IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Nanoparticles Advances In Drug Delivery System:A Theoretical Review.

[1]Navnath Subhash Kabadi* , [2]Miss.Ashwini A.Wakade and [3]Dr. Megha T. Salve .

Department of B.Pharmacy.

Shivajirao Pawar College Of B.Pharmacy , Pachegaon ,

Ahilyanagar - 413725.

ABSTRACT:

Recent breakthroughs in nanotechnology are set to transform drug manufacturing, drug delivery systems, and medical diagnostics. Nanoparticles exhibit distinct properties that differ from larger micro- and macro-particles, making them highly effective in various applications. In the field of life sciences, nanotechnology is expected to drive groundbreaking changes, particularly in drug delivery, diagnostic tools, nutraceuticals, and the development of biomaterials. Nanoparticles are utilized in a wide array of industries, including electronics, magnetic pharmaceuticals, cosmetics, energy production, catalysis, and materials science. According to the U.S. Food and Drug Administration (FDA), nanotechnology encompasses research and development activities at the atomic, molecular, or macromolecular level, typically within the 1-100 nanometer (nm) range. This field focuses on creating and utilizing structures, devices, and systems with unique properties and functions attributable to their small size, with the capacity to control or manipulate materials at the atomic scale. In the near future, nanoparticles hold significant potential for applications in new products like cosmetics, textiles, and paints. In healthcare, these technologies could enhance the potency of traditional drugs and provide innovative solutions for diseases previously considered untreatable. This paper will explore different types of nanoparticles, examining their benefits, limitations, and applications across various fields.

Keywords: Nanotechnology, Nanosuspension, Nanoparticles, solid lipid Nanoparticles (SLN).

INTRODUCTION:

Nanoparticles are colloidal structures on a sub-nano scale, made from either synthetic or semi-synthetic polymers. The earliest examples of nanoparticles were non-biodegradable, utilizing polymers like polyacrylamide, polymethyl methacrylate, and polystyrene. These tiny particles can transport drugs or protein-based substances (such as antigens) by embedding them within a polymer matrix as particulate or solid solutions, or attaching them to the particle surface through physical adsorption or chemical bonds. Drugs can be incorporated into nanoparticles either during or after their preparation. Nanomedicine, a growing branch of nanotechnology, leverages these ultra-small particles—which are more than 10 million times smaller than the human body—for medical purposes. Given their size, nanoparticles are much smaller than living cells, opening new avenues for treatment across various diseases. This emerging field holds promise for developing innovative therapies to combat cancers, neurodegenerative disorders, and other difficult-to-

treat conditions.[1] When designing nanoparticles for drug delivery, key goals include precisely controlling particle size, surface properties, and the release of active agents. This strategy helps ensure that drugs act specifically at the target site and are delivered at the ideal rate and dose. Although liposomes have shown promise as carriers, with benefits like protecting drugs from degradation, targeting delivery, and reducing toxicity or side effects, they have some drawbacks. These challenges include low efficiency in encapsulating drugs, quick leakage of water-soluble drugs in the presence of blood components, and limited storage stability. Polymeric nanoparticles, however, offer distinct advantages over liposomes. They provide increased stability for drugs and proteins and have useful properties for controlled release, making them a valuable alternative in drug delivery applications.[2,3]

TYPES OF NANOPARTICLES APPLIED IN DRUG DELIVERY:

The types of nanoparticles applied in the drug delivery system include:

Sr. No.	Type of Nanoparticles	Material used	Applications	Ref.
1	Nanosuspensions and Nanocrystals	Drug powder is dispersed in surfactant solution	Stable system for controlled delivery of poorly soluble drug	4
2	Solid lipid Nanoparticles	Melted lipid dispersed in Aqueous surfactant	Least toxic and more stable Colloidal carrier systems as alternative materials To polymers	5
3	Polymeric nanoparticles	Biodegradable polymers	Controlled and targeted drug delivery	6
4	Polymeric micelles	Amphiphilic block co polymers	Controlled and systemic Delivery of water insoluble Drugs	7
5	Magnetic Nanoparticles	Magnetite Fe2O3,Meghe Mite coated with dextran	Drug targeting diagnostics to in medicine	8
6	Carbon Nanotubes	Metals ,semiconductors or carbon	Gene and DNA delivery Controlled release of drug	9
7	Liposomes	Phoshpolipid vesicles	Controlled targeted drug delivery	10
8	Nanoshells	Dielectric core and metal shell	Tumor targeting	11
9	Ceramic Nanoparticles	Silica,alumina,titania	Drug and biomolecule delivery	12
10	Nanopores	Aerogel,which is produceded by cell gel chemistry	Controlled release drug carriers	13
11	Nano wires	Silicon, cobalt, gold or Copper based nanowires	Transport electron in nano Electronics	14
12	Quantum dots	cdSe-cdS core shell	Targeting ,imaging agent	15
13	Nano films	polypeptides	Systemic or local drug Delivery.	16
14	Ferrofluids	Iron oxide magnetic Nanoparticles surrounde-d by polymeric layer	For capturing cells and other biological targets.	17

Nanosuspension:

Nanosuspensions (NSs) are colloidal systems consisting of finely dispersed drug particles, typically smaller than 1 μm. These systems are biphasic, where solid drug particles are suspended in a liquid medium. While the precise definition of nanosuspensions may vary in the literature, they are generally described as dispersions of pure active pharmaceutical ingredients (APIs) with particle sizes ranging from 10 to 1000 nm, stabilized by surfactants or polymers. In some instances, the terms "nanosuspensions" and "nanocrystals" are used interchangeably, with the latter referring to drug particles within the size range of 200–600 nm, composed

entirely of the active substance. Stabilizers are employed to maintain the drug in its nanosized crystalline form, preventing aggregation and enhancing bioavailability and therapeutic effectiveness.[18-20] An example of a nanosuspension is the preparation of ibuprofen using the emulsion-solvent diffusion method. This technique is designed to enhance the drug's availability in the eye, thereby improving its absorption and therapeutic effectiveness when administered ocularly. Reducing the drug particles to the nanoscale facilitates better bioavailability and more efficient treatment outcomes.[21]

Solid lipid Nanoparticles (SLN:

Solid lipid nanoparticles (SLNs) were developed in December 1991 as a novel drug delivery method, providing an alternative to traditional colloidal carriers. These particles are made up of stable lipid spheres in the nanometer range and are generally dispersed in a solution of surfactants or in water. The solid lipid structure allows for controlled release of the medication and protects the active ingredients, enhancing stability and bioavailability. This makes SLNs a valuable tool for applications in pharmaceuticals and biotechnology.[22] Targeted drug delivery remains one of the most complex fields of research in pharmacy. Advances in colloidal nanoparticle systems, including liposomes, micelles, and solid lipid nanoparticles (SLNs), have presented new challenges and opportunities to improve drug delivery methods. SLNs stand out for combining the benefits of polymeric nanoparticles, lipid emulsions, and liposomes. They offer numerous advantages, such as high biocompatibility, non-toxicity, stability against aggregation, minimal drug leakage, resistance to hydrolysis, biodegradability, physical stability, and effective transport for lipophilic drugs. Nonetheless, there are notable differences and conflicting characteristics between lipid emulsions and liposomes.[23] Solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs) have a wide array of beneficial properties, making them valuable for drug delivery methods, such as parenteral, dermal, pulmonary, and topical applications. These formulations were created to minimize the side effects of highly potent drugs while enhancing treatment effectiveness. SLNs and NLCs also play a significant role in gene delivery systems and are increasingly used in the cosmetic and food industries. However, due to certain inherent limitations and obstacles, their commercial production remains relatively restricted and is available in only a limited range of products.[24]

Polymeric nanoparticles:

In nanoparticle-based drug delivery systems, the drug can be dissolved, entrapped, absorbed, attached, or encapsulated within the nanoparticle matrix. The preparation method influences whether nanoparticles, nanospheres, or nanocapsules are produced, each offering distinct properties and release behaviors for the therapeutic agent. Nanoparticles act as vesicular systems where the drug is confined in a cavity surrounded by a polymer membrane, while nanospheres are matrix systems where the drug is uniformly distributed. The advantages of nanoparticles in drug delivery are due to two main characteristics: first, their small size enables them to pass through fine capillaries and be absorbed by cells, allowing for efficient drug accumulation at target sites. Second, the use of biodegradable materials in nanoparticles supports a sustained release of the drug at the target site, potentially lasting from days to weeks.[25]

