges offer several advantages, including prolonged release, reduced irritation, and improved patient compliance, while also presenting limitations such as the inability to encapsulate large molecules. Their versatility extends to applications in cancer treatment, antiviral therapy, and biomedical engineering, with promising future prospects in vaccine delivery and advanced drug targeting. Overall, nanosponges represent a significant.

Keywords : Oral delivery ,Targeted drug delivery ,Nanotechnology , Nanosponges ,types ,Methods ,Evaluation ,Application .

INTRODUCTION:

With several benefits over other delivery methods, such as low discomfort, simplicity of self-administration, and high patient compliance, oral administration is unquestionably the most practical way to provide drugs. Around the world, the vast majority of marketed pharmaceuticals are regularly used orally. These drugs' oral absorbability, which is mostly influenced by the physiology of the GI tract and drug-based properties, determines how effective they are.[1] Drug transit across the gastrointestinal (GI) barriers is negatively impacted by certain drugs' unfavorable characteristics, including lack of permeability, inadequate hydrophobicity, chemical instability & rapid metabolism during the first pass, among other things..[2] The transit and efficacy of poorly absorbed medications are impacted by the The intestinal membrane barriers include physiological, metabolic, chemical, and physical ones.

Benefits using of drugs via oral route

- Oral medication administration is the safest and most efficient method [3] .The commercially available oral preparations generate sufficient in vivo therapeutic concentrations and are simple to use.
- Compared to parenteral methods, the oral administration technique provides a number of benefits, example as avoiding cannula infections brought on by the likely iatrogenic spread of microorganisms via the patient's implanted cannula [4].
- Furthermore, patients experience less discomfort, particularly when they are treated for serious illnesses that can be managed at a lower risk and frequently with a brief hospital stay or no hospitalization at all[5].
- Oral administration is recommended since it can be more economical for the prolonged treatment for serious heart and neurological issues , painless, and patient-compliant [6].
- Drugs may be broken down in the gastrointestinal tract because of the stomach's high acidity, intestinal lumen enzymes like insulin, or interactions with endogenous substances like bile that change how well they are absorbed. Drugs with a high hepatic first-pass impact and quick metabolism, such ezetimibe, also have low bioavailability [7].

Limitations of Oral Drug Delivery System :

- The gastrointestinal tract degrades; absorption and bioavailability vary; and drug loading capacity is limited.
- First Pass Metabolism Process.
- Possibility of Rapid Drug Release.

Targeting drug delivery is currently the primary problem that researchers are addressing . while limiting its ability to reach normal cellular linings that are not its target, so reducing harmful effects and increasing the drug's therapeutic index [8]. As novel drug delivery systems (NDDS), several polymers have been studied and employed [9]. Medical experts have long struggled with the delivery of certain medications to the human body. Controlling the drug's release rate and appropriately directing them to the appropriate location in the body are the two primary challenges [10]. The key trends in the field of therapeutics will be target-oriented drug delivery with improved therapeutic effectiveness, less adverse reactions, and

the ideal dose regimen. [11].

Fig. 1: Some advanced medicine delivery systems based on carriers

Nanotechnology, which has important ramifications for research on healthcare, diagnostics, and treatments. Examples of many types of nanocarriers include dendrimers, liposomes and micelles, Lipid nanoparticles that are solid or polymeric, lipid or albumin nanocapsules, nanovesicles , nanogels, nano-emulsions, and nanosuspensions. [12] Nanomaterials have been thoroughly studied as potential agents for cancer treatment and drug delivery. particularly in the context of clinical translation research. These produced nanomaterials are among them [13].

Nanosponges

"Nanosponge" refers to microscopic sponges with porous structures. It provides solutions to a variety of formulation-related issues. Nanosponges are virus-like nanoparticles that are less than 1 μm in diameter on average. Their tiny size and porous shape allow them to bind poorly soluble medications within the matrix, altering the pharmacokinetic characteristics of drug molecules to increase their bioavailability. [14]. Nanosponges, whose backbone is long-length polyester, resemble a three-dimensional scaffold or net. It is combined with cross-linkers, which are microscopic molecules that serve as fine grabbing attachments to secure different parts of polymers together. The production of circularly molded, cavity-filled nanoparticles is the ultimate outcome. A variety of compounds can be found in nanosponges, a novel class of materials composed of minuscule particles having chambers that are just a few nanometers wide[15]. Nanosponges are tiny structures that resemble pores and may hold a variety of materials. Their spherical colloidal nature has been demonstrated, and they have a high capacity to dissolve poorly soluble drugs, based on the presence and absence behavior. [16]. These microscopic sponges can move throughout the body until they reach the precise location, stick to the surface, and start releasing the drug in a controlled and predictable way. Due of their function in regulated drug distribution [17] and drug molecule storage, nanosponges have become among biological science's most promising fields. Because it is

biodegradable, the polyester breaks down gradually in the body. By altering the ratio of cross-linkers to polymer, the size of the nanosponge particles may also be adjusted [18].

