Review Article **Nanotechnology**

International Journal of Pharma and Bio Sciences

ISSN
0975-6299

ADVANTAGES OF VARIOUS APPROACHES BY USING DIFFERENT NANOPARTICLES IN DRUG DELIVERY

CHANDRA KANT SHARMA, KARISHMA SHARMA, ARCHANA SHARMA, MONIKA SHARMA*

Department of Bioscience and Biotechnology, Banasthali University,
P.O. Banasthali Vidyapith, Rajasthan, India-304022

ABSTRACT

The emerging applications of nanotechnology in medical field and more precisely in the delivery of drug has been reported in various area of research that includes pharmaceutical sciences which are utilizing nanoparticles in order to minimize the toxic effects as well as side effects of the doses of drugs and their potential improvements by increasing the biocompatibility of nanoparticles in order to intensify the diagnostic as well as therapeutic moieties in to diseased cells with higher efficacy. Specifically at atomic, molecular and supramolecular scale it exhibit fundamentally new properties. Incorporating the prodrugs in to nanotechnology based carrier combines the methods of developing drug invasion and their biocompatibility. Various nanostructure including liposome's polymers, dendrimers, silicon or carbon material have been detected as well as tested as carriers in drug delivery system. The modern form of approaches are most important when there is inconsistency together with dose and the strength of a remedy in order to understand the extent of transfer of drug from plasma to target region. Cell specific targeting can be achieved by adding the preparations to separately intended transporters.

KEYWORDS: ***Drug delivery; Dendrimers; Liposomes; Nanoparticles; Organic nanoparticles.***

MONIKA SHARMA*

Department of Bioscience and Biotechnology, Banasthali University,
P.O. Banasthali Vidyapith, Rajasthan, India-304022

Received on: 21-07-2017
Revised and Accepted on: 21-09-2017
DOI: http://dx.doi.org/10.22376/ijpbs.2017.8.4.p131-138

INTRODUCTION

The scientific and tremendous approaches of nanoparticles in the biomedical area of research and its precise role in the drug delivery in order to deliver the therapeutic drug have demonstrate it as a new targeting tool for the treatment of various disease[1]. 'Nanotechnology is the technology to facilitate controlled implications and widely utilized for the manufactures of structures and devices at atomic or molecular scale'[2]. The nanosized objects termed as nano particles, its unique properties as well as roles can vary remarkably from those objects which are prepared of alike material[3]. Unique mechanism of nano particles allowed to act together with complicated cellular purposes in various approaches, on the basis of its tiny size, enhanced solubility, personalized surface, multifuctionality of nano particles have ensured its promising result in the area of medicines. It has been investigated that not only biotechnology also the pharmaceutical sciences are using nano particles in order to reduce the toxicity and side effects of drugs, medicine is transported to the site of accomplishment, for this reason its effect on essential tissue furthermore fatal consequences could be diminished by involving controlled drug delivery system[4]. Various nanostructure including liposome's polymers, dendrimers, silicon or carbon material have been detected as well as tested as carriers in drug delivery system[5]. The recent mode of approaches is extremely valuable when there is disagreement involving dose and the drug's concentration in order to understand the extent of transfer of drug from plasma to target region. Cell specific targeting can be accomplished by nailing the medicines to separately intended carriers[6]. Latest trends of nanotechnology have determined that nano particles constructs lesser than 100 nm at least one dimension, because of its minute dimensions its nanostructures demonstrate distinctive physicochemical as well as biological belongings that have improved its efficacy along its utilization in biomedical applications and several research area that depicts the role of nanotechnology[7]. According to the definition from NNI (National Nanotechnology Initiative) nanostructures or nano particles resemble of size ranging from 1 to 100 nm in at least one dimension[8] The mode of conjugating the preparation to the nanocarrier besides the tactic which entails its targeting is extremely emphasized for intracellular drug delivery treatment for bioactivity, here the medicine may be adsorbed or covalently attached to a nanocarrier exterior or it can be encapsulated into it[9]. Cell specific targeting with nanocarriers conjugated to the concerned location by using detected ligands attached to the outside of conjugated antibodies, low molecular ligands e.g. peptides, folic acids etc.[10] Passive targeting involves the enhances permeability and retention effects that facilitate targeted drug delivery as drug carriers are expected to stay for long time, accumulation will be done at pathological site of action with affected leaky vasculatures (tumour, inflammation etc). The core objective of nano particles is to control and implicate bimolecular construct and supramolecular assemblies in order to improve quality of human health[11]. Nanocarriers used for biomedical applications have to be biocompatible (ability to integrate with a biological system in a synchronized mannered without eliciting immune response. It has been analyzed that nano particles in the form of nanocarriers are employed so that it can improved the pharmacokinetics of loaded poorly dissolved hydrophobic drugs by dissolving them in hydrophobic compartments[12].

DRUG DELIVERYAND NANOPARTICLES

The liberation of drug as well as analogous pharmaceutical development in connection with nano medicine could be understood as science and technology of nano meter scale (10 to 1000 nm)[13]. The total system leads to certain functions with respect to its treatment, prevention, and diagnosing the disease known as smart drug delivery system. The scientific approaches of drug delivery through nanoparticles include[14].