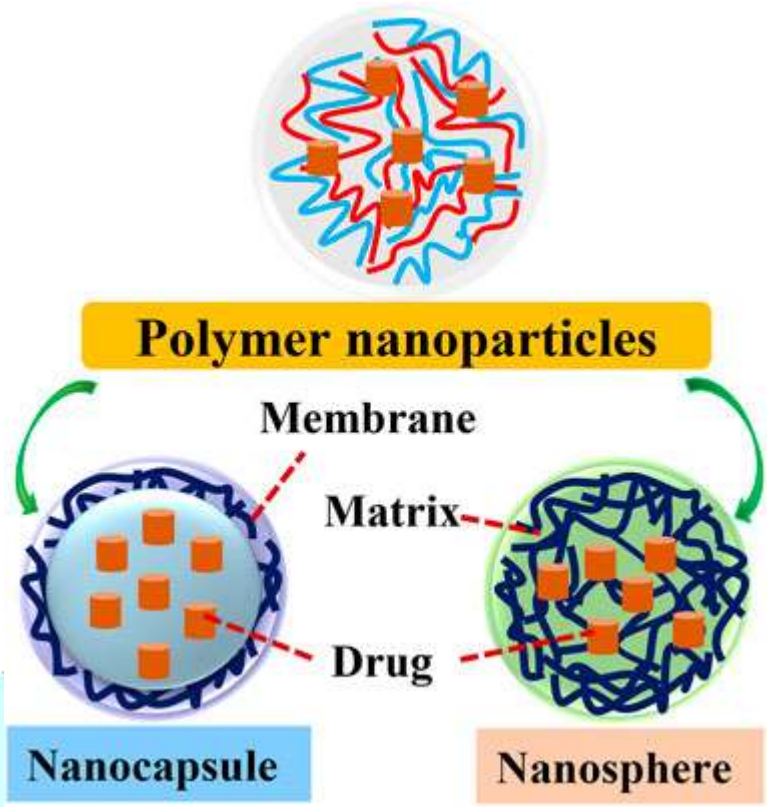

Fig.no:1 polymer nanoparticle[26]

Polymeric micelles:

Amphiphilic block or graft copolymers behave in ways similar to traditional amphiphiles. In solution, attaching a water-soluble polymer to a water-insoluble one enables micelle formation, giving these amphiphilic block copolymers distinctive structural and flow properties not found in either polymer alone. A primary difference between micelles formed by typical surfactants and those made by polymeric surfactants is that polymeric surfactants possess covalent bonds in their hydrophobic core. This covalent linkage prevents the exchange of monomers between the surrounding solution and the micellar phase, leading to increased stability and rigidity in the polymeric micelles.[27]The development of these supramolecular structures relies on a precise balance between strong covalent bonds linking the molecular components and reversible intermolecular forces that enable their organization. The size of polymeric micelles is affected by several factors, including the molecular weight of the amphiphilic block copolymer, the aggregation number of amphiphiles, the ratio of hydrophilic to hydrophobic segments, the amount of solvent retained in the micellar core, and the preparation method employed.[28,29]in water-based solutions, amphiphilic block copolymers can primarily self-organize into structures such as spherical micelles, worm-like or cylindrical micelles, and polymer vesicles (also called polymersomes). The main factor determining the morphology of these micelles is the hydrophilic-hydrophobic balance of the block copolymer, characterized by the hydrophilic volume fraction, f. For f values near 35%, polymer vesicles form, while values exceeding 45% result in spherical micelles. Other experimental factors affecting micelle structure include the degree of corona swelling, concentration, temperature, pH, ionic strength, and the specific method of preparation.

