Review Article

Nanoparticles for Drug Delivery Systems

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ABSTRACT

Nanotechnology is one of the fastest growing technology that is being explored and utilised all over the world for research and development. One such application where nanotechnology is progressing is, its use in drug delivery systems in the form of Nanoparticles (NP). Nanoparticles are the particles whose size range is in between 1-100 nm. These particles size since being very fine, they have larger surface area which can be used as carriers for targeting drugs to specific sites in the body, thereby providing precise drug activity. These Nanoparticles because of its unique physical, chemical and physiological properties are being used widely for various commercial, therapeutics and drug discovery process. They can be classified into various types based on its size & shape like Metallic NPs, Semiconductor NPs, Carbon based NPs, Polymeric NPs, Dendrimers, Liposomes, Ceramic NPs and others. These nanoparticles find its applications in treatment of various diseases like Cancer, bone growth enhancers, in cosmetics, as well as they have the potential to cross the blood brain barrier and treat site specific disorders. Although NPs provide with wide range of applications in drug delivery systems, they also come with their own risks like slow biodegradability and thus result in systemic toxicity. Nevertheless, the benefits they provide surpass the risks associated with them, thus making it one of the potentials for novel approaches in developing various drug delivery systems. All the mentioned above would be discussed in this review article about Nanoparticles - An application of Nanotechnology in Drug delivery systems.

Keywords: Nanoparticles, Nanotechnology, Applications of Nanoparticles, Types of nanoparticles.

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INTRODUCTION

The major challenge in the treatment of many diseases is the delivery of therapeutic medicament to the desired site. Controlling drug delivery techniques, have the potential to bypass these restrictions for instance, by carrying medications to the site of action utilising Nanoparticles.[1] Nanoparticles are the ultrafine, colloidal, non-biodegradable particles whose

size range from 10 to 1000 nm. This small size of nanoparticles serves an advantage over their conventional counterparts for having less point defects. Nanotechnology is the study of particles ranging in size from 10^{-9} to 10^{-7} meters. In addition, it is the science of material and devices whose structure and composition exhibit new and significantly altered physical, chemical and biological phenomenon due to their nanoscale dimensions. Thus, nanotechnology can be defined as the manipulation of matter at the atomic level, and application of such material by altering their design and physio-chemical characteristics. Nanoparticles deliver the drug to a particular site or organ that helps in minimizing the side effects and reduces the dosage and dosage frequency of the therapeutic agent. The use of nanotechnology aids in achieving site-specific pharmacological action at a therapeutically appropriate rate and dosing regimen.[2] Nanoparticles are appealing because of crucial and unique features such as their surface to mass ratio, which allows for catalytic enhancement of reactions, and their ability to absorb. Biodegradable nanoparticle formulations are required for drug delivery as the drug must be transported and released in order to be effective. A magnetic nanoparticle that can be drawn to a specific part of the human body by a magnetic field can be an excellent drug delivery system. Drugs which have very low solubility when formulated as conventional dosage forms, have a variety of biopharmaceutical drawbacks, such as limited bio availability, less diffusion capability into the outer membrane, higher dose requirements when given through intravenous routes, and various side effects. All of these constraints, however, could be solved with the use of nanotechnology in drug delivery.

Advantages of nanoparticles in drug delivery system [3]

- Nanoparticles are biodegradable, non-toxic, and can be stored for an extended period of time.
- To achieve site-specific targeting for decreasing the accumulation of drug in healthy tissues, targeting ligands can be added to the surface of nanoparticles or magnetic guidance can be utilised.
- They control and sustain drug release during transit and at the site of localisation, modifying drug organ

distribution and subsequent clearance in order to obtain increased medication therapeutic efficacy and reduced side effects.

- They aid in the enhancement of therapeutic efficacy by extending the half-life of pharmaceuticals, boosting the solubility of hydrophobic medications, lowering possible immunogenicity, and releasing drugs in a sustained or stimuli-triggered manner.[4]
- Transportation of drugs becomes easier across the cell barriers.
- Fine nanoparticles are less likely to cause blockages in even the smallest vessels and less likely to exhibit a form of sedimentation.
- Penetration is easier, nanomaterials can be also be used primarily as carrier vehicles.