1. More precise drug delivery and drug targeting,
2. Minimization in toxicity by maintaining therapeutics effects,
3. Larger safety and its biocompatibility,
4. They have capability to integrate with the biological system without eliciting immune response,
5. Smaller particles have larger surface area, they are more reactive,
6. Smaller particles are manipulated to tissue extravasations and renal clearance etc.

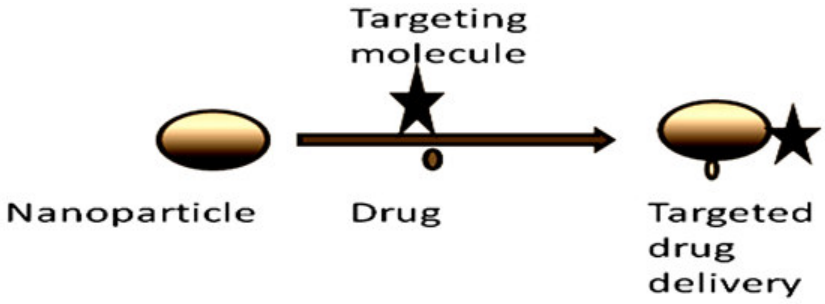

Figure 1
Drug delivery through nanoparticles.

ORGANIC NANOPARTICLES

One of the main as well as significant aspects of nanotechnology tools for product improvement is the prospect to convert accessible drug and with inadequate water solubility, rate of dissolution in to swiftly water soluble dispersion by changing them in to nano-sized

drugs[15]. Liposomes are the largely clinically customary nanosystem for several remedial liberation approaches their effectiveness could be understood by reducing systemic effects as well as toxicity; drug is incorporated in the liposome by the encapsulation process[16]. The release of drugs from liposomes depends on the composition of liposome's, pH, and osmotic gradient and surrounding environment. There are lot of examples to illustrate liposomal formulations with the help of drugs such as anticancer drugs, neurotransmitter, antibodies etc. liposome also having some limitations as its deplete encapsulation competence, rapid spurt discharge of drugs, poor shortage ability etc.[17] Designing of liposomes have controlled over the release and drug bio availability. The discharge of medicines from liposome's approachable polymers or hydro gel is subjected to drastic changes in their pH, temperature, radiofrequency or magnetic field[18]. It has been investigated that liposome's increases the solubility of drugs and also tends to increases upon their pharmaceutical co-kinetic property such as, therapeutic index of chemotherapeutic drugs, rapid metabolism and reduction of harmful side effects, increases of in vitro & in vivo cancer activity. The multi functionality of liposome's containing the specific properties, antigen or other biological system can be used to design drugs which act upon selectively on particular tissue[19].

POLYMERIC NANOPARTICLES

Polymeric nanoparticles are consisting a diameter ranging from 10 to 100 nm.the polymeric nano particles are isolated from synthetic polymers such as Polycaprolactone (PCL), polyacrylamide and native polymers for example gelatin, albumin, collagen, alginate and numerous methods that involves for example spontaneous emulsification, solvent evaporation, solvent diffusion and salting out. The division of polymeric nanocarriers can be classified on the basis of 3 medicine amalgamation mechanism. Firstly it concludes polymeric carrier that utilize covalent chemistry for candid drug conjugation.

The second approach comprises hydrophobic connections flanked by drugs in addition to nano carriers' example, (polymeric micelles from amphiphillic type co-polymers) [20]. It increases the constancy of some volatile pharmaceutical agents, effortlessly as well as economically fabricated in enormous quantity by a numerous techniques. Biodegradable polymers or nanopolymers have been widely used as drug delivery vehicles due to its large bioavailability, allowed better encapsulation and constitute less toxic properties. The process that is employed during the release of drug by polymeric nano particles in which polymeric drug carrier delivers the drug at tissue location by following 1 of 3 common physiochemical mechanism[21]. It involves the swelling of polymers nano particles by hydration followed via diffusion. By the enzymatic reaction resulting in rapture or degradation or cleavage of polymer at the place of release, so there by it releases medication from captured internal core .

HYDROGEL NANOPARTICLES

Hydrogel are cross linked network of hydrophilic polymers that could be absorbs and keep >20% of their heaviness in water[22]. Hydrogels are one of the extreme drug delivery system among several types, in order to enhance effectiveness & bicompatibilty. Hydrogel are utilized to transport small molecules, hydrophilic drugs which have elevated solubility in together aqueous solvent swelling as well as hydrophilic hydro gel matrix. Hydro gel nanoparticles also referred as polymeric nanogels or macromolecules[23]. The most important goal in designing nano particles as a deliverance system are to manage size of particle, their properties of surface in addition to the liberation of pharmacologically dynamic representatives with the intention of to get location precise accomplishment of medicine[24]. The polymers commonly used in preparation of hydro gel constitute pharmaceutical biological applications. Hydro gels that are commonly utilized in the delivery of medicine are generally produced external of the body furthermore infused with medicines prior to its presence in the body. There are various strategy employed which includes UV photopolymerisation & other cross linking techniques[25]. Apart from this non cross linked linear polymers can be employed as medicine release medium. Cross linking of polymers chain could be accomplished by using a range of ecological causes (temperature, pH, ionic strength). Polymers constituting hydrophobic interactions cross link in aqueous environment through thermal gelatin .the hydro gel based delivery are of two major category one time controlled system to stimuli –induced release system[26]. The major limitation of stimuli induced release system is their slow response time, which results in los of mechanical strength in polymer network.

