Pharmaceutical Nanotechnology-Based Systems

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Abstract- *Nanotechnology is referred to as the science of nanoscale which is objects that range in nanometers in size. The term nanotechnology refers to material processing on the atomic or molecular scale, especially for the construction of microscopic-level devices with the ability to calculate, function, and organize. Nanotechnology plays a key role inmedicine and other areas ofproduction and also plays a significant role in the treatment of diseases through the development of a system for the delivery of smart medicines. Nanotechnology has revolutionized virtually allmedicine andscience disciplines these days by offering new, small-scale devices and materials that are beneficial to living organisms. Nanoparticles are used for disease detection, treatment, and delivery of medications, nanopores, polymeric nanoparticles, liposomes, and dendrimers. The nano-scale and nanotechnology have created one of the most dynamic science and technology domains at the confluence of physical sciences, molecular engineering, biology, biotechnology, and medicine. This domain includes a better understanding of living and thinking systems, revolutionary biotechnology processes, synthesis of new drugs and their targeted delivery, regenerative medicine, and the developmentof a sustainable environment. The reduction of drug particles into the sub-micron range leads to a significant increase in the dissolution rate and therefore enhances bioavailability. There has been a considerable research interest in the area of developing drug delivery using nanoparticles (NP's) as carriers for small and large molecules. Targeting the delivery of drugs to diseased lesions is one of the most important aspects of the drug delivery system.*

Keywords- Polymeric nanoparticles, anodevices, Dendrimers, Nanomedicine, Drug carrier.

I. INTRODUCTION

Nanoscience and nanotechnology have great approaches in research and application in the pharmaceutical field. In 1974, the term ‘‘nanotechnology’’ was being used. Any technology that works on the nanoscale and has multidisciplinary applications will be considered nanotechnology. It deals with the nano length scale sizeor molecular level process [1]. Over the past decades, there has been considerable research interest in the area of developing nanotechnology by using nanoparticles as carriers for small and large molecules. Various polymers have been used in the formulation of nanoparticles. This review presents the most outstanding contributions in the field of nanotechnology. The word ‘Nano’ is derived from the Latin word, which means dwarf. Nano size refers to one thousand millionth of a particular unit thus nanometer is one thousand millionth of a meter. The term nanotechnology has been most commonly used in the fields of science like electronics, physics, and engineering for many decades. However, bio-medical and pharmaceutical fields remain yet to be explored. Nanotechnology is a multi-disciplinary field, the convergence of basic sciences and applied disciplines like biophysics, molecular biology, and bioengineering. Size reduction is a fundamental unit operation that has important applications in pharmacy. The main reasons for preparing nanoparticles as a drug delivery system are to get a pharmacologically active agent for site-specific action of the drug at an optimum rate and fix the dose regimen, as well as control the particle size [2]. E.g. solid lipid nanoparticles show various distinctive features such as low toxicity, prolonged drug release, large surface area, and superior cellular uptake in comparison to the traditional colloidal carriers also the capability to improve the bioavailability and solubility of drugs[3].

Drug delivery systems are engineered structures used to protect, transport, and release a pharmaceutical compound in a controlled manner. Compared to traditional drugs, nanotechnology-based drug delivery systems have several advantages, including a high surface area-to-volume ratio for efficient drug loading, improved targeting due to their small size allowing them to overcome biological barriers, enhanced drug solubility and physical stability in biological media, ease of surface functionalization to sense, image, diagnose and deliver pharmaceuticals by the conjugation of biological targeting moieties, controlled dissolution rates/drug bioavailability, reduced adverse side effects, and size similarity to interact with and modulate biological component[4,5]. Major advantages of nano sizing include Increased surface, Enhanced solubility,Increased rate of dissolution and oral bioavailability, Rapid onset of action, and Less amount of doses required in the field of pharmacy. For applications to medicine and physiology these materials and devices can be designed to interact with a high degree of functional specificity, thus allowing a degree of interaction between technology and biological systems not previously attainable. It should be appreciated that nanotechnology is not in itself a single emerging scientific discipline but rather a meeting of traditional sciences such as chemistry, physics material science, and biology to bring together the required collective expertise needed to develop these novel technologies.