Attractive features of polymeric micelles:

The colloidal size of micelles makes them ideal for sterilization via simple filtration, eliminating the need for complex aseptic processing. The hydrophobic core of the micelle creates a domain that allows polymeric micelles to solubilize hydrophobic substances through hydrophobic and/or ionic interactions. Many poorly water-soluble drugs can be effectively incorporated into the micellar core, addressing solubility issues. Polymeric amphiphiles have attracted growing interest due to their distinctive physicochemical properties, water-based morphology, and potential to produce polymers suitable for various applications. These amphiphilic block copolymers can be synthesized with ease, offering control over factors such as block ratio,

molecular weight, chemical structure, and the ability to conjugate with biomolecules. The size and shape of polymeric micelles formed from these copolymers can be precisely adjusted by altering the structure of the amphiphilic copolymer. Key factors influencing micelle size include the molecular weight of the copolymer, the aggregation number of amphiphiles, the hydrophilic-to-hydrophobic chain ratio, the amount of solvent trapped in the micellar core, and the preparation method.[30]

Magnetic Nanoparticles:

In recent years, there has been growing interest in innovative materials within the field of nanotechnology. Magnetic nanoparticles, a subset of nanotechnology-based materials, have made a significant impact in areas such as analytical chemistry, biosensing, and nanomedicine. Nearly fifteen years have passed since Pankhurst and colleagues published their seminal review on magnetic nanoparticles in biomedicine. According to the Web of Science, over 50 reviews with the term "Magnetic nanoparticle" in their titles have been published in the last decade. The four main applications of magnetic nanoparticles and microparticles highlighted in their review have contributed to advancements in disease diagnosis and treatment: (i) Magnetic separation of biological entities played a role in improving diagnostic methods; (ii) Magnetic nanocarriers facilitated drug delivery; (iii) Radio frequency-controlled magnetic nanoparticles offered a new method for cancer treatment; and (iv) Magnetic resonance imaging (MRI) applications were enhanced. Furthermore, the functionalization and modification of nanoparticles with various biomolecules was already being explored at that time.[31-33]

The increasing number of scientific publications on magnetic materials highlights a growing interest in the field across the scientific community. Significant progress has been made in the development of magnetic materials with tailored sizes, shapes, chemical compositions, and surface chemistries. The stability of these materials, both physically and chemically, is achieved through coating. Furthermore, surface modifications with polymers, silica, biomolecules, and other materials can be engineered to enhance affinity for specific target molecules. The ability of these materials to respond to external magnetic fields, combined with the diverse range of available coatings, makes them versatile tools for the magnetic separation of small molecules, biomolecules, and cells. In biomedicine, magnetic particles and composites are used as drug delivery systems, MRI contrast agents, and in magnetic hyperthermia. Moreover, multifunctional magnetic particles that allow for both diagnosis and therapy simultaneously are emerging. This review summarizes recent advancements in the design and synthesis of magnetic materials for biomedical applications, with a focus on their use in separation, preconcentration of molecules and cells, and their roles in diagnosis and therapy.[34]

Carbon Nanotubes:

Carbon is an exceptionally versatile element with various allotropes and structures that exhibit different properties, thanks to its sp, sp2, or sp3 hybridization. These characteristics enable the creation of a wide range of structures, from just a few nanometers to several millimeters in size. Carbon nanomaterials, which can be synthesized and analyzed at the nanoscale, have become a central focus in nanotechnology. These materials possess unique attributes, such as a high specific surface area, excellent carrier mobility, enhanced electrical conductivity, flexibility, and optical transparency. As a result, they are used in diverse fields, including drug delivery, biosensing, molecular imaging, and tissue engineering. Carbon nanomaterials can be shaped into various forms, such as nanowires, 2D films, and various 3D structures. Examples include fullerenes, graphene, carbon nanotubes (CNTs), and their derivatives, including nanodiamonds, graphene oxide, and carbon-based quantum dots. The discovery of CNTs by Iijima in 1991 captured widespread attention due to their remarkable electrical, optical, thermal, and mechanical properties, making them one of the most significant inventions in nanotechnology. CNTs are composed of carbon atoms arranged in a hexagonal pattern, rolled into a tube structure, and consist of sp2 hybridized carbon atoms with a 1.4 Å interatomic distance. These hollow tubes, often referred to as buckytubes, have diameters in the nanometer range.[35-40]

Liposomes:

Drug delivery systems (DDSs) have the potential to improve the therapeutic effectiveness of drugs by enhancing their concentration, prolonging their duration in target cells, and reducing side effects. DDSs work by transporting the active drug to the target site using a nano-vehicle, which helps to improve the pharmacological properties of the drug while reducing its undesirable aspects. This is achieved by optimizing the drug's pharmacokinetics and biodistribution and serving as a drug reservoir. The size of these nanoparticles (NPs) typically ranges from a few nanometers to several hundred nanometers, depending on their intended purpose. NPs can be made from a variety of natural, organic, and inorganic materials, including ceramics, polymers, metals, and lipids, which form nanoparticle structures such as micelles and liposomes.