CLASSIFICATION OF BIODEGRADABLE DENDRITIC POLYMERS USED IN DRUG DELIVERY.

Dendrimers supported liberation of drug paid attention on encapsulating medicines. The tremendous improvements in polymers in addition to dendrimers chemistry have offered a innovative class of molecules identified dendronized polymers which constitute linear polymers & offer drug release rewards for the reason of their increased flow time[27]. The arrangement of dendrimers consist not triple distinctive architectural provinces as a moiety otherwise core, layers of branches reiterate units that are up-and-coming from core & the purposeful ending groups on external coating of reiterate components. Dendrimers constituting following polymers when used in drug delivery studies are polyamidoaminemelamine (PAMAM), polyamidoamine-organosilicon, amphiphilic dendrimer, polyethyleneimine, polypropyleneimine, polyethylene glycol chitin[28]. Dendrimers could be obtain by either divergent or convergent ways. Whereas in divergent approaches, dendrimers are produced from core in addition to additional made to outer layers termed as generations[29]. For convergent approach synthesis start from the fringe of dendrimer molecule furthermore stops at center. Drugs that are connected with dendrimers can be employed for the healing of cancer. They are also known for well defined structure and molecular weight[30].

Table 1
Dendritic biodegradable polymer in drug delivery

Dendrimer types	Drug loaded	Application
Polyamidoamine (PAMAM)	Nadifiloxacin Prulifloxacin	Treatment of certain disorders of the heart, brain and blood vessels
polypropylene Amine	Nystatin and terbinfine	Antifungal against Candida albicans
Polylysine dendrimer	Viva gel	HIV,HSVand STD(sexually transmitted diseases)

SOLID LIPID NANOPARTICLES IN TARGETED DRUG DELIVERY

Solid lipid nanoparticles (SLN) were developed in 1991, are particulate system which involves the traditional colloidal carrier for parenteral drug administration with particle diameter of 50 to 1000 nm .They are employed in drug delivery system due to their size dependent properties, and the tendency to incorporate the drugs in to nano carrier such as liposome's, emulsion, polymeric nano and micro particles[32]. The tendency of SLN to be administered for different routes and controlled drug delivery has attracted wide attention of researchers[33]. On the other hand, insufficiency of protected polymers have limited the wide spread application of nano particles in nano medicine[34]. In order to conquer these limitations, lipid has been put forth as an alternative carrier for liphophilic pharmaceuticals. These lipid nano particles are known as solid lipid nanoparticles.

ADVANTAGES OF SOLID LIPID NANO PARTICLES

- Precise and targeted drug release,
- Enhanced biocompatibility,
- Improved bioavailability and biocompatibility,
- long term consistency,
- Chemical stability to labile integrated compounds.

PREPARATION OF SOLID LIPID NANO PARTICLES

SLN are prepared from lipid, emulsifier and water solvent, the lipids those are utilized for formulations involves triglyceride, glycerol, phospholipids, steroid, and waxes etc.[36] Methods that are commonly employed for preparation of SLN are high pressure homogenization, solvent emulsification/ solvent evaporation, super critical fluid method, spray drying method, precipitation technique etc.[37]

SLN FOR TROPICAL USE

SLN have been utilized for various tropical applications includes peculiar drugs such as imidazole[38], antifungal[39], anticancer[40], ketoconazole[41], flurbiprofen[42] etc. The invasion of podophylotoxin SLN in to stratum corneum along with skin surface tends to epidermal targeting. The isotretinoin loaded lipid nano particles are encapsulated for tropical delivery of drugs. The utilization of soybean lecithin and tween 80 for hot homogenization method, by employing glycerol behenate, vitamin A loaded nano particles can be prepared [43].

TOPICAL ROLE OF FULLERENES IN TARGETED DRUG DELIVERY

Fullerenes have exerted influence upon dissimilar areas of knowledge ever since their breakthrough in 1985. The investigations of chemical, physical and biological possessions of fullerenes have provided capable information that includes hydrophobicity, size and electronic configuration which make them an exploring matter in the field of therapeutic chemistry[44]. Fullerene family more specifically C_{60} which constitutes electrochemical, physical as well as photo properties can be advantageous within different medicinal fields[45]. The exclusive carbon age structure that coupled for derivitazation process enables the therapeutic agent. Fullerenes have the tendency to fit within hydrophobic void of HIV proteases that suppress the entrance of substrate to the catalytic location of an enzyme[46]. It could also adopt for radical scavenger and antioxidant. Similarly, if they are exposed to sunlight, fullerenes can fabricate singlet oxygen in elevated quantum yield[47]. This mechanism collectively with the undeviating electron transport commencing energized position of fullerenes are utilized for cleave DNA bases. They are also been put forth as a carrier for gene and drug delivery system[48]. Today's the important area of research is concerned with modern material nano science that involves carbon based materials. Fullerene the most generous representative of fullerene family was first introduced in 1990 by resistant heating of graphite[49]. Fullerene molecules are totally collected of carbon in the form of void ellipsoid, sphere and tube. Sphere-shaped fullerene also known as bucky balls 60 are generally insoluble in aqueous media and assembled very easily, so there are several ways to overcome the limitations of natural repulsion of fullerenes for water that involves[50].