SCOPE AND OPPORTUNITY: All the applications of nanotechnology are related to pharmacy, provide smart and intelligent drug delivery systems, and developthe most helpful and powerful tool in the pharmaceutical field. To fight against various diseases, pharmaceutical nanotechnology plays a very important role. It helps in detecting neurodegenerative diseases, diabetes mellitus, and cancer as well as detecting viruses and microorganisms associated with any infection. Pharmaceutical nanotechnology starts from intelligent tools in drug delivery and diagnosis to smart material for tissue engineering, artificial RBC, etc [6]. Furthermore, nanotechnology is used in pharmacy like the development of nanomedicines, nanorobots, advanced diagnostics, tissue engineering, and diagnostic agents like biomarkers, biosensors, image enhancement devices, implant technology, etc.Moreover, many nanosystems are being developed in pharmacies like carbon nanotubes, quantum dots, dendrimers, nanofibers, liposomes, metallic nanoparticles, etc [7].The nanoscale manipulation provides site-specific targeting and delivery, as well as the controllable release of drugs, genes, and imaging agents.[8,9] A variety of nano-based drug delivery systems have been recently developed from different materials such as lipids, polymers, metals, inorganic materials, and small molecules.[10]

PHARMACEUTICAL NANOTECHNOLOGY-BASED SYSTEMS: Pharmaceutical nanotechnology consists of two basic types, which are nano-materials and nanodevices, which play a key role in pharmaceutical nanotechnology and other fields. Nanomaterials These are made from biomaterials; these are used in orthopedic or dental implants or as scaffolds for tissue-engineered products. Their surface can be modified or coatings can be done which enhances biocompatibility with the living cells. These are further classified into two types nanocrystalline and nanostructure materials. Nanocrystalline These are readily manufactured and can substitute the less-performing bulk material. These materials are directly used in drug encapsulation, bone replacement, prostheses, and implants. Nanostructured materials These are processed forms of nanomaterials with special shapes and functions. These include quantum dots, dendrimers, fullerenes, and carbon nanotubes.

Nanodevices: These are the small devices on the nanoscale. These include nano and microelectromechanical systems (NEMS/MEMS), microfluidics, and micro assays. These also include biosensors and detectors, which are used in diagnosis. Carbon nanotubes These are hexagonal networks of carbon atoms. The length and diameter of these tubes are 1nm and 1-100nm in length. Nanotubes are of two type's single walled nanotubes (SWNTS) and multi walled nanotubes (MWNTS). These are small macromoleculesthat have unique sizes, shapes, and remarkable physical properties.

Polymeric nanoparticles:Polymeric nanoparticles are particles within the size range from 1 to 1000 nm and can be loaded with active compounds entrapped within or surface-adsorbed onto the polymeric core. The term "nanoparticle" stands for both nanocapsules and nanospheres, which are distinguished by their morphological structure. Polymeric NPs have shown great potential for targeted delivery of drugs for the treatment of several diseases[11]. These nanoparticles provide an alternative to above mentioned nanosystems due to inherent properties like biocompatibility, non-immunogenicity, non-toxicity, and biodegradability. Polymeric nanoparticles are classified and comprised of nanocapsules and nanosphere. Nanocapsules are systems in which the drug is confined to a cavity surrounded by a unique polymeric membrane, whereas nanospheres are systems in which the drug is dispersed throughout the polymer matrix. Natural polymers used are gelatin, albumin, and alginate in the preparation of nanoparticles synthetic polymers used for nanoparticles preparation of nanoparticles synthetic polymers used for nanoparticles of preparation may be in the form of preformed polymer. e.g.:- polyesters like polycaprolactone.

Dendrimers: Dendrimers are the emerging polymeric architectures that are known for their defined structures, versatility in drug delivery, and high functionality whose properties resemble biomolecules. These nanostructured macromolecules have shown their potential abilities in entrapping and/or conjugating the high molecular weight hydrophilic/hydrophobic entities by host-guest interactions and covalent bonding (prodrug approach) respectively. Moreover, the high ratio of surface groups to molecular volume has made them a promising synthetic vector for gene delivery [12]. These are hyperbranched, tree-like structures and have compartmentalized chemical polymers. It contains three different regions core, branches, and surface. The core forms the central part and the branches radiate from it forming an internal cavity and a sphere of groups. The branches can be altered or modified according to requirements. The dendrimers can be made into more biocompatible compounds with low cytotoxicity and high permeability according to the requirements. These can deliver bioactive substances like drugs, vaccines, materials, and genes to desired sites.