Therapeutic drugs are typically incorporated into nanoparticles (NPs) through physical interactions like entrapment, surface attachment, or encapsulation. The diverse properties and variations of these NPs can be utilized to enhance the effectiveness of traditional therapies. Nanomedicine offers the opportunity to create novel treatment options at the nanoscale, enabling the delivery of various active biomedical agents for the treatment, prevention, and diagnosis of numerous diseases.[41-49]

Nanoshells:

A nanoshell, also known as a nanoshell plasmon, is a spherical nanoparticle made up of a dielectric core covered by a thin metallic shell, usually gold. These nanoshells feature a quasiparticle called a plasmon, which is a collective excitation or oscillation of electrons relative to the ions. This oscillation is referred to as plasmon hybridization, where the energy of the oscillation depends on the interaction between the inner and outer shells. The result can be either a lower or higher energy state, with the lower energy state coupling strongly with incident light, while the higher energy state, which is anti-bonding, weakly couples with the light. The hybridization effect is stronger when the shell is thinner, meaning the shell thickness and overall particle size determine which light wavelength the nanoshell will interact with. Nanoshells can be tuned to interact with a broad spectrum of light, ranging from visible to near-infrared regions. The way light interacts with the nanoparticles affects the distribution of charges, which influences the strength of the coupling. When incident light is polarized parallel to the substrate, it causes s-polarization , pushing the charges further from the substrate surface and enhancing the interaction between the core and the shell. In contrast, p-polarization leads to a greater shift in plasmon energy, resulting in a weaker interaction and coupling.[50,51]

Ceramic Nanoparticles:

In recent years, nanoparticles have become a focal point in the development of novel drug delivery systems. Several types of nanosystems, such as nanoclays, scaffolds, and nanotubes, have been created, offering diverse applications in drug loading, targeted cell uptake, bioassays, and imaging. This study highlights various nanoparticle types, with a particular focus on ceramic nanocarriers. Ceramic materials are valued for their high mechanical strength, biocompatibility, and minimal biodegradability. The article delves into the advantages of ceramic nanoparticles over other systems, examining their cellular uptake and addressing concerns related to their potential toxicity.

Nanotechnology stands as one of the most groundbreaking innovations of this decade, impacting the fields of medicine, technology, and pharmaceuticals. This fast-growing field focuses on the development of synthetic materials within the 5–200 nm size range. Nanotechnology involves systems where structures and components exhibit unique properties at the nanoscale, typically smaller than 100 nm (< 10–7 m). The small size, structural flexibility, highly reactive surfaces, and distinct physical and chemical characteristics of nanomaterials, along with their ease of modification, make them excellent candidates for drug delivery and controlled release systems. The integration of nanotechnology in medicine has given rise to nanomedicine, an interdisciplinary area with vast potential for treating a wide range of diseases. Nanomaterials have already made a clinical impact, particularly in the targeted delivery of bioactive molecules, including therapeutic agents, nucleic acids, and imaging contrast agents.[52-54]

Nanopores:

Fluid mechanics focuses on the study of fluid flow through macroscopic channels and is applicable to various fields in engineering and biology. In contrast, recent years have seen a rapid growth in the exploration of transport phenomena within microscopic channels, or nanopores, with sizes ranging from 1 nm to 100 nm. These nanoscale systems were originally found in biological membranes of organelles, cells, and organs, where they play essential roles in controlling the transport of ions and molecules. This regulation is crucial not only for maintaining physiological conditions but also for signal transduction that enables various biological processes.[55]

ADVANTAGES OF NANOPARTICLES:

1. Easy preparation process.

2. Targeted drug delivery.

3. Due to their small size, nanoparticles can easily pass through tiny capillaries and be absorbed by cells, facilitating efficient drug delivery to the intended sites in the body.

