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APPLICATION OF NANOTECHNOLOGY IN HEALTH SCIENCES

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Abstract

Nanotechnology is an interdisciplinary field of science that collaborates engineering, physics, chemistry and biology. It is branch of engineering and science that involves the designing of nano tools/devices having size in the range of nano scale *i.e.*1-100nm. In pharmaceutical sciences a large number of nano devices have been prepared including carbon nano tubes, dendrimers, liposomes, nanoparticles and quantum dots. These nano devices have unique physical (size, shape, and strength), chemical (high catalytic activity) and biological (specificity) properties. Therefore, these devices offer many advantages over conventionally used medicines which are more toxic and more side effects. Biomedically, these nano devices have been used for the diagnosis and treatment of various diseases such as cancer, Alzheimer's, Parkinson's, tuberculosis, dentistry, tissue engineering etc. The present review explains the role of nano devices in pharmaceutical sciences and medical application of nanotechnology that significantly improve the health of human.

Key words : Nanotechnology, nano tools, diagnostics, medicine, therapeutics.

Introduction

Nanotechnology is a branch of diverse sciences including life sciences, material science and information technology. It involves the design, synthesis, characterization and application of materials and devices whose smallest functional entity in at least one dimension is on the nanometer scale (Silva, 2004). Nanotechnology has changed the field of medicine where size of nanoparticles synthesized ranges between 1 - 100 nm and they are being used for diagnosis, therapeutics and as biomedical tools for research (Nikalje, 2015).

It is a promising field of science capable of resolving problems and issues that are impossible to solve in engineering and medical sciences. Combination of nano-science and technology involve studying and working of a material on a nano scale that allow us to work, manipulate and invention of new tools, materials and structures at the molecular level, by rearranging their atom sequence into functional structures having size in nano scale (Ray *et al*., 2009).

Nano scale and Nanostructures

The nano scale is the measurement of dimension where the properties of a matter are determined just above the scale of an atom. Matter in the nano scale range has at least one dimension (height, length, depth) that measures between 1 and 999 nanometers (1-999 nm) (Nikalje, 2015).

Nano tools in pharmaceutical nanotechnology are nano materials and nano devices. These materials have been further sub classified into nano crystalline and nano structured materials. Nano structure consists of nano-particles, dendrimers, micelles, drug conjugates, metallic nano particles etc.

Classification of nano materials

Nano materials have been classified according to their dimension into various categories which are given table 1.

Carbon nano tubes

They are rolled seamless cylindrical in shape having size in the range of 50 nm to 1 cm^{-1} and exhibiting good physical, mechanical and chemical properties. These carbon nano tubes have been used in drug delivery and diagnosis of diseases (Liu *et al*., 2009).

Liposomes

These have been used and most developed nano carriers for novel and targeted drug delivery due to their small size, these are 50-200 nm in size. When dry

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phospholipids are hydrated, closed vesicles are formed. Liposomes are biocompatible, versatile and have good encapsulation efficiency. It finds application as long circulatory and in passive and active delivery of gene, protein and peptide. Structure of liposomes used in drug delivery is shown in fig. 1.

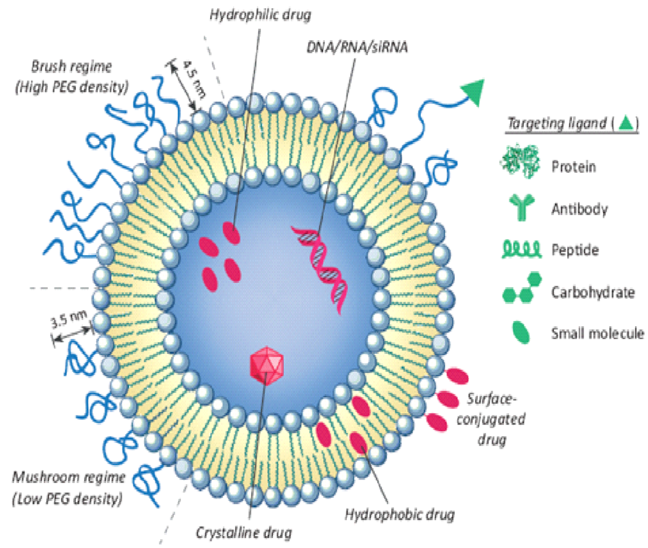

Fig. 1 : Structure of Liposomes.

Dendrimers

Dendrimers are hyper branched, tree-like structures. It consists of three different regions including core moiety, branching units, and closely packed surface. It has globular structure and encloses internal cavities. It has size less than 10 nm. These are used more because of their size, shape, and have good physical properties (fig. 2). Nano tubes have many advantages over other drug delivery and diagnostic systems due to their distinctive physical properties (Chaudhari *et al*., 2016).