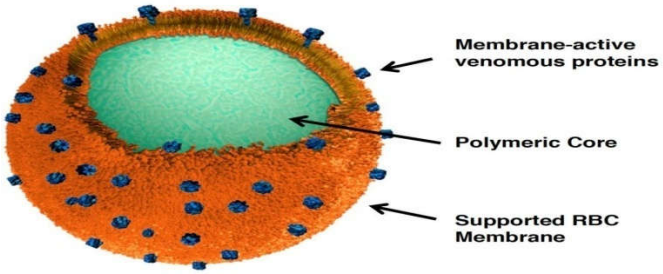

Fig. 2: Polymer Based Nanosponge.

The solid-natured nanosponges can be made orally, parenterally, or topically or inhaled types of dosage. It can be mixed with lubricants, solvents, additives, and anti-caking reagents for oral delivery; this works well for making pills or capsules [19]. Nanosponges that mimic red blood cells protect the body. They have the capacity to limit and halt the spread of illness. They mainly target the toxins, which then combine to generate pore formation, which is the mechanism by which the toxins puncture the red blood cell membrane (nanosponges). When poisons adhere to nanosponge, cell damage and death occur [20]. A novel class of tiny sponge-like structures known as nanosponges (NSs) may play a vital part in the therapy for a variety of illnesses. Early research indicates that NSs are more effective than traditional techniques at delivering medications for various cancers, including breast, lung, and colon cancers [21]. It is not harmful, irritating, mutagenic, or allergenic to use nanosponges Cyclodextrin-based nanosponges (CDNS) are based on novel cross-linked cyclodextrin polymers that possess a three-dimensional network nanostructure.A novel nanosized delivery device. [22].

The nanoparticles can be divided into three classes according to how they interact with medications.

1. Nanoparticle packaging: Examples of this class are nanocapsules and NSs. Alginate nanosponges are drug-transporting nanoparticles with many pores that resemble sponges. Furthermore, nanoparticles can be housed in poly (isobutyl cyanoacrylate) (IBCA) nanocapsules. Medicinal compounds can be captured by their aqueous core..

2. Complexing Nanoparticles: This group include complexing nanoparticles, which use electrostatic charges to draw molecules to them.

3. Conjugating Nanoparticles: Covalent linkages allow these conjugating nanoparticles to attach to medications [23].

Mechanism of drug release from nanosponges: Since there is no continuous barrier surrounding the nanosponges due to their open structure, Encapsulated, the active ingredient is delivered to the vehicle. The active substance that is encapsulated can freely flow from the particles into the vehicle until equilibrium is reached and the vehicle saturates. The active ingredient's vehicle becomes unsaturated as soon as the product is applied to the skin, disrupting the balance. According to (Mandava and Thavva 2012), the active ingredient is

released into the skin for a longer duration even after the nanosponge particles have remained on the stratum or skin's surface.

Nanosponges' types :