- Encapsulation and micro encapsulation in spherical carriers like cyclodextrin and callixareness[51], polyvinyl pyroliidone[52], micelles and liposome's[53].
- Suspension is done with the help of co solvents by the saturation of fullerenes in benzene solution.
- Hydrophilicity can be increased by chemical functionalization with amino acids, poly hydroxyl groups, amphiphilic polymers[54].

MAGNETIC NANOPARTICLE FOR TARGETED DRUG DELIVERY

Magnetic nanoparticles (MNP) & its scientific approaches in biomedical areas of research has become relatively common place[55]. The recent observations and research analysis constitute magnetic micro and nano particles. Magnetic marking is supported upon the desirability of magnetic nano particles to an outer magnetic field[56]. Magnetic targeting offer most important advantages of delivery of drug, the capability to aim particular location that can be seen in

tumor, in vivo, in order to reduce the general allocation of cytotoxic composites as well as attractive for their uptake at intented location. For designing magnetic nano particles it includes physical constraints for instance size of carrier particles, magnetic properties as well as strength of field etc.[57] Iron oxides with core/shell structure are extensively utilized as source of magnetic particles. There are several crystalline polymorphs of iron oxides such as alpha-Fe_2O_3, beta-Fe_2O_3 and so on[58]. Coating of magnetic nanoparticles along with polymers describes a way of stability of nano particles against oxidation[59]. Another drug delivery involves transporting magnetic core/shell Fe_3O_4/Si_2 SiO_2 nanoparticles by means of electrophoresis deposition on to an electrically conductive bendable PET substrate[60]. Recent studies demonstrated that, the organic compounds were applied for MNP functionalization, which involved the folate- intervened aqueous super paramagnetic iron oxide that included in to micelles[61]. MNP were also having its promising role in studying of in vitro drug accumulation inside leukemia k562 cell lines[62]. The tremendous role of MNP stems from inherent possessions of their magnetic core united with their medicine loading competence biochemical property[63].

NOVEL ROLE OF MESOSPOROUS SILICA NANOPARTICLES

Mesosporous silica nanoparticles (MSN) can be used as drug delivery system which will increase the efficiency of drug delivery. MSN constitutes exclusive assets for example elevated pore capacity, excessive exterior area as well as controlled aperture size[64]. Physical & chemical properties could be improved by surface modifications by different functional group which result in an increased of capacity of drug loading[65]. The involvement of different material for the modification of surface of MSN includes gelatin, 3 amino proplyltriethoxy orthodilane, and methoxy di ethoxy silane etc.[66] MSN are effectively used by reason of their squat toxicity as well as elevated capacity of packing of medicine. As silica is enormously exist in an surroundings in contrast to further metal oxides akin to titanium in addition to iron oxides[67]. MSN constitute well distincted structure possessions that permit effortless functionalization of silanol holding exterior to control[68]. Loading of drug, surface functionalization is requiring for load proper type of drug molecules. The synthesis of mesosporous particles characterized by employing a easy sol-gel technique otherwise spurt drying method[69]. The most extensively utilized kinds of MSN are the crystalline materials (MCM-91), which constitute MSN, can stack a amount of remedial medicine with 200-300 mg silica. Production of MSN takes place at small concentration of surfactant to formulate the construction of mesosphere that is dependent upon the interaction among anionic oligomers of orthosilic acid and cationic surfactant[70]. The most commonly used msn are mobile crystalline materials (MCM-41) that requires liquid crystal templating of an alkyl triethyl ammonium bromide. Mesosporous silica nanoparticles, used as biosensing element because of its size and structure. The most important advantage of porous nano material is its ability of surface functionalization. The targeting moieties is the outstanding way to deliver drug. They are promising nano carrier to efficiently transport and site specific drug delivery of chemotherapeutic agents for effective cancer treatment[71] .

FABRICATION OF NANOPARTICLES DRUG DELIVERY WITH MICROFLUIDICS TOOL

The advancement of composite nano and micro particles can be studied in broad area of research. They are employed in drug delivery studies because of their enormous potential on the basis of their size, distribution and their biomedical applications in various areas related to medical disciplines. There are various technique that are involved in the production of nano particles but among them micro fluidics play a dynamic role in manufactures of particles on the basis of their precise size, small size distribution, high encapsulation efficiency. However the development of polymeric nano particles drug delivery could be well understood when its production involves encapsulation with micro fluidics tools and various strategy on the basis of its enormous potential will comes out as an emerging field of today research areas. Micro fluidics, the science which deals with the engineering of fluid flow at nano scale allowed us to understand the approach of lab-on-a-chip technology. The involvement of drug delivery devices at cellular, tissue and at organism level constitute three different ways which are employed for the synthesis of smart particles by using lab-on a-chip-technology. The potentiality to understand the effects of certain drugs at cellular level, which involves micro fluidics based cell culture platforms in order to generate the different form of environment, lab on a chip technology allowed us to administer the drug at controllable rate. At organ level the delivery of drug based on LOC involves the usage of microneedels and the implantable devices for fluid handling, which works as targeted delivery. In other words micro fluidics is the science and technology of inserting nano liter volume in micro scale fluidics channel that employed wide range of applications such as chemical synthesis, single cell analysis, tissue engineering.