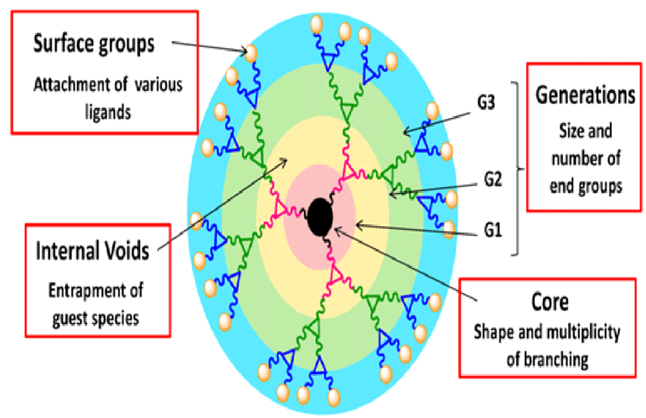

Fig. 2 : Structure of a Dendrimer.

Metallic nano particles

Inorganic metals such as iron, silica, silver, gold and quantum dots have been used for the preparation of nanoparticles**.** These metallic nano-particles have been used in drug delivery, particularly in the treatment of cancer and also in construction of biosensors. Silver and gold nanoparticles (fig. 3) have prime importance in medical applications (Bhuiyan *et al*., 2016).

Quantum dots (QDs)

These are like "artificial atoms" having size 1 nm structures made up of inorganic metals such as silicon, containing electrons which are controlled by applying a given voltage. Te use of quantum dots is characterized by emitting light of different wavelengths which help in imaging of biological samples. Presently, biological molecules are imaged using naturally fluorescent molecules, such as organic dyes, with a different dye attached to each kind of molecule in a sample. But the dyes emit light over a broad range of wavelengths, which means that their spectra overlap and only about three different dyes emit light over a broad range of wavelengths, which means that their spectra overlap and only about three different dyes can be used at the same time. With QDs, full-colour imaging is possible because large numbers of dots of different sizes can be excited by a light source with a single wavelength. The wide range of colors that can be produced by quantum dots also means they have great potential in security. It is helpful in making light-emitting diodes (LEDs) from QDs which could produce white light. By controlling the amount of blue in the emission-control the "flavor" or "tone" of the white light can be tuned. QDs are also possible materials for making ultrafast, all-optical switches and logic gates that work faster than 15 terabits a second.

Table 1 : Dimensions of various nanomaterials used in nanotechnology (Nikalje, 2015).

Name of nanomaterial	**Size**
Nano rods, nano wires	100nm
Tubes, fibres, platelets	100nm
Particles, quantum dots, hollow spheres	0-3nm

Biologists are trying to use these quantum dots in living cells which could help in repairing of damaged neural pathways or to deliver drugs by activating the dots with light (Paul, 2003).

Applications of Nanotechnology in Medicine

Conventional medicines have poor specificity, efficiency and impart high toxicity thus; these medicines put adverse effects to the health of a patient. Now, it has become possible to provide therapy at molecular level because synthesis of drugs using nano tools offer unique physical properties such as higher specificity, sensitivity, efficiency and minimal toxicity, which make easier detection and treatment of diseases. A large number of diseases have been treated with the aid of nano tools such as diabetes, cancer, Parkinson's disease, Alzheimer's disease, cardiovascular diseases and multiple sclerosis as well as infectious diseases (*e.g.* HIV) (Jhong and Borm, 2008). Presently, nanotechnology is being widely used to provide targeted drug delivery, diagnostics, tissue regeneration, cell culture, biosensors and other tools in the field of molecular biology. For the treatment of diseases specific nano devices such as nanotubes, quantum dots, nanopores, dendrimers, liposomes, magnetic nanoprobes and radio labelled nanoparticles have been developed (Surendiran *et al.*, 2009). Fig. 4 shows the various applications of nanotechnology in medicine which is given below:

Nanotechnology in the treatment of Cancer

Small size of nano particles makes it easy to study the physiology of cancerous cells at the site of tumor. Quantum dots have been used in combination with magnetic resonance imaging (MRI), to produce better images of cancerous cells at the site of tumor. When these nanoparticles compared with organic dyes, they produce more fluorescence and require light as a source for excitation. Therefore, the uses of these fluorescent quantum dots are cost effective and produce better images than organic dyes used as contrast media. But quantum dots are usually made up of high toxic elements (Jaibir *et al.*, 2012). Nano particles have more surface area to volume ratio, which help in binding of diverse nature of functional groups with nano particle followed by binding with cancerous cells. In addition, the 10 to 100 nm small size of nanoparticles, permits them to get accumulate in cancerous cells because these do not contain an efficient lymphatic drainage system. Multifunctional nano particles could be prepared that would help in detection, imaging, and then treat a tumor in future cancer treatment (Nie *et al.*, 2007). Detection and diagnosis of proteins and other biomarkers of cancerous cells in the early stages from a single drop of a patient's blood have been made possible by using nano wires by constructing sensor test chips (Zheng, 2005). Drug delivery based on nanotechnology depends on: (i) efficient encapsulation of the drugs (ii) successful delivery of said drugs to the targeted region of the body and (iii) successful release of that drug there. Nano shells with 120 nm diameter, coated with gold have been used to kill cancer cells in mice by Prof. Jennifer at Rice University. These nano shells are targeted to bond to cancerous cells by conjugating antibodies or peptides to the nano shell surface. Area of the tumor is irradiated with an infrared laser, which heats the gold sufficiently and kills the cancer cells (Loo *et al.*, 2005). Quantum dots of cadmium selenide have been used are used for the detection of tumors. The cancerous cells give fluorescence when they are exposed to ultraviolet light (Abhilash, 2008).

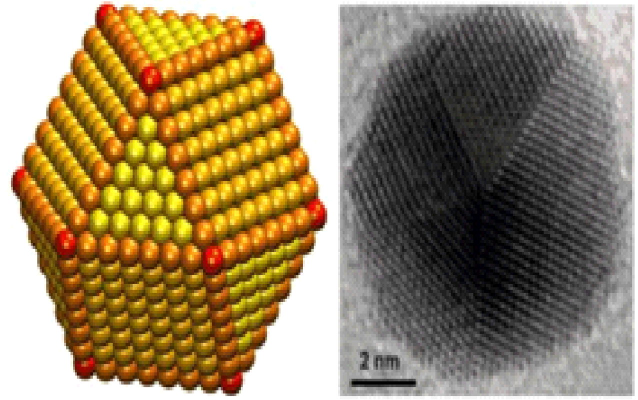

Fig. 3 : Gold and silver nanoparticles.

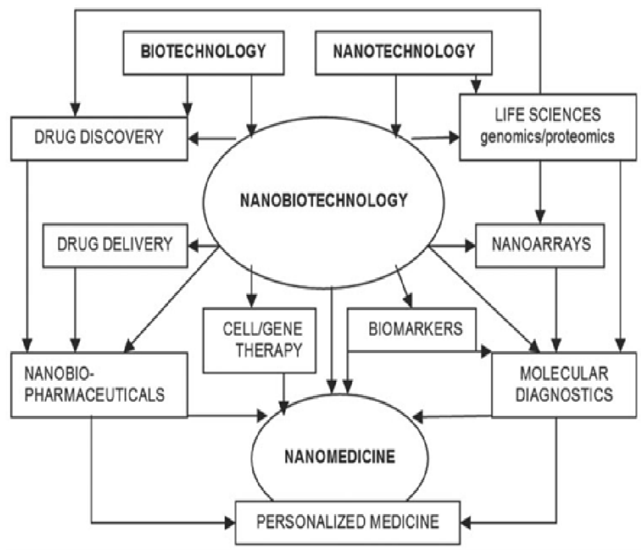

Fig. 4 : Applications of nanotechnology in medicine (Jain, 2007).

Nanotechnology in the treatment of neurodegenerative disorders

Nanotechnology offers promising application in the treatment of neurological dissorders by synthesizing nano devices such as dendrimers, nano gels, nano emulsions, liposomes, polymeric nano particles, solid lipid nano particles, and nano suspensions, which are targated to central nervous system (CNS). Delivery of nano medicines to CNS either *in vitro* or *in vivo* to the respective part of CNS has been made accompanied by the process of transcytosis and endocytosis (Wong *et al.*, 2012).

Table 2 : Properties of nanomaterials and applications in medicines (Barkalina *et al*., 2014).

Small Size	Comparability with the size of biological molecules. Potential for a straightforward integration into cellular processes and physiological pathways.
Large surface area	Capacity to carry large amounts of biological cargo, including simultaneous transport of various types of cargo on one nanocarrier
Versatility	Adjustable physicochemical properties (size, shape, surface change and architecture) for the covalent or non-covalent absorption of a particular type of payload. Options for the 'fine-tuning of surface chemistry through the addition of highly-specific ligands for molecular recognition and further enhanced selectivity of targeting.
Targeted action	High sensitivity and specificity. Decreased 'off-target' effects of cargo. Improved accuracy of detection profiles for diagnostic agents. Increased bioavailability and/or decreased toxicity for therapeutic agents.
Stability	Distance of action. Options for systemic administration. Protection of 'sensitive' payloads and optimized biodistribution.