Types of Nanoparticles

Nanoparticles can be classifies into different types based on their size, shape and physio-chemical characteristics. The following are a few of them

Metallic Nanoparticles :[5] Metallic nanoparticles are metals having dimensions (length, breadth, and thickness) between 1 and 100 nanometres. Submicron-sized metal or metal complex particles (for example, gold, platinum, silver, titanium, zinc, cerium, iron, and thallium) are known as metal nanoparticles (e.g., oxides, hydroxides, sulphides, phosphates, fluorides, and chlorides) Quantum dots, gold nanoparticles, and magnetic nanoparticles are examples of metallic nanoparticles that have therapeutic value as drug carriers. Quantum dots, gold nanoparticles, and magnetic nanoparticles are examples of metallic nanoparticles that have therapeutic use as drug delivery systems. Metallic nanoparticles, such as quantum dots, gold nanoparticles, and magnetic nanoparticles, offer a therapeutic advantage as drug carriers. Gold nanoparticles are non-toxic and inert, with a gold core and a size of less than 150 nanometres. A mixed monolayer of a zinc phthalocyanine and a lactose derivative was used to create gold nanoparticles and functionalize them. When phthalocyanine-gold nanoparticles were functionalized with lactose, water-dispersible nanoparticles were created that can generate singlet oxygen and cause cell death when irradiated. Quantum dots or artificial atoms are nanoparticles with a distinct discrete electronic energy level; most commonly, but not always, they are made up of conventional semi conductive materials. Semiconductor quantum dots are nanometre-sized crystals having photochemical and photophysical capabilities not found in isolated molecules or bulk solids. They are spherical nanocrystals with diameters ranging from 1 to 10 nm. Other shapes of semiconductor nanocrystals, such as rods and tetrapods, can be made, however spherical quantum dots are the most extensively employed for biological purposes. Among the many known nanomaterials, those in which isolated magnetic nanoparticles (magnetic molecule clusters) are divided by a dielectric nonmagnetic medium have a unique place. The gigantic magnetic pseudo atoms in these nanoparticles have a large overall magnetic moment and “collective spin”. The domain structure of nanoparticles distinguishes them from traditional magnetic materials in this aspect.

Carbon based nanoparticles[6]**:** Carbon-based or carbon nanoparticles are all nanomaterials made up of carbon atoms. They were thought to be 10 nm carbon-based nanoparticles, either crystalline or amorphous. Until recently, several studies depicted CNPs as a collection of structures with identical or overlapping emission. They are now thought to be a combination of fluorophores responsible for the luminescent qualities, or a low-luminescent carbon matrix modified with molecular fluorophore (s). Carbon-based materials have recently become prized due to the existence of diverse allotropes of carbon, ranging from well-known allotropic phases such as amorphous carbon, graphite, and diamonds, to the recently discovered promising carbon nanotubes (CNTs), graphene oxide (GO), graphene quantum dots (GQDs), and fullerene.

Polymeric Nanoparticles[7]**:** Instillation of cationic and hydrophobic parts in the chains of synthetic polymers makes them antimicrobial. Former moiety aids the contact with negatively charged bacterial cell wall whereas the latter moiety ease the membrane penetration of the microbe. Polymer Micelles are the core-shell Nanoparticles formed by the Block Co-Polymers after they assemble on their own, which has both hydrophilic and hydrophobic parts. Polymersomes or polymer vesicles are the polymeric Nanoparticles made from the covalently connected homopolymer blocks that gives block copolymers with both hydrophobic and hydrophilic characters, that are enclosed in the system with inner hollow compartment enclosed in a membrane with two layers. Unlike, self - assembled Block Polymers, Core Star Polymer Nanoparticles are the Unimolecular particles attached with the covalent bond to each other. This has a 3D globular structure consisting of a core attached with the linear chains around it giving it a branched

appearance.

Dendrimers [8]**:** Dendrimers are Polymeric in nature, with a core consisting of atom or group of atoms from which the branches of other atoms called ‘dendrons’ arise by chemical reactions. The dendrimers have –

- Core
- Number of circular rings with branch points known as generations
- End or peripheral or terminal groups.