OTHER ADVANTAGES OF NANOPARTICLES

Nanoparticles have utmost worth in the development of medical diagnostics as well as treatments. Nanoparticles carry out as fluorescent imaging mediator which brings to cell along with then elucidate the access of biological substance similar to peptides within the cell. Silver nanoparticles are essentially employed since it gives improved amalgamation of light therefore demonstrates stronger as well as sharper plasmon resonance. Nanoparticles in medicine in addition to gene delivery by nanoparticles comprise nanospheres along with nanocapsules in which medication is watery, wrapped up as well as separated into the contiguous matter in addition to remedy is surrounded to an aqueous enclosed by a covering like barrier, correspondingly. Nanoparticles can conquer the shortcoming akin to little movement directs to recurrent administration as well as undesired targeting associated to the minute remedial representatives. Polymer nanoparticles can expand the in vivo movement time with permeable blood vessels which augments the

submissive release of remedy to tissue as well as viability of administration in the course of diverse ways *i.e.* gulp of air as well as oral administrations. Delivery of genes through nanoparticles can substitute malfunctioning or omitted gene, conveyed gene can source the obliteration of faulty cell in addition to grounds flawed cells to revert back to usual cell. Nanoparticles in malignancy cure a conservative remedy for malignancy which consists of emission, chemotherapy, surgical treatment as well as therapy by hormone have a few restrictions as they indistinctively have an effect on the individual body together with normal as well as cancerous cell. Nanoparticles can conquer the boundaries of conservative remedy as it is applied as medicine release mediator which heaps the preparation in large quantity to the cancer location as a consequence progresses for the handling of cancer. Nanoparticles perform as cancer precise biomarker in addition to imaging potential which identify the tumor. Silver nanoparticles synthesized by using leaves of some medicinal plants like as *Vitis vinifera* L, *Rosa damascene, Ocimum Sanctum* leaf extract can be used for various intentions like as in the detection of different bacteria[72-77].

CONCLUSION

The emerging applications of nano technology in medicine and more precisely in drug delivery has been reported in various area of research that includes pharmaceutically sciences that are utilizing nano particles in order to minimize the toxic effects and side effects of doses of drugs and their potential improvements increasing the biocompatibility of nano particles in order to intensify the diagnostic and therapeutic moieties in to diseased cells with greater efficacy. At atomic, molecular and supramolecular scale it exhibit fundamentally new properties. Incorporating the prodrugs in to nanotechnology based carrier combines the methods of developing drug invasion and their biocompatibility. So there are so many methods are used for the synthesis of nanoparticles and applied for the various purposes.

ACKNOWLEDGEMENTS

We are grateful to Prof. Aditya Shastri, Vice-Chancellor, Banasthali University; DST, Govt. of India for supporting Banasthali University under its CURIE scheme and bioinformatics centre intended for make available the required services.

CONFLICT OF INTEREST

Conflict of interest declared none.