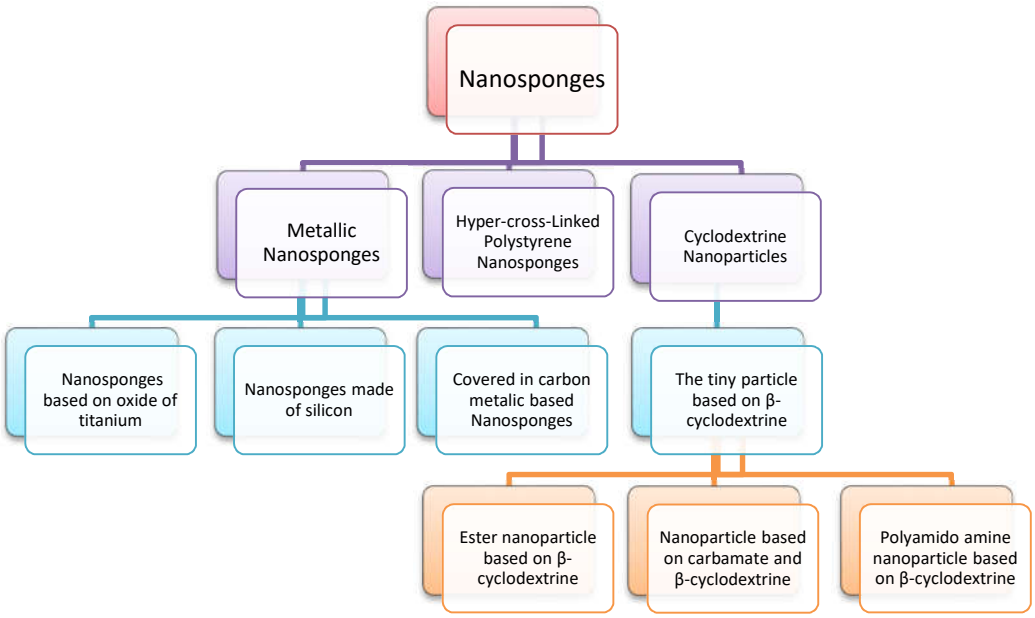

Fig. 3: Classification of NS [24]

DeQuan Li and Min Ma first used the term "cyclodextrinnanosponges" (CDNS) in 1998 to describe a crosslinked β-cyclodextrin with organic diisocyanates that creates an insoluble network that indicates a high inclusion constant with a variety of organic pollutants CDNS is a three-dimensional configuration of crosslinked cyclodextrin nanostructure polymers , a new nanoscale medication delivery platform.There are three types of CDs: The circular diameters & solubilities of the three naturally occurring The α-, β-, and γ-CDs are different. The alpha-, beta-, and gamma-cyclodextrins are α, β, and δ. [25].

Advantages:

1.Drug delivery that is targeted to a specific location.Develop a drug delivery method that protects the molecule.
2. A broad variety of chemicals can be trapped by this nanosponge technology, which also has fewer adverse effects.increase the formulation's flexibility and stability.
3. They are self-sterilizing because of their normal hole size of 0.25 µm, which prevents germs from penetrating. They also help to reduce discomfort and improve tolerance, both of which improve patient compliance.stable up to 130 °C [27].

4. Extended release action is possible for up to 12 hours. enhances material processing by turning liquid into powder. These mixtures are stable over a wide pH range of 1 to 11[28].
5. It masks up undesirable flavors. Enhance the bioavailability [29].

Disadvantage:

1.Nanosponges can only contain tiny molecules.
2.Crystalline or paracrystallinenanosponges may be present.
3. In nanosponges, the degree of crystallization largely determines the loading capacity .
4. Paracrystalline nanosponges can have different loading capacities [30].
5. Dose Dumping may take place. The ability to enclose tiny molecule [31].

Factors Influencing Nanosponges: Factors affecting nanosponges' formation:
1) Cross-linkers and polymers: The type of polymer utilized may have an impact on the makeup and performance of nanosponges.

Hydrophilic nanosponge: Even in formulations for quick release, hydrophilic nanosponges act as a powerful drug carrier by altering the enhancing medication absorption across biological barriers and accelerating drug release. hydrophobic nanosponges they act as long-term delivery systems for water-soluble medications, such as protein and peptide medications[32].

2) Heat Complexation : Temperature variations have an impact on a complex's stability constant. Because the drug/nanosponge contact forces diminish with rising temperature, the apparent stability constant's size also decreases. Making nanosponges therefore necessitates careful temperature control [33].
3) Preparation method : The drug/nanosponge complexation may be impacted by the way the drug is loaded into the nanosponge. But the structure and polymer of the medication determine how effective an approach is. [34].

4) Level of replacement: The nanosponge's capacity to complex can be significantly impacted by the quantity, position, and softness of the substituent on the parent molecule [35].

Method for creating nanosponges:

1.solvent methodology :

A polymer is dissolved in a polar aprotic solvent, such as DMF or DMSO, and then combined with a cross-linker, preferably in a 1:4 ratio, as part of the solvent technique. Cross-linkers like dimethyl carbonate or carbonyl diimidazole are used in the process, which lasts one to forty-eight hours at high temperatures (100°C to boiling point).After cooling, the mixture is put into more double-distilled water, filter and cleanse using extraction of soxhlet and ethanol. After that, the material is ground into a uniform powder and vacuum-dried [36].

2.Melting (Fusion) process:

In the melt process, cyclodextrin is mixed with a suitable crosslinker, such as 2, 2-bis (acryl amide) Acetic acid, dimethyl and diphenyl carbonates, isocyanates, diaryl carbonates, carbonyl diimidazole (C7H6N40), and acid anhydrides .After thoroughly mixing all the materials, they are heated to 100°C for five hours in a 250 ml flask with a magnetic agitator. To make sure that all unreacted excipients are eliminated, let the mixture cool before dissolving it and rinsing it with the appropriate solvent.