Larger Dendrimers with more than three generations are globular. The solubility of dendrimers, responsible for many of its applications in drug delivery, attributes to the large number of peripheral groups.

Liposomes[9]: These are lipid Based vesicles, spherical in shape, ranging from 30nm to micrometres are produced from hydration of the non-toxic, dry phospholipids. Liposomes are classified according to their average size and number of bilayers., into

- Multilamellar Vesicles- Contains numerous lipid bilayers divided by the aqueous space
- Unilamellar Vesicles- has only one lipid bilayer enclosing the aqueous space.

Unilamellar are again two types based on size,

- Large Unilamellar vesicles with a diameter more than 100nm
- Small Unilamellar vesicles- diameter less than 100nm.

Liposomes are believed to follow any (more than one can be followed at the same time) of the four mechanisms for drug delivery.

- By Adsorption on cell surface components
- Endocytosis by macrophages or neutrophils
- Induce the lipid bilayer of the liposome into the plasma membrane to
- release the entrapped drug directly into the cytoplasm.
- Counter current mechanism between contents of the liposome and the
- contents of cell Membrane.

Ceramic Nanoparticles[10]: These are the inorganic metalloid Solids made up of silica, Titania and alumina. These NPs are broadly used for the protein or peptide delivery as they provide protection against the swelling and porosity effects caused by external pH and temperatures. Most of the Ceramic NPs are acid sensitive, so they're coated with the enteric polymers to combat with the acidic pH in the stomach. These NPs follow either phagocytosis or endocytosis for induction into cells, followed by the disruption of the endosomal membrane for the release of proteins/peptides into cytoplasm.

Applications of Nanoparticles

The applications of nanotechnology in the medical aspects and more particularly to the targeted drug delivery are set to increase swiftly.

- The usage of nanoparticles for drug delivery supplies the development of enhanced therapies with targeted delivery and lesser side effects.[11]
- The use of nanoparticles - particles that are 100nm smaller than human cells - enables nanotechnology to locate and kill cancer cells more accurately than other cancer treatments.[12]
- In a targeted drug delivery system, Nanotechnology can be applied in improving the uptake of poorly soluble drugs and the bioavailability of drugs at the site of disease.
- The incorporation of Nanotechnology in a cosmetic formulation is an emerging technology that is helpful in various aspects. Cosmetic preparations use the nanoscale size of ingredients to dispense deeper penetration into the skin, UV protection, long-lasting effects, increased colour, finished quality, and many more.
- Nanomaterials reflects the nano-features of bones and provides the special roles are promising for better bone fracture repair.
- Nano coatings allow the use of largely insoluble drugs or potentially ones with greater activity or even toxicity. Coatings that have been explored can be quite thin - only several nanometres thick. [13]
- In coronary artery diseases, nanomedicines can be used as accurate therapy at cellular levels.
- Nanotechnology is also applied to new dental composites.
- Now-a-days, toothpastes and mouthwash solutions also apply nanotechnology advancements as nano-calcium fluoride reduces caries activity, reduces the permeability of dentine, and increases labile fluoride in oral fluid when added to mouthwash products.
- Numerous types of antimicrobial polymer coatings, composites and nanocomposites are used in bioinformatics applications.
- The surface of numerous metallic implants may be modified with nanomaterial coatings in order to provide them with orthopaedic applications.

Disadvantages of Nanoparticles [14]

In the pharmaceutical sciences, nanoparticles may be used to improve drug efficacy and decrease toxicity, but until recently they are not aware that the carrier systems may also associate risk to the patient.

- Nanotechnology is a highly cost consuming and laborious process.
- It requires highly qualified engineers and workers, causing additional concerns.
- The biotransformation of polymers results in toxic metabolites on repeated administration.
- Despite being relatively slow degradable, polymeric nanoparticles can cause systemic toxicity.
- Dental implants may cause a hypersensitivity reaction.
- Owing to their small size and huge surface area, nanoparticles can cause particle-particle

agglomeration, making physical handling of them in liquid and dry forms challenging and thus results in limited drug loading and burst release.