4. Excellent control over particle size and distribution.

5. Effective protection of the encapsulated drug.

6. Drug retention at the site of action.

7. Prolonged clearance time.

8. Improved therapeutic effectiveness.

9. Higher bioavailability.

10. Dosing proportionality.

11. Stable drug formulations that would otherwise be unstable or have low bioavailability in non-nanoparticulate forms.

12. Increased surface area leads to quicker dissolution of active compounds in water.

13. Faster dissolution generally results in higher bioavailability.

14. Reduced drug dosage requirements.

15. Decreased toxicity.

DISADVANTAGES OF NANOPARTICLES:

1. The common use of polyvinyl alcohol as a detergent raises toxicity concerns.

2. Limited effectiveness in targeting specific sites.

3. Discontinuing treatment is not an option once initiated.

4. Possible cytotoxic effects.

5. Risk of causing pulmonary inflammation and potential carcinogenicity.

6. Inflammation in the alveoli.

7. Nanoparticles may disrupt autonomic balance, directly affecting heart and vascular functions.

CONCLUSION:

Nanoparticles are seen as a promising drug carrier for various drug delivery systems. Nanotechnology is a revolutionary field that is continuously expanding, with new applications being explored globally. Nanoparticles help address the solubility and bioavailability issues of drugs, making them suitable for use with poorly soluble medications. Transforming a drug into nanoparticle form can increase its saturation solubility, dissolution rate, and generally improve its adhesion to surfaces. Nanoparticulate drug delivery systems are increasingly recognized as an advantageous solution for biological drugs. Additionally, nanoparticles enable efficient treatments by allowing for targeted and controlled drug release, making them a promising strategy for the biopharmaceutical industry moving forward.

Acknowledgement: The author would like to thank Miss.Ashwini A.Wakade,Mr.Babasaheb L. Chopade,Dr.Megha T. Salve,Dr.Abhijeet R. Shete and all persons directly or indirectly involved in the preparation of this article.

REFERENCES:

1. Birrenbach G. and Speicer R.(1976) J. Pharm. Sci..65,1763.
2. Vila A, Sanchez A, Tobio M, Calvo P, Alonso MJ. Design of biodegradable particles for protein delivery. J Control Release 2002; 78: 15-24.
3. Mu L, Feng SS. A novel controlled release formulation for the anticancer drug paclitaxel (Taxol(R)): PLGA nanoparticles containing vitamin E TPGS. J Control Release 2003; 86: 33-48.
4. Akerman ME,chan WC,LAAKKOEN P,Bhatia SN, Nanocrystal targeting in-vivo. Proc Natl ACade Sci USA 2002; 99:12617-21
5. Marzola P et al. Invitro and Invivo study of SLN Loaded with perparamagnetic ironoxide.J drug target 2003,1924.
6. Desai M.P. et al. GIT Uptake of Biodegradable Microparticles. Pharma RES 1996,13,1838-45.
7. Nishiyama N et. al. Polymeric micelle drug carrier system. Adv Exp Med Biol 2003,519,155-77.
8. Quintana A,Piechler I, et.al .Design and function of a dendrimer-based therapeutic nanodevice targeted through the folate receptor. Pharma Res.2002;19:1310-16.
9. Ayutlede J,Gandhi M ,et.al. Carbon nanotube reinforced bombyx morisilk nanofibres by the electrospinning process Biomacromolecules 2006;7:208-14.
10. Allel TM .Liposomes :Opportunities in drug delivery .Drugs1997;57:8-14.
11. Thomas M, Kilbanov AM. Conjugates to Gold Nanoparticles Enhances Polyethyenimines Transfer to Plasmid DNA into Mammalian Cells. Proc Natl Acad Sci USA 2003;100:9138-43
12. Cherian AK,Rana AC , Jain S K.; Self-assembled carbohydrate –stabilized ceramic nanoparticles for the parentral delivery of Insulin Drug Dev. Indian Pharma., 2000; 26:459-63.
13. Smeets RM., Dekker NH., et. al, Dependance of Ion transport and DNA translocation through solid state nanopores.Nano-Lett.2006;6:89-95.
14. Kataoka K., Harada., et. al. Nanoelecronics Nano Lett 2001;519:155-177.
15. Chan WC, Maxwell DJ et.al. Luminescent Quantum Dots for Multiplexed Biological Detection and Imaging . Curr Opin Biotechnol 2002;13:40-46.
16. Donald T.Haynie.Polypeptide multilayer nanofilms in drug delivery. Pharma Tech Drug Delivery 2008;S6-S10.
17. Babincova M, Babinnec P. High Gradient Magnetic capture of Ferrofluids :Implication for drug targeting and tumor immobilization Z . Naturforsh 2001;56:909-11
18. Zhang J., Xie Z., Zhang N., Zhong J. Nanosuspension Drug Delivery System: Preparation, Characterization, Postproduction Processing, Dosage Form, and Application. Elsevier Inc.; Amsterdam, The Netherlands: 2017. pp. 413–443.
19. Müller R.H., Olbrich C. Medicament Vehicle for the Controlled Administration of an Active Agent, Produced from Lipid Matrix-Medicament Conjugates. No. WO2000067800A2. Germany Patent. 2000 November 16;