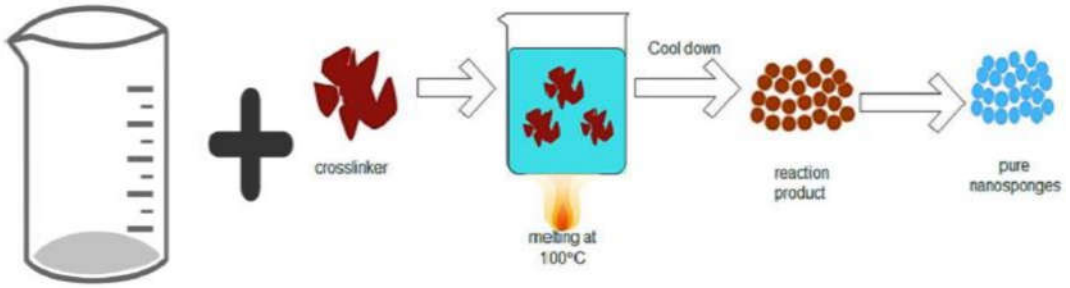

Fig.4.Melting Fusion process

3.Nanoprecipitation Method :

NSs can be made by varying the ratios of ethocell (EC) and vinyl alcohol.150 milliliters of the water continuous phase were used to gradually mix a predefined volume of vinyl alcohol with the dispersed phase after the medicine and ethocell had been dissolved in 20 milliliters of chloroform.The reaction mixture was stirred at 1000 rpm for two hours. The resulting nanosponges were filtered and then dried for 24 hours at 400ºC in an oven. The dehydrated nanosponges were then stored in a vacuum oven to make sure that any remaining solvents were removed [37].

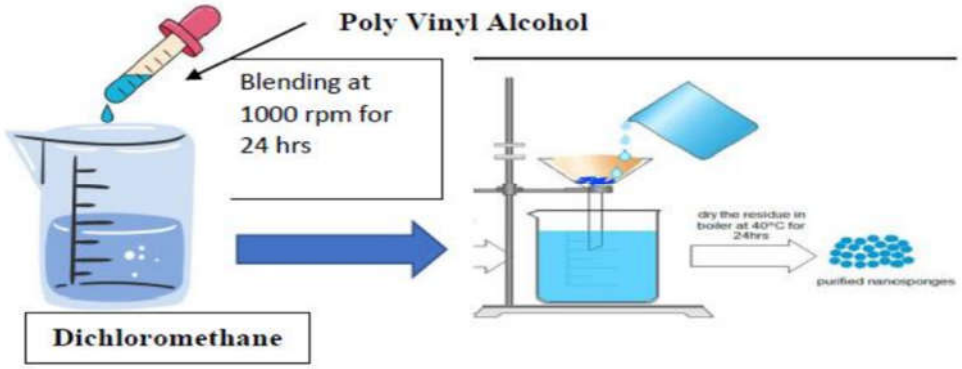

Fig.Nanoprecipitation Method

4.HyperCross-Linked β-CD : The drug transport medium β-cyclodextrin (β-CD) can be utilized in this case. When CD and a cross-linking agent are combined, nanosponges can be produced. Tiny sponges that are neutral or acidic could be produced. The normal diameter of a nanosponge is less than 1 μm, however fractions less than 500 nm can be used [38].

5.Ultrasound-assisted method: This synthesis technique makes use of the polymer's ultrasonic junction. Solvent free crosslinking achieved through ultrasonic vibration . At the ideal molar ratio, the polymer and crosslinker were combined in a flask. The combination was then placed in an ultrasonic bath set at 90°C for five hours. Following sonication, the combination was allowed to cool before the resultant solids was separated, thoroughly cleaned with water to eliminate contaminants and unreacted polymer, and then further clarified using Soxhlet extraction and alcohol solvent. The purified nanosponges were then treated and dried under vacuum prior to drug loading." [39].