Liposomes When a dry phospholipid is hydrated and close vesicles are formed, these vesicles are called liposomes. There are 3 types of liposomes based on the number and size of the vesicles such as Multi lamellar vesicles (MLVs) with several vesicles separated by aqueous space, small uni-lamellar vesicles (SUVs), and large uni-lamellar vesicles consisting of single bilayer surrounding the entrapped space[13]. Cationic liposomes are employed as transfection agents in gene delivery by conquering the limitations linked with viral vectors [14].

Quantum Dots: Quantum dots are semiconductor particles a few nanometres in size with optical and electronic properties that differ from those of larger particles via quantum mechanical effects. They are a central topic in nanotechnology and materials science. When a quantum dot is illuminated by UV light, an electron in the quantum dot can be excited to a state of higher energy. In the case of a semiconducting quantum dot, this process corresponds to the transition of an electron from the valence band to the conductance band. The excited electron can drop back into the valence band releasing its energy as light. The color of that light depends on the energy difference between the conductance band and the valence band, or the transition between discrete energy states when the band structure is no longer well-defined in QDs [15]. These are semi-conducting materials consisting of a semiconductor core coated by a shell to improve optical properties. Their properties originate from their physical size which ranges from 10-100A⁰ in radius. Quantum dots have wide applications in medical as well as pharmaceutical areas like DNA hybridization, time-graded tissue fluorescence imaging, immunoassays, celllabeling, biomolecules analysis, DNA cells or drugs, transporting vehicles, and therapeutic tools for cancer management.These have a large impact on imaging, in-vitro, and in-vivo detection and analysis of biomolecules, immunoassay, and DNA hybridization and in non-viral vectors for gene therapy. It has the main function of labeling cells and therapeutic tools for cancer treatment.

Metallic nanoparticles: Metallic NPs have several applications that are useful in diagnosis and therapeutic procedures. Metallic NPs like quantum dots, gold NPs, and magnetic NPshave their advantage in therapy as drug carriers or as bioimaging agents.Physiochemical properties, high stability, high reactivity, and photothermal and plasmonic properties of metallic NPs make them potent carriers as a therapeutic agents. The metal- and metal oxide–supported nanomaterials have shown significant therapeutic effects in medical science. The mechanisms related to the interaction of nanoparticles with animal and plant cells can be used to establish their significant role and to improve their activity in health and medical applications [16]. Metallic nanoparticles are more favored in good delivery as a carrier for drugs and biosensors. Nanoparticles of various metals have been made yet silver and gold nanoparticles are of prime importance for biomedical use, a large number of ligands have been linked to nanoparticles such as sugar, peptides, proteins, and DNA. These nanoparticles have surface Functionalization and are very easy to decorate ligands onto the surface. Due to this Functionalization ability, these are used for active delivery of bioactive, drug discovery, bioassays, detection, imaging, and many other applications.

Nanotechnology in imaging and diagnosis: Diagnosis of a disease is one of the most crucial steps in the healthcare process. All diagnoses are desired to be quick, accurate, and specific to prevent ‘false negative’ cases. In vivo imaging is a noninvasive technique that identifies signs or symptoms within a patient's live tissues, without the need to undergo surgery [17]. A previous improvement in diagnostic imaging techniques is the use of biological markers that can detect changes in the tissues at the cellular level. The aim of using a biological marker is to detect illnesses or symptoms, thereby serving as an early detection tool [18]. Notably, some of these high-precision molecular imaging agents have been developed through the use of nanotechnologies. In addition to diagnosis, imaging is also vital for detecting potential toxic reactions, in controlled drug release research, evaluating drug distribution within the body, and closely monitoring the progress of therapy. Potential drug toxicity can be reduced with the possibility of monitoring the distribution of drugs around the body and by releasing the drug as required (26). Diagnostic imaging. Imaging techniques such as X-ray, ultrasound, computed tomography, nuclear medicine, and magnetic resonance imaging are well-established and are widely used in biochemical and medical research. However, these techniques can only examine changes on the tissue surface relatively late in disease progression, although they can be improved through the use of contrast and targeting agents based on nanotechnologies, to improve resolution and specificity, by indicating the diseased site at the tissue level. Currently used medical imaging contrast agents are primarily small molecules that exhibit fast metabolism and a nonspecific distribution, and can thus potentially result in undesirable toxic side effects [19]. This particular area is where nanotech- nologies make their most significant contribution to the field of medicine, by developing more powerful contrast agents for almost all imaging techniques, as nanomaterials exhibit lower toxicity, and enhanced permeability and retention effects in tissues. The size of the nanoparticles significantly influences their biodistribution, blood circulation half-life, cellular uptake, tissue penetration, and targeting.