Nanotechnology in the treatment of Parkinson's disease (PD)

It is a central nervous system disorder which causes neuro inflammatory responses and severe pain during body movement. Currently, used therapeutics improves the possible functional capacity of the patient but cannot alter the progress of the neurodegenerative process. Nanotechnology in combination with advances made in neurophysiology, neuropathology and cell biology resolve this problem by regeneration and neuro protection environment, which guide the growth of axon. Side-effects of conventional therapy can be minimized by using biometric simulation and optimization of an intracranial nano-enabled scaffold device (NESD) for the delivery dopamine to the specific site of brain. Nano particles of peptides and peptidic have also been designed for various CNS diseases.

Nanotechnology in the treatment of Alzheimer's disease

Alzheimer's is the most common form of dementia. Nano technology finds significant applications in neurology by synthesizing plethora of nanoparticulate entities with high specificity for brain capillary endothelial cells. These nano particles exhibits high affinity for the circulating amyloid-β (Aβ) forms and thus, produce "sink effect" and recover the patient from Alzheimer. *In vitro* diagnosis of AD has now become advanced due to ultrasensitive NP-based bio-barcodes and immune sensors, as well as scanning tunneling microscopy procedures that are capable of detecting Aβ1–40 and Aβ1–42 (Davide *et al*., 2011).

Nanotechnology in the treatment of Tuberculosis treatment

Tuberculosis is the fatal infectious disease. Sustainable use of commercial therapeutics results in the formation of multi-drug-resistant (MDR) strains. The development in nano-based drug delivery systems for encapsulation and release of anti-TB drugs can lead to development of an efficient and cost effective TB pharmacotherapy (Madeeha *et al*., 2016).

Nanotechnology in the treatment of Diabetes

It is a metabolic disorder characterized by hyperglycemia due to which level of glucose increases in the blood due to non availability of insulin hormone secreted by β-cells of langerhans in pancreas. It has also been treated by designing nano devices such as liposomes, nano rods, dendrimers and gold nanoparticles. These devices have been used for the delivery of drugs, hormones and proteins (Satyabrata *et al*., 2017).

Nanotechnology in the treatment of cardiovascular treatment

Cardiovascular diseases (CVD) such as atherosclerosis, stroke, heart failure, hypertensive heart disease, rheumatic heart disease, cardiomyopathy, heart arrhythmia, congenital heart disease, carditis, aortic aneurysms, peripheral artery disease, thromboembolic disease, and venous thrombosis. These CVD has been treated by preparing nano carriers assisted for small interfering RNA (siRNA) (Maheshwari *et al.*, 2015), nano constructed carriers loaded with anti oxidants (Jain *et al*., 2015), advanced therapeutics based on nanosystems (Chauhan *et al*., 2105)

Table 3 : Applications of nanoparticles in medicine (Surendiran *et al*., 2009).

Study phase	Product	Description	Use	Manufacturer
Preclinical	MRX 952	Nanoparticles preparation-to encapsulate camptothecin analogues	Tumors	IMA Rx Therapeutics
Preclinical	Targeted Nano Therapeutics (TNT)™ system	TNT with poymer coated iron oxide magnetic particle	Solid tumors	Triton biosystems
Preclinical	AutoLase™	Gold nanoshell	Head and neck cancer	Nanospectra Biosciences Inc
Preclinical	Dendrimer-magnevist	PAMAM dendrimer	MRI imaging agent	Dendritic nanotechnologies Inc
Phase 1	VivaGel®	Dendrimer basedmicrobicide gel	HIV prevention	Starpharma Pty Ltd
Phase 1	INGN401	Nanoparticle formulation of tumour suppression gene FUSl	Lung cancer	Introgen Therapeutics Inc
Phase 1 &2	Cyclosert-Camptothecin-IT 101	β-Cylcodextrin polymerdrug delivery system	Solid tumours	Calando Pharmaceuticals
Phase 2	VivaGel®	Dendrimer basedmicrobicide gel	HSV prevention	Starpharma Pty Ltd
Phase 2	MRX815	Nanobubble technology	Treatment of intravascularclot	IMA Rx Therapeutics
Phase 3	Combidex® / Ferumoxtran10	Iron oxide nanoparticle	MRI contrast agent	AMAG Pharmaceuticals
Marketed	Abraxane*	Albumin bound taxaneparticles	Non small cell lung cancer	Abraxis Oncology
Marketed	AmBisome®	Liposomal preparation of amphotericin B	Fungal infection	Astellas Pharma US
Marketed	Doxil*	Liposomal doxorubicin	Ovarian tumour	Ortho Biotech