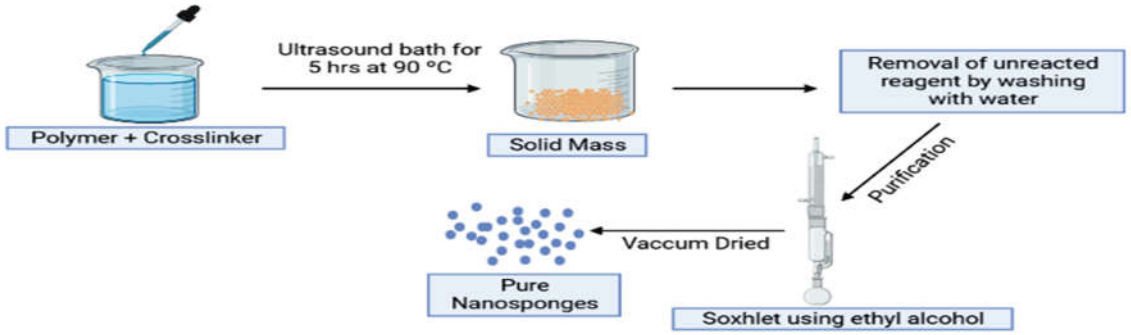

Fig.6.Ultrasound Assisted Method

6. Electric bubble spinning: The primary elements of a typical fiber electrospinning configuration are a carteridge,an infusion pump, a voltage supply unit, and a neutral collector, per many sources. However, the volume at which nanofibers are produced is one of the primary issues restricting their application. Additionally, It is possible to use vinyl alcohol as a polymer in bubble electrospinning. To make the 10% polymer solution a one-phase mixture, distilled water was added and heated to 80 to 90°C for two hours. Prior to being utilized to produce nanoporous fibers, It was allowed to settle with the polymer solution at ambient temperature [40].

7. Synthesis using microwave radiation: The scientific microwave system was used to conduct microwave processes. To quantify the reaction mixture's thermal flux, a phototonics probe was placed within the reaction chamber. Cyclodextrin-based nanosponges were created using diphenyl carbonate as a crosslinking agent and diphenylformamide as a solvent. In summary, a 250 ml flask containing a combination of diphenyl carbonate and cyclodextrin in dimethylformamide was microwaved for a predefined period of time under predefined conditions. A solution was almost entirely eliminated. Following that, the resultant material was suitably purified using ethanol-based Soxhlet extraction. After that, the white dust was processed in an oven set to 60 °C in order to get it ready for use in an experiment. The NSs generated by microwave synthesis [41].

8. The solvent method of quasi-emulsion: With different polymer concentrations, the quasi-emulsion solvent diffusion technique can also be used to create the nanosponges. The inner phase was prepared by dissolving Eudragit RS100 in an appropriate solution.After that, the medication can be included in the mixture and ultrasonically dissolve at 350°C. After mixing the interior and outer phases of the polyvinyl alcohol solvent in water, the nanosponges were

separated by filtering after an hour of spinning. For 12 hours, the nanosponges are dried at 400° C in an air-heated oven [42].

9. Polymerization : The monomer produces a non-polar drug solutionThis is followed by the addition of an aqueous phase that contains surfactant & dispersant to help with suspension. Polymerization occurs once the monomers have been reacted with enzyme or elevated temperatures to form a solution with distinct drops of the appropriate size.A reservoir-type structure with the polymerization procedure involves the production of surface pores. [43].

Nanosponges Characterization And Evaluation Test :

1.Studies of solubility:

Higuchi and Connors' phase solubility method, which looks at how nanosponges affect medication studying inclusive association is most commonly done using solubility. This technique involved adding the drug into an Erlenmeyer flask that has a watery solution with varying amounts of nanosponges in it. The Erlenmeyer flask was shaken mechanically at the ambient temperature. A 3000 Dalton molecular filter (TINY YN 30, Millipore corporation, Bedford MA 1730 U.S.A.) was used to centrifuge the mixture once it had stabilized. To ascertain the drug concentration, HPLC analysis was performed on the resulting solutions. [44].

Single crystal x-ray analysis and X-ray diffraction : Since the drug unit is liquid and liquids don't have a distinct refraction pattern, powder X-ray diffractiometry can be utilized to identify associations in the state of matter .The complicated growth is indicated by this variation in the refraction pattern. The diffractograms of the putative complexes must be compared with the biomechanical combination of the drug and polymer molecules when the medicinal component is robust. The diffraction peaks of a mixture of substances can be used to determine the formation of complexes and the breakdown of chemicals. The diffraction patterns are changed when a drug forms a compound with nanosponges[46].

2. Thermoanalytical techniques: These techniques determine whether the drug material alters in any way prior to the nanosponge's heat breakdown. The drug substance may undergo polymorphic transition, oxidation, breakdown, melting, or evaporation. The complex formation can be noted by the alteration in the drug's composition. The thermogram derived from it is possible to check thermal reaction analysis and calorimetric detector for expanding , transferring, the emergence of new high points,and the removal of particular peaks.Weight reduction alterations may also promote the formation of inclusion complex. [47].

3. Identification of Particle Sizes: One important factor in the optimization process is the size of the nanosponge's particle. Zeta sizers or infrared diffractometry can be used to measure particle size. One can examine how particle size influences drug release by charting the average amount of medication released from nanosponges with different particle sizes over time. For topical medication administration, particles bigger than 30 m may feel rough, while particles between 10 and 25 m may be suitable [48].