20. Keck C.M., Müller R.H. Drug nanocrystals of poorly soluble drugs produced by high pressure homogenisation. Eur. J. Pharm. Biopharm. 2006;62:3–16.
21. Pignatello R, Bucolo C., et. al., Nanosuspensions for the ophthalmic controlled delivery of ibuprofen ,Eur .J.Pharma. Sci,2002;16(1-2),53-61.
22. Bouwstra J.A., Honeywell-Nguyen P.L, M. Ponec ., G.S. Gooris, Structure of the skin barrier and its modulation by vesicular formulations, Prog Lipid Res, 42 :2003, 1-36.
23. Muller R.H., Mader K. , Gohla S., Solid lipid nanoparticles (SLN) for controlled drug delivery - a review of the state of the art, Eur J Pharm Biopharm, 50 : 2000, 161-177.
24. Siekmann B., Westesen K., Investigations on solid lipid nanoparticles prepared by precipitation in o/w emulsions, Eur. J. Pharm. Biopharm, 42 (1996) 104 109.
25. Akerman ME ,Chan WC et.al., Nanocrystals Targrtting in vivo, Proc Natl Acd Sci. USA 2002;99:12617-21
26. https://in.images.search.yahoo.com/search/images;_ylt=Awrx_9GsnjBnTAIAaeq7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3BpdnM-?p=polymeric+nanoparticles+reviews&fr2=piv-web&type=E210IN826G0&fr=mcafee#id=5&iurl=https%3A%2F%2Fwww.frontiersin.org%2Ffiles%2FArticles%2F1097205%2Ffchem-10-1097205-HTML%2Fimage_m%2Ffchem-10-1097205-g001.jpg&action=click
27. Hickok , RS , Wedge , SA , Hansen , AL , Morris , KF , Billiot , FH and Warner , IM . 2002 . Pulsed field gradient NMR investigation of solubilization equilibria in amino acid and dipeptide terminated micellar and polymeric surfactant solutions . *Magnetic Resonance in Chemistry* , 40 : 755 – 761 .
28. Jones , MC and Leroux , JC . 1999 . Polymeric micelles a new generation of colloidal drug carriers . *European Journal of Pharmaceutics and Biopharmaceutics* , 48 : 101 – 111 .
29. Trubetskoy , VS and Torchilin , VP . 1996 . Polyethyleneglycol-based micelles as carriers for delivery of therapeutic and diagnostic agents . *STP Pharma Sciences* , 6 : 79 – 86 .
30. Zarafshani , Z , Akdemir , O and Lutz , JF . 2008 . A ‘‘click’’ strategy for tuning in situ the hydrophilic-hydrophobic balance of AB macrosurfactants . *Macromolecular Rapid Communications* , 29 : 1161 – 1166 .
31. Pankhurst Q.A., Connolly J., Jones S.K., Dobson J. Applications of magnetic nanoparticles in biomedicine. J. Phys. D Appl. Phys. 2003;36:167–181.
32. Katz E., Willner I. Integrated nanoparticle-biomolecule hybrid systems: Synthesis, properties, and applications. Angew. Chem. Int. Ed. 2004;43:6042–6108.
33. Brigger I., Dubernet C., Couvreur P. Nanoparticles in cancer therapy and diagnosis. Adv. Drug Deliv. Rev. 2002;54:631–651.
34. https://pmc.ncbi.nlm.nih.gov/articles/PMC5618354/#sec1-nanomaterials-07-00243
35. Speranza G (2021) Carbon nanomaterials: Synthesis, functionalization and sensing applications. Nanomaterials.
36. Tiwari SK, Pandey R, Wang N et al (2022) Progress in diamanes and diamanoids nanosystems for emerging technologies. Adv Sci.
37. Patel KD, Singh RK, Kim HW (2019) Carbon-based nanomaterials as an emerging platform for theranostics. Mater Horiz 6(3):434–469.
38. Tiwari SK, Kumar V, Huczko A, Oraon R, de Adhikari A, Nayak GC (2016) Magical allotropes of carbon: prospects and applications. Crit Rev Solid State Mater Sci 41(4):257–317.
39. Sadegh H, Shahryari-Ghoshekandi R (2015) Functionalization of carbon nanotubes and its application in nanomedicine: a review 1, 2. Nanomed J 2(4):231–248.
40. Rauti R, Musto M, Bosi S, Prato M, Ballerini L (2019) Properties and behavior of carbon nanomaterials when interfacing neuronal cells: How far have we come? Carbon N Y 143:430–446
41. Kim B.Y., Rutka J.T., Chan W.C. Nanomedicine. N. Engl. J. Med. 2010;363:2434–2443.
42. Allen T.M., Cullis P.R. Drug delivery systems: entering the mainstream. Science. 2004;303:1818–1822.
43. Khater D., Nsairat H., Odeh F., Saleh M., Jaber A., Alshaer W., Al Bawab A., Mubarak M.S. Design, preparation, and characterization of effective dermal and transdermal lipid nanoparticles: a review. Cosmetics. 2021;8