REFERENCES

1. Nurunnabi M, Parvez K, Nafiujjaman M, Revuri V, Khan HA, Feng X, Lee YK. Bioapplication of graphene oxide derivatives: drug/gene delivery, imaging, polymeric modification, toxicology, therapeutics and challenges. RSC Adv. 2015;5(52):42141-61.
2. Nazem A, Mansoori GA. Nanotechnology solutions for Alzheimer's disease: advances in research tools, diagnostic methods and therapeutic agents. J Alzheimers Dis. 2008 Mar 18;13(2):199-223.
3. Horcajada P, Gref R, Baati T, Allan PK, Maurin G, Couvreur P, Ferey G, Morris RE, Serre C. Metal–organic frameworks in biomedicine. Chem Rev. 2011;112(2):1232-68.
4. Panday A, Sahoo MK, Osorio D, Batra S. NADPH oxidases: an overview from structure to innate immunity-associated pathologies. Cell mol Immuno. 2015 Jan 12(1): 5-23.
5. Kamaly N, Xiao Z, Valencia PM, Radovic-Moreno AF, Farokhzad OC. Targeted polymeric therapeutic nanoparticles: design, development and clinical translation. Chem S Rev. 2012;41(7):2971-3010.
6. Gupta AK, Gupta M. Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. Biom. 2005;26(18): 3995-4021.
7. Gullotti E, Yeo Y. Extracellularly activated nanocarriers: a new paradigm of tumor targeted drug delivery. Mol Pharmaceutics. 2009 April 14;6(4):1041-51.
8. Torchilin VP. Multifunctional nanocarriers. Adv Drug Deliv Rev. 2006 Dec 1;5:302-15.
9. Albrecht MA, Evans CW, Raston CL. Green chemistry and the health implications of nanoparticles. Green Chem. 2006 Mar 23;8(5):417-32.
10. Kulkarni M, Mazare A, Gongadze E, Perutkova S, Kralj-Iglic V, Milosev I, Mozetic M. Titanium nanostructures for biomedical applications. Nanotech. 2015 Feb 13;26(6):062002.
11. Mornet S, Vasseur S, Grasset F, Duguet E. Magnetic nanoparticle design for medical diagnosis and therapy. Int J Mater Sci. 2004 Jun 19;14(14):2161-75.
12. Dasgupta N, Ranjan S, Mundekkad D, Ramalingam C, Shanker R, Kumar A. Nanotechnology in agro-food: from field to plate. Food Res Int. 2015 Mar 31;69:381-400.
13. Wilczewska AZ, Niemirowicz K, Markiewicz KH, Car H. Nanoparticles as drug delivery systems. Pharmacol Rep. 2012;64(5):1020-37.
14. Liu M, Gan L, Chen L, Xu Z, Zhu D, Hao Z, Chen L. Supramolecular core–shell nanosilica liposome nanocapsules for drug delivery. Langmuir. 2012 Jun 29;8(29):10725-32.
15. Ganta S, Devalapally H, Shahiwala A, Amiji M. A review of stimuli-responsive nanocarriers for drug and gene delivery. J Control Release. 2008 Mar 20;126(3):187-204.
16. Raveendran S, Yoshida Y, Maekawa T, Kumar DS. Pharmaceutically versatile sulfated polysaccharide based bionano platforms. Nanomed. 2013 Jul;9:605-26.
17. Mohanraj VJ, Chen Y. Nanoparticles-a review. Trop J Pharm Res. 2006 Jun;5(1):561-73.
18. Gong JP, Katsuyama Y, Kurokawa T, Osada Y. Double-network hydrogels with extremely high mechanical strength. Adv Mater. 2003 Jul;15(14):1155-58.
19. Lombardo D, Calandra P, Barreca D, Magazu S, Kiselev MA. Soft interaction in liposome