4. separation with thin layer : The technique significantly reduces a drug molecule's Rf value, which helps identify complexes that develop between a medication and a nanosponge.

Reverse inclusion association takes place between the guest and host molecules. Consequently, throughout the chromatographic procedure, the complex may fully divided into guest and host molecules, allowing the TLC-plate to display only the visitor and host molecule locations[49].

5. IR spectroscopy: Infrared spectrum is utilized in the solid state to ascertain how therapeutic molecule and nanosponge interact. The infrared spectrum is altered if a complex appears between the active ingredient and the nanosponge, or if the complexes contain a small portion that contains the drug's molecules.(fewer than 25% of the frequency) and ascribed to contain a fragment of a different molecule that can be recognized by bands of the nanosponge spectra. Some drugs with carbonyl or sulfonyl groups have limited use for IR. Information about drugs with functional groups is provided by IR studies [50].

6. Fourier Transform Infrared (FTIR) analysis: In particular, the presence of the chemical group in the structure is made clear by the sample's FTIR measurement. Regarding medications, polymers,The monitoring range for drugpolymer complexes, blank NSs, drug encapsulate NSs, and possible interaction is 4000 to 650 cm. FTIR measurements make it easier to identify the hydrophilic and hydrophobic areas of NSs. Analysis of infrared spectra provides data on the presence of hydrogen in various chemical groups[51].

7.Spectroscopy of nuclear magnetic resonance (NMR): Knowing how crosslinked polymers are structured is helped by NMR techniques such as 13C, 1H, Magical Angle rotating with excellent resolution and 2D NMR.The structure of the reaction is determined by altering the chemical shift values (δ), which shows proton transfer between species in the reaction [52].

8. Electron microscopy with scanning: NSs the products (drug/NS complex), and the drug's surface properties can all be examined using SEM and TEM. Under an optical microscope, the crystallization stage of the finished products was different from that of the original constituents. indicating the formation of inclusion complexes .In order to the sample was viewed under a microscope after five microliters of the watery combination were put on a system that was then set upon a glass plate [53].

9. Dissolution test : Using five meters of stainless steel wire in a customized basket and rotating at 150 rpm, the USP XXIII dissolution apparatus can be used to assess the dissolution profile of NSs. When examining the solubility of active chemicals, selecting dissolve medium ensures that sink conditions are maintained. The available analytical techniques are used to analyze the final samples [54].

10. Research on in vitro release : Using a customized container made of five meters of steel mesh and the dissolving apparatus USP xxiii, the dissolution profile of the nanosponge can be examined .150 rpm is the spinning speed.The dissolving media is selected with the actives' ability to dissolve in mind to ensure outflow conditions. Using a modified container made of 5m steel mesh and the appropriate analytical protocol, sample from the disintegration media can be examined using the dissolving apparatus USP xxiii [55].

11.Tests of resilience: properties of viscoelasticity, or Depending on the requirements of the previous formulation, the resilience (viscoelastic properties) of sponge may be altered to produce softer or stiffer beadlets. Crosslinking lowers the frequency of discharge. Therefore, the resilience of sponges will be assessed and modified as needed by taking into account releasing as a function of time-dependent cross-linking [56].

12.Circulardichroism (CD): This spectroscopy technique is used to determine whether CD inclusion chemicals are present, particularly in aqueous solutions.Dichroic absorbance requires both molecular asymmetry and molecular electronic absorption. In fact, when an achiral foreign molecule was inserted in an asymmetric CD cavity, its absorbing band showed external Cotton effects, as seen by circular dichroism. Inversely , The Cotton effect is not caused by an inner interface interaction among CDs and foreign molecules; rather, it merely modifies other spectrum features[57].

Application Nanosponges :

In the pharmaceutical sector, nanosponges can be used as an additive to create cutaneous preparations, tablets, capsules, granules, suspensions, solid dispersions, and pallets. [57]. Enhanced chemical, physical, and thermal stability, longer release, reduced irritation, and better goods performance & appearance can all be achieved with nanosponges. The following list of uses for nanosponges illustrates its adaptability [59].

1. Solubility Enhancement: The clinical usage of about 40% of new drugs is restricted due to their poor water solubility [61]. NS may increase a substance's solubility and wetting. Enhancing a substance's solubility and rate of dissolution can alleviate a number of formulations and bioavailability problems, and NS can significantly increase a drug's permeability. [62]. Itraconazole is an antifungal medication that prevents and treats oral and throat yeast infections by preventing the fungus-mediated production of ergosterol through 14α-demethylase inhibition. The drug's water solubility is approximately 1 ng/mL at physiological pH. Encapsulating β-CD NS increases drug solubility by almost 27 times [63]. When polyvinyl pyrrolidone (PVP k-30) is added as an auxiliary component utilizing a solid dispersion system of the β-CD NS formula, the ratio rises to 55 times [64].