44. Yezhelyev M.V., Gao X., Xing Y., Al-Hajj A., Nie S., O'Regan R.M. Emerging use of nanoparticles in diagnosis and treatment of breast cancer, the Lancet. Oncology. 2006;7:657–667.
45. Sahoo S.K., Labhasetwar V. Nanotech approaches to drug delivery and imaging. Drug Discov. Today. 2003;8:1112–1120
46. Nsairat H., Khater D., Odeh F., Al-Adaileh F., Al-Taher S., Jaber A.M., Alshaer W., Al Bawab A., Mubarak M.S. Lipid nanostructures for targeting brain cancer. Heliyon. 2021;7
47. Celia C., Paolino D., Santos H.A. Advanced nanosystems for clinical translation. Adv. Ther. 2021;4:2000215
48. Haley B., Frenkel E. Nanoparticles for drug delivery in cancer treatment. Urol. Oncol. 2008;26:57–64.
49. Doane T.L., Burda C. The unique role of nanoparticles in nanomedicine: imaging, drug delivery and therapy. Chem. Soc. Rev. 2012;41:2885–2911
50. *Loo, C; Lin, A; Hirsch, L; Lee, Mh; Barton, J; Halas, N; West, J; Drezek, R (February 2004). "Nanoshell-enabled photonics-based imaging and therapy of cancer"*
51. Brinson, Be; Lassiter, Jb; Levin, Cs; Bardhan, R; Mirin, N; Halas, Nj (November 2008)
52. Rawat M, Singh D, Saraf S, Saraf S. 2006. Nanocarriers: Promising vehicle for bioactive drugs. Biol Pharm Bull. 29:1790–1798.
53. Ferrari M. 2005. Cancer nanotechnology: opportunities and challenges. Nat Rev Cancer 5:161–171.
54. Sakamoto JH, van de Ven AL, Godin B, Blanco E, Serda RE, Grattoni A, et al. 2010. Enabling individualized therapy through nanotechnology. Pharmacol Res. 62:57–89.
55. https://www.nature.com/articles/s41427-021-00313-z