Nanotechnology in operative dentistry

Nano filled complex resin materials possess exceptional wear resistance, potency, and essential aesthetics due to their unique polishing and luster maintenance. In operative dentistry, nano fillers constitute spherical silicon dioxide (SiO_2) particles with an average size of 5-40 nm (Tsuzuki, 2013).

Nanotechnology in ophthalmology

To achieve the advantages of nano medicine by using nano devices and nanostructures have played a significant role in scrutinizing, control, construction, repair, protection, and recovery of human physiological systems at the molecular level, because these nano devices function in comparable at the unit cell level. Role of nanotechnology to ophthalmology includes treatment of oxidative stress; measurement of intraocular pressure, use of nano particles for treatment of choroidal new vessels, to prevent scars after glaucoma surgery and for treatment of retinal degenerative disease using gene therapy; prosthetics; and regenerative nano medicine. Therefore, Nanotechnology will solve many unsolved problems such as restoration of sight of patients having retinal degenerative diseases (Zarbin *et al*., 2013) because presently used medicinal therapy has faced many challenges such as drug delivery and postoperative scarring for the treatment of severe evaporative dry eye, nanoscale-dispersed eye ointment (NDEO) has been prepared successfully (Zhang *et al*., 2014).

Nanotechnology in tissue engineering

Nanotechnology has also been applied in the field of tissue engineering for reproducing and repairing of damaged tissues. This has been accompanied by use of nanomaterial-based scaffolds and growth factors which stimulate the proliferation of cell artificially during organ transplants that consequently extended the life span of a living cell (Mohamed and Xing, 2012).

Nanotechnology in antibiotic resistance

Nano particles in combination therapy have reduced the antibiotic resistance. Use of zinc oxide nano particles has decreased the antibiotic resistance and increases the antibacterial activity of Ciprofloxacin against microorganism, by interfering with various proteins that are involved in the antibiotic resistance or pharmacologic mechanisms of drugs action (Banoee *et al*., 2010).

Immune response

The nano device bucky balls have been designed and used to change the immune response generated by release of histamine into blood and tissues from mast cells. Histamine binds to free radicals more effectively than any anti-oxidant available for *e.g.* vitamin E (Abraham, 2010).

Role of Nanotechnology in Pharmaceuticals

In nano pharmaceuticals, delivery of nano drugs having size 1-100 nm to the target site for the particular disease without interfering the physiology of adjacent cells. Nano tools have been used for the diagnosis of diseases in the early stage and their diagnostic applications are based on conventional methods by using nanoparticles. Delivery of a suitable dose of a particular active agent to specific disease site still remains difficult in the pharmaceutical industry. Nano pharmaceuticals deliver the appropriate dose of a drug at the target site of disease and reduce toxicity and other systemic side effects (Jhong *et al*., 2008).

Pharmaceutical industry faces many logical challenges in delivery of high-quality products to patients with profit. Therefore, pharmaceutical companies are more focused on the applications of nanotechnology to improve the drug formulation and drug target discovery. Because use of nano devices and nanoparticles make the drug discovery process cost effective, resulting in the improved Research and Development success rate, thereby reducing the time for both drug discovery and diagnostics (Bawa *et al*., 2010). **S**everal applications of nano devices in medicine are given in table 3.

Conclusion

Nanotechnology has revolutionized the field of pharmaceutical sciences by designing efficient nano tools for the delivery of nano medicine in appropriate amount at the particular site. Nanotechnology promises to overcome the limitations of existing molecular diagnostics and enable early stage diagnosis of diseases. Presently, the most important clinical applications of nanotechnology are in the field of biomarker invention, cancer diagnosis, tuberculosis and detection of infectious microorganisms. Nano medicines play an important role in the future development of diagnostic and therapeutic methods. Nanotechnology is fast assisting scope with the aid of nanoparticles in life science and cancer treatment. Use of nanodevices based technology provides a platform for the analysis and revolution of biological systems. Application of nanotechnology has greatly increased the worth of human life. Nanotechnology has been used to inhibit infection, decreased inflammation, and increases the initial formation of tissue required to extend lifetime of implanted tissue. Therefore, the future research should be focused to develop advance diagnostics and economical therapeutics without toxicity.

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