2. Modulating medicine Release: The goal of a controlled relese formulation is usually to enhance the therapeutic process. As a result, adverse effects can be decreased, the dosage can be decreased, and the pharmacokinetic profile can be altered. In immediate-release formulations, hydrophilic CDNS are used to change the pace of drug delivery and improve drug absorption through biological barriers [65]. Hydrophobic CDNS, such as ethylated and acylated CDs with reduced water solubility.This action shows that the NS formula can protect pharmaceuticals in the stomach environment while allowing medicine release in the intestine [66] Meloxicam, a strong anti-inflammatory and selective Cox-2 inhibitor, is used to treat osteoarthritis. It has low oral absorption due to its weak stability and solubility. [67] looked into the use of NS to avoid these issues.

3. Targeted Drug Delivery: The development of targeted drug delivery (TDD) nanosponges has advanced significantly under Eva Harth's direction. Synthetic polymer NS is one such distribution strategy for TDD. that researchers at Vanderbilt University have created. To guarantee that these NS would bind selectively to tumor cells upon injection.They were filled with anti-cancer drugs, The development of targeted drug delivery (TDD) nanosponges has advanced significantly under Eva Harth's direction. Synthetic polymer NS is one such distribution strategy for TDD. As a result, it has greater effectiveness and less negative impact on healthy cells [68].

4. Delivery of gas: vehicle In order to diagnose and cure medical diseases, gases are important. Numerous illnesses are linked to inadequate oxygen availability, like cancer and inflammation. Hypoxia is the term used for this situation.Since transcutaneous oxygen therapy can store and deliver oxygen gradually over a longer duration of time, In practical settings, it could be difficult to deliver oxygen in the right form and dosage. To provide oxygen topically, NS preparations with the capacity of storing and releasing oxygen progressively over time were created [69].

5. Delivery Protein : For pharmaceuticals to be successfully created, stability over the long term is essential , especially macromolecules such as proteins [70] However, during lyophilization, proteins may experience irreversible (or ideally permanent) degrade and conformational changes.Thus, one of the key challenges in the creation of protein formulations is preserving the unique protein structure both while in preparation and throughout time [71].

6. Enzyme immobilization: Because it improves the stability of lipases and regulates elements like enantioselectivity and reaction rates ,this issue is particularly significant for lipases.[72].In order to continuously expand, a suitable family of enzymes needed a new stable foundation. On a new kind of CD-based nanosponge, adsorbed, bacteria fluorescence lipase showed exceptional catalytic activity [73].

7. Antiviral therapy: Nanocarriers have the ability to target viruses such as respiratory syncytial virus, influenza virus, and rhinovirus in order to cause respiratory tract infections (RTIs). by selectively delivering antiviral medications to the lungs and nasal epithelia. Acyclovir, zidovudine, saquinavir, and interferon-α are a few medications that are administered by nanotechnology. Also these nanodelivery devices can also be applied to HSV (Herpes Simplex Virus) and HIV (Human Immuno Virus) as well [74].

Nanosponges can be used to deliver anticancer medications to tumors during cancer treatment. The surface of the nanosponge has drug-filled microscopic sponges that expose a specific peptide that will attach to the tumor's radiation-induced cell surface receptor.Upon contact with the tumor cell, the sponge adheres to its surface and releases its contents. One of the key medications that is made as a nanosponge is paclitaxel, which has been the subject of studies in animals using it as the sponge load. [75].

8.Biomedical Engineering: Recently, the use of NS substrates for mammalian cell micropatterning has been investigated. On oxidized silicon NS, Chung-Yao Yang et al.

explained a method for micropatterning mammalian cells, such as the epithelial cells of the Madin-Darby canine kidney (MDCK), HIG-82 fibroblasts, and Chinese hamster ovary (CHO) cells [76].Using Silicon NS as a mold, Chung Yao Yang et al. developed Chitosan NS in another published study. As a substrate, the produced chitosan NS membrane was adhered to human breast tumor cells MDA-MB-231, and several cellular behaviors and molecular-level structural responses of these adherent cells were investigated using modified NS.StefanoBorini et al. announced 3D protein nanopatterning on silicon NS. They showed that proteins could bind selectively to the silicon NS substrate's active region. [77].