nanocarriers for therapeutic. Nanomaterials (Basel). 2016 Jun 25;6(7):125-8.
20. Bajpai AK, Shukla SK, Bhanu S, Kankane S. Responsive polymers in controlled drug delivery. Prog Polym Sci. 2008;33(11):1088-118.
21. MacEwan SR, Chilkoti A. Applications of elastin-like polypeptides in drug delivery. J Control Release. 2014 Sep 28;190:314-30.
22. Gandhi NS, Tekade RK, Chougule MB. Nanocarrier mediated delivery of siRNA/miRNA in combination with chemotherapeutic agents for cancer therapy: current progress and advances. J Control Release. 2014;194:238-56.
23. Gao C, Yan D. Hyperbranched polymers: from synthesis to applications. Progress Poly Sci. 2004;29(3):183-275.
24. Soler M, Newkome GR. Supramolecular dendrimer chemistry. John Wiley & Sons, Ltd. 2006;7:p96-108.
25. Muller RH, Keck CM. Challenges and solutions for the delivery of biotech drugs-a review of drug nanocrystal technology and lipid nanoparticles. J Biotechnol. 2004. Sep 30;113(1):151-70.
26. Kumar MNVR. Nano and microparticles as controlled drug delivery devices. J Pharm Sci. 2000;3(2):234-58.
27. Almeida AJ, Souto E. Solid lipid nanoparticles as a drug delivery system for peptides and proteins. Adv Drug Deliv Rev. 2007 Jul 10;59(6):478-90.
28. Daniel MC, Astruc D. Gold nanoparticles: assembly, supramolecular chemistry, quantum-size-related properties, and applications toward biology, catalysis, and nanotechnology. Chem Rev. 2004 Jun; 104(1):293-346.
29. Severino P, Andreani T, Macedo AS, Fangueiro JF, Santana MHA, Silva AM, Souto EB. Current state-of-art and new trends on lipid nanoparticles (SLN and NLC) for oral drug delivery. J Drug Deliv. 2012. Article ID 750891, 10 pages, 2012. doi:10.1155/2012/750891.
30. Mehnert W, Mader K. Solid lipid nanoparticles: production, characterization and applications. Adv Drug Delivery Rev. 2001;47(2):165-96.
31. Schwarz C, Mehnert W, Lucks JS, Muller, RH (1994). Solid lipid nanoparticles (SLN) for controlled drug delivery. I. Production, characterization and sterilization. J Cont Rele, 30(1):83-96.
32. Rigon RB, Oyafuso MH, Fujimura AT, Goncalez ML, Prado AHD, Gremiao, MPD, Chorilli M. Nanotechnology-based drug delivery systems for melanoma antitumoral therapy: a review. BioMed Res Int. 2015;8:367-450.
33. Cho K, Wang XU, Nie S, Shin DM. Therapeutic nanoparticles for drug delivery in cancer. Clin Cancer Res. 2008 Mar1;14(5):1310-16.
34. Rieter WJ, Pott KM, Taylor KM, Lin W. Nanoscale coordination polymers for platinum-based anticancer drug delivery. J Am Chem Soc. 2008 Sep 3;130(35):11584-5.
35. Parnami N, Garg T, Rath G, Goyal AK. Development and characterization of nanocarriers for topical treatment of psoriasis by using combination therapy, Artif Cells Nanomed Biotechnol. 2014;42(6):406-12.
36. Amrutiya N, Bajaj A, Madan M. Development of microsponges for topical delivery of mupirocin. AAPS PharmSciTech. 2009 Jun;10(2):402-9.
37. Tucek J, Kemp KC, Kim KS, Zboril R. Iron-oxide-supported nanocarbon in lithium-ion batteries, medical, catalytic, and environmental applications. ACS Nano. 2014 Aug 26;8(8):7571-612.
38. Sapsford KE, Algar WR, Berti L, Gemmill KB, Casey BJ, Oh E, Medintz IL. Functionalizing nanoparticles with biological molecules: developing chemistries that facilitate nanotechnology. Chem R. 2005;113(3):1904-2007.
39. Kulkarni M, Mazare A, Gongadze E, Perutkova S, Kralj-Iglic V, Milosev I, Mozetic M. Titanium nanostructures for biomedical applications. Nanotech. 2007; 26(6):620-702.
40. Bakry R, Vallant RM, Najam-ul-Haq M, Rainer M, Szabo Z, Huck CW and Bonn GK. Medicinal applications of fullerenes. Int J Nanomedicine. 2007;2(4) 63-90.
41. Kumar AP, Depan D, Tomer NS, Singh RP. Nanoscale particles for polymer degradation and stabilization-trends and future perspectives. Prog Polym Sci. 2009;34(6):479-515.
42. De Volder MF, Tawfick SH, Baughman RH, Hart AJ. Carbon nanotubes: present and future commercial application. Science. 2013 Feb 1;339(6119):535-9.
43. Jha PK, Chaudhury K, Rana SV, Guha S. An emerging interface between life science and nanotechnology: present status and prospects of reproductive healthcare aided by nano-biotechnology. Nano Rev. 2014;5(1):22762.
44. Nguyen DH, Choi JH, Joung YK, Park KD. Disulfide-crosslinked heparin-pluronic nanogels as a redox-sensitive nanocarrier for intracellular protein delivery. J Bioact Compat Polym. 2011 May 1;26(3):287-300.
45. Allen TM, Cullis PR. Drug delivery systems: entering the mainstream. Sci JP. 2004 Mar 19:1818-22.
46. Sahoo NG, Rana S, Cho JW, Li L, Chan SH. Polymer nanocomposites based on functionalized carbon nanotubes. Prog Polym Sci. 2010;35(7):837-67.
47. Gupta AK, Gupta M. Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. Biomaterials. 2005;26(18):3995-4021.
48. Laurent S, Forge D, Port M, Roch A, Robic C, Vander Elst L, Muller RN. Magnetic iron oxide nanoparticles: synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. Chem Rev. 2008;110(4):2064-110.
49. Mahmoudi M, Sant S, Wang B, Laurent S, Sen T. Super paramagnetic iron oxide nanoparticles (SPIONs): development, surface modification and applications in chemotherapy. Adv Drug Delivery Rev. 2011;63(1):24-46.
50. Chirita M, Grozescu I, Taubert L, Radulescu H, Princz E, Stefanovits-Banyai E, Muntean C. Fe_2O_3–nanoparticles, physical properties and their photochemical and photoelectrochemical applications. Chem Bull. 2009;54(68):1-8.