CONCLUSION

As discussed above, Nanoparticles offer a wide range of advantages and applications. But the best advantage and reason for its widespread use in drug delivery system is, that it offers to modify the size of already existing compounds/drugs into nano range, thereby decreasing the need for new drug molecule discovery and increasing their drug activity compared to the already existing moieties by increasing the surface area, which increases its solubility in body fluids there by enhancing the drug effect. Nanoparticles would definitely be the future of drug delivery systems owing to their plethora of applications like drug carriers and targeting specific sites in the body which would increase the bio availability and patient compliance, reduces the side effects. Though they have a bounty of advantages, it comes with its drawbacks like high cost and time consuming process, slow bio degradability, systemic toxicity which needs further research to minimise the same and make it easily and safely available for future generations.

REFERENCES

1. Bhatia.S, Natural Polymer Drug Delivery Systems. Switzerland: Springer International Publishing; 2016.
2. Wim De Jong H, Paul Borm JA .Drug delivery and nanoparticles: Applications & hazards. International Journal of Nanomedicine 2008; 3(2): 133-149. DOI - 10.2147/IJN.S596; PMID: 18686775.
3. Velavan.P, Karruppusamy.C, Venkatesan.P. Nanoparticles as Drug Delivery Systems. Journal of Pharmaceutical Sciences and Research 2015; 7(12):1118-1122.
4. Wechsler M.E, Vela Ramirez J.E, and Peppas N.A. Nanoparticles Mediated Drug Delivery for the treatment of Alzheimer's disease: crossing the blood-brain barrier. Industrial Engineering and Chemistry Research 2019; 58: 15079-15087. DOI:10.1021/acs.iecr.9b02196; PMID :32982041
5. Saba Hasan. A Review on Nanoparticles: Their Synthesis and Types. Research Journal of Recent sciences, 2015; 4:1-3.
6. Rajora A.K, Ravishankar.D, Osborn H.M.I, Greco.F. Impact of the enhanced permeability and retention (EPR) effect and cathepsins levels on the activity of polymer-drug conjugates. Polymers 2014; 6: 2186-2220.DOI:10.3390/polym6082186.
7. Lam Shu J, Wong Edgar HH, Boyer Cyrille, Qiao Greg G. Antimicrobial Polymeric Nanoparticles. Progress in Polymer Science, 2018; 76:40-64.DOI: 10.1016/j.progpolymsci.2017.07.007.
8. Lee C., MacKay.J, Fréchet, Szoka J.C. Designing dendrimers for biological applications. Nature Biotechnology, 2005; 23:1517–1526. DOI: 10.1038/ nbt1171.
9. Akbarzadeh. A., Rezaei-Sadabady.R, Davaran, Sang Woo Joo, Nosratollah Zerghami Y, Hanifehpour, Samiei.M, Kouhi.M, Koshki K.N. Liposome: classification, preparation, and applications. Nanoscale Research Letters, 2013; 8: 102. DOI: 10.1186/1556-276X-8-102.
10. Deependra Singh, Pooja Dubey, Madhulika Pradhan, Manju Rawat Singh. Ceramic nanocarriers: versatile Nano system for protein and peptide delivery. Expert Opinion on Drug Delivery, 2013; 10(2): 241-259. DOI: 10.1517/17425247.2012.745848.
11. Swartejas, J.J.T.M, Sharma P.K, Kooten, Mei T.G.V, Mahmoudi M, Busscher H.J, Rochford E.T.J. Current Developments in Antimicrobial Surface Coatings for Biomedical Applications. Current Medicinal Chemistry, 2015; 22: 2116–2129. DOI: 10.2174/0929867321666140916121355.PMID-25245508.
12. National Cancer Institute- Benefits of Nanotechnology for Cancer. [Internet] [Updated 2017 Aug 8] Available from: https://www.cancer.gov/nano/cancer-nanotechnology/benefits.
13. Farrokhzad O.C, Langer. Impact of Nanotechnology on Drug Delivery. *American Chemical Society, 2009; 3(1)*: 16-20. DOI: 10.1021/nn900002m.
14. Walker N, Bucher J. A. 21st century paradigm for evaluating the health hazards of nanoscale materials. Toxicological Sciences, 2009; 110(2): 251-254. DOI-10.11093/toxsci/kfp106.

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