9.Water purification: Organic contaminants in water can be eliminated using CD NS. β-CD NS has the ability to encapsulate organic contaminants from water and is totally insoluble in it. These NS can be implanted into ceramic porous filters to create organic/inorganic hybrid filter modules. It has been demonstrated that these hybrid filter modules can efficiently remove a range of water contaminants [78].The removal of polycyclic aromatic hydrocarbons (PAH) has been found to be quite simple Additionally, the contaminants group of trihalomethanes (toxic heavy metals) (>95%), single aromatic hydrocarbons (BTX), and pesticides (simazine) (>80%) can be successfully eliminated.[79].Torasso N. et al. used acetylene plasma polymerization to create superhydrophobic carbonaceous NS for oil sorption. and It showed promise for use in cleaning up water bodies after oil spills [80].

10. Absorbent in the treatment of blood poisoning: NSs offer a unique method for using nanocarriers to detoxify blood. By injecting NSs into the bloodstream, they can absorb the toxins as an alternative to an antidote. These NSs mimic RBCs in appearance, which deceives poisons into attacking them. They then absorb the toxins and divert their course away from the cellular target . created NSs by combining ovine erythro vesicles with poly (d,l-lactic-co-glycolic acid) (PLGA) cores. The most vulnerable erythrocytes to streptolysin-O lysis were those from cows. Ovine nanosponges adsorbed the cholesterol-binding toxin streptolysin-O at 37 and 40 °C [81].

11.Benefits for material handling and a decrease in irritation: Some medicine ingredients cause irritation to the skin, eyes, or stomach. By lowering the local concentration of free medication below the irritancy threshold, NS can lessen their irritation. As the complex slowly separates and releases the free medication, the local free concentration of the drug consistently stays below levels that could irritate the mucosa. It might be challenging to handle and combine materials that are liquids or oils at room temperature to create stable solid dosage forms. By using standard production techniques and processes, NS can transform these materials into easily handled amorphous or microcrystalline powders that can be formed into solid dosage forms [82].

12. Method of topical administration of drugs : For topical medication distributionNS can be included in creams and gels. Among these, Pathak et al. prepared one .A hydrogel mixture of polymeric NS was used to extend the duration of the econazole salt form's retention on the skin. For twelve hours, drug release was controlled. [83].

Future Prospects:

- By reducing technology to the nanoscale, nanotechnology and nanofarmulation have transformed medical research. Nanoporous particles, or NPs, can solve formulation-related issues such increasing solubility and stability while also enhancing the pharmacokinetic and pharmacodynamic characteristics of medications.
- Because of their crucial significance in the advancement of nanotechnology, NS have been the subject of this review. NP might become a commonplace water purifier in the future. R. Nevertheless ,It would be challenging to lower the price by looking into different polymers, cross-linkers, and more sophisticated manufacturing processes.
- It is possible to create biodegradable and bioabsorbable carriers that will decompose inside the body without releasing any harmful byproducts. More in-depth investigation is required to ascertain these nano-carriers' efficacy and destiny. Moreover.NP can be used by the pharmaceutical and medical sectors to address a variety of biological, chemical, and physical issues related to disease management. Investigating NS as diagnostic agents, such as in cancer imaging, could be intriguing..
- NP may stabilize cancer biomarkers that would often be broken down by enzymes before being found. Optimizing the safe and effective transport of these substances to the eukaryotic cytoplasm is one of the primary difficulties in bioactive targeting. It is necessary to address the problem of brain-targeting drugs for cancer treatment..
- Nanosponge compositions will probably be used in the future to administer vaccines. Nanofoams laden with drugs are fascinating new findings that merit more research. By overcoming physiological obstacles, magnetic nanoparticles have been able to deliver therapeutically relevant concentrations of the substance to the site of action for a duration that allows for therapeutic activity without destabilization or elimination.
- We propose that NP be investigated further for drug delivery to sick cells, with magnetic NP being one of the NDDS that play a significant role.

Conclusion :- According to the information given, nanosponges are a major development in drug delivery systems, especially when it comes to improving the stability, solubility, and targeted distribution of different drugs. Their potential to increase therapeutic efficacy while reducing adverse effects is highlighted by their capacity to encapsulate poorly soluble medications and enable controlled release at particular areas, such as tumors. Their application in a variety of therapeutic areas is further demonstrated by the utilization of biodegradable components and their adaptability in formulation for various routes of administration , such as biomedical engineering, antiviral therapy, and cancer treatment. The creation and efficacy of nanosponges are being improved by continuous research and developments in nanotechnology, despite certain drawbacks including the incapacity to encapsulate big compounds and the possibility of dose dumping. Prospects for the future show promise for their application in better drug targeting and vaccine delivery, confirming their position as a cutting-edge solution in pharmaceutical formulations.

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