51. Lu AH, Salabas EE, Schuth F. Magnetic nanoparticles: synthesis, protection, functionalization, and application. Angew Chem Int Ed Engl. 2007;46(8):1222-44.
52. Zhou L, Gao C, Xu W. Robust Fe_3O_4/SiO_2-Pt/Au/Pd magnetic nanocatalysts with multifunctional hyperbranched polyglycerol amplifiers. Langmuir. 2010;26(13): 11217-25.
53. Chomoucka J, Drbohlavova J, Huska D, Adam V, Kizek R, Hubalek J. Magnetic nanoparticles and targeted drug delivering. Pharmacol Res. 2010 Aug;62(2):144-9.
54. Flora G, Gupta D, Tiwari A. Nanocurcumin: a promising therapeutic advancement over native curcumin. Crit Rev Ther Drug Carrier Syst. 2013;30(4):331-68.
55. Colombo M, Carregal-Romero S, Casula MF, Gutierrez L, Morales MP, Bohm IB, Parak WJ. Biological applications of magnetic nanoparticles. Chem Soc Rev. 2012;41(11):4306-34.
56. Zhao W, Gu J, Zhang L, Chen H, Shi J. Fabrication of uniform magnetic nanocomposite spheres with a magnetic core/mesoporous silica shell structure. J Am Chem Soc. 2005;127(25):8916-17.
57. Slowing II, Vivero-Escoto JL, Trewyn BG, Lin VSY. Mesoporous silica nanoparticles: structural design and applications. J Mater Chem. 2010;20(37):7924-37.
58. Yang P, Quan Z, Hou Z, Li C, Kang X, Cheng Z, Lin J. A magnetic, luminescent and mesoporous core–shell structured composite material as drug carrier. Biomater, 2009;30(27):4786-95.
59. Li J, Li J, Meng H, Xie S, Zhang B, Li L, Yu M. Ultra-light, compressible and fire-resistant graphene aerogel as a highly efficient and recyclable absorbent for organic liquids. J Mater Chem. 2014;2(9):2934-41.
60. Bharti C, Nagaich U, Pal AK, Gulati N. Mesoporous silica nanoparticles in target drug delivery system: A review. Int J Pharm Investig. 2015;5(3):124.
61. Wang S, Gao R, Zhou F, Selke M. Nanomaterials and singlet oxygen photosensitizers: potential applications in photodynamic therapy. J Mater Chem. 2004;14(4):487-93.
62. Peer D, Karp JM, Hong S, Farokhzad OC, Margalit R, Langer R. Nanocarriers as an emerging platform for cancer therapy. Nat Nanotechnol. 2007;2(12):751-60.
63. Zheng M, Zhong Y, Meng F, Peng R, Zhong Z. Lipoic acid modified low molecular weight polyethylenimine mediates nontoxic and highly potent in vitro gene transfection. Mol Pharm. 2011;8(6):2434-43.
64. Shewan HM, Stokes JR. Review of techniques to manufacture micro-hydrogel particles for the food industry and their applications. J Food Eng. 2013;119(4):781-92.
65. Sahoo SK, Parveen S and Panda JJ. The present and future of nanotechnology in human health care. Nanomedicine. 2007 Mar;3(1):20-31.
66. Dong L, Jiang H. Autonomous microfluidics with stimuli-responsive hydrogels. Soft Matter. 2007;3:1223-30.
67. Kubik T, Bogunia-Kubik K, Sugisaka M. Nanotechnology on duty in medical applications. Curr Trends Biotechnol Pharm. 2005;6(1):17-33.
68. Zrinyi M, Nakano M, Tsujita T. Electrorotation of novel electroactive polymer composites in uniform DC and AC electric fields. Smart Mater Struct. 2012;21(6):065022.
69. Edelhauser HF, Boatright JH, Nickerson JM. Drug delivery to posterior intraocular tissues: third annual ARVO/Pfizer ophthalmics research institute conference. Invest Ophthalmol Vis Sci. 2008 Nov;49(11):4712-20.
70. Bashir R. BioMEMS: state-of-the-art in detection, opportunities and prospects. Adv Drug Deliv Rev. 2004;56(11):1565-86.
71. Mieszawska AJ, Mulder WJ, Fayad ZA, Cormode DP. Multifunctional gold nanoparticles for diagnosis and therapy of disease. Mol Pharm.2013 Mar4;10(3):831-47.
72. Sharma CK, Sharma, M. Fruit extract mediated green synthesis of silver nanoparticles from *Vitis vinifera* L.: Synthesis, characterizaton, antimicrobial and cytotoxic activities. Kar, K. K., Shah, A. and Sharma, R. (Eds.) In: Proceedings of third international conference on “Nanotechnology for better living”, Theme: Nano-Materials for electronics, energy, environment and structure; 2016. 3(2):p. 222.
73. Sharma M, Sharma CK. *Rosa damascena* leaf extract mediated green synthesis of silver nanoparticles: Characterization and antimicrobial studies. Kar, K. K., Shah, A. and Sharma, R. (Eds.) In: Proceedings of third international conference on “Nanotechnology for better living”, Theme: Nano-Materials for electronics, energy, environment and structure; 2016. 3(2): p. 223.
74. Sharma CK, Panwar A, Sharma M. Biomedical applications of green synthesized nanoparticles. In: Communication and Computing Systems – Prasad et al. (Eds) ISBN 978-1-138-02952-1, CRC press, Taylor & Francis Group, London; 2017. p. 1071-75.
75. Sharma CK, Rathi A, Sharma M. Therapeutic efficacy of nanoparticles synthesized by different plants against different hepatotoxicants in the field of medical sciences. In: Communication and Computing Systems – Prasad et al. (Eds) ISBN 978-1-138-02952-1, CRC press, Taylor & Francis Group, London; 2017. p. 1077-81.
76. Boken J, Sharma M, Sharma CK, Kumar D. Synthesis of silver nanoparticles by using *Ocimum Sanctum* leaf extract and detection of antibacterial activity. In: Global Sustainability Transitions: Impacts and Innovations (Ed. G. C. Mishra), ISBN: 978-93-83083-77-0, Excellent Publishing house, New Delhi; 2014. p. 278-84.
77. Sharma CK, Sharma M, Verma O, Sharma V. Green synthesis of different nanoparticles and their potential applications in different fields- a critical review. Int J Pharm Bio Sci. 2015 July;6(3):555-67.

Reviewers of this article

Prof. Srawan Kumar G.Y

Associate Professor,Nalanda Institute of Pharmaceutical Sciences, Sattenapalli, Guntur, Andrapradesh, India

Prof.Dr.K.Suriaprabha

Asst. Editor , International Journal of Pharma and Bio sciences.

Prof.P.Muthuprasanna

Managing Editor , International Journal of Pharma and Bio sciences.

We sincerely thank the above reviewers for peer reviewing the manuscript