APPLICATIONS OF PHARMACEUTICAL NANOTECHNOLOGY:

Miniaturization is beneficial in pharmaceutical technology. Since It has increased complexity It also imparts a large number of benefits in drug delivery and diagnosis. The various pharmaceutical and biochemical areas where nanosystems are used are:-

I) **As nanomaterials for tissue engineering**: The nanomaterials are used for tissue repair and replacement, Implant coatings, Tissue regeneration, Structural implant materials, Bone repair, Bio-reusable materials, Implantable devices (sensory aids, retina implants), Surgical aids, Operating tools and also in Smart instruments.

II) **Drug carrier system**:Nanotech-enabled drug delivery system with optimized physical, chemical, and biological properties, which can serve as effective delivery tools for currently available bioactive. Some nano-based carrier systems are polymeric nanoparticles, liposomes, dendrimers, polymeric micelles, polymer-drug conjugates, and antibody-drug conjugates. These can be classified as 1. Sustained and controlled delivery system. 2. Stimuli-sensitive delivery system. 3. Functional system for delivery of bioactives. 4. Multi-functional system for combined delivery of therapeutics, biosensing and diagnostic. 5. Site-specific targeting (intracellular, cellular, tissue).

III) **Molecular diagnostics**: It represents, characterizes, and quantifiessub-cellular biological processes including gene expression, protein-protein interaction, signal transduction, and cellular metabolism. They are used in magnetic resonance imaging, optical imaging, ultrasonic imaging, and nuclear imaging. Other applications are specific labeling of cells and tissues, useful for long-term imaging, multicolor multiplexing, dynamic imaging of sub-cellular structures fluorescence resonance energy transfer, and magnetic resonance imaging (MRI). MRI agents are replaced by nanomaterials like dendrimers, quantum dots, carbon nanotubes, and magnetic nanoparticles. They are very efficient, stable, intense, and clearer images due to high intensity, photostability, resolution, and resistance.Quantum dots, iron oxide nanocrystals, and metallic nanoparticles.

IV) **Nanobiosensors**- The merging of Nanotechnology with Biosensors. Nanobiosensors are the sensors that are made up of nanomaterials and interestingly these are not the specialized sensors that can detect the nanoscale events and happenings. The question that sustains interest from the above description is why nanomaterials are intended to be used in making biosensors or whether they are going to drive any significant difference in the overall technology. Nanomaterials are a unique gift of nanotechnology to mankind; these are materials that have dimensions between 1-100 nanometres. The size constraints of these materials make them very special as they have most of their constituent atoms located at or near their surface and have all vital physicochemical properties highly different from the same materials at the bulk scale. They can play very efficient roles in the sensing mechanism of the biosensing technology. Integrated devices of the nanomaterials with electrical systems give rise to nanoelectromechanicalsystems (NEMS) which are very active in their electrical transduction mechanisms[20]. These tools are employed for the determination of various pathological proteins and physiological-biochemical indicators associated with disease or disrupted metabolic conditions of the body. A biosensor is a measurement system that consists of a probe with a sensitive biological recognition element or bio-receptor, a physiochemical detector component, and a transducer to amplify and transducer these signals into measurable form. A nano biosensor or nanosensor is a biosensor that has dimensions on the nanometer size scale. Biosensors are used in target identification, validation, assay development, and toxicity determination.

V) **Drug discovery:** Nanotech helps in the identification and validation of targets by identifying the protein present on the surface or target surface. Nanotech will enhance the drug delivery process, through miniaturization, automation, and reliability of assays. Single-walled nanotubes are successfully used to identify surface proteins of pathogens. Quantum dots- track individual glycine receptors and analyze their dynamics in the neuronal membrane of living cells, for periods ranging from milliseconds to minutes. Gold nanoparticles, and nanobodies (smallest, available, intact antigen-antibody fragments) produced by Ablynx are some commonly used nanomaterials in diagnosis. Pharmaceutical nanotechnology is used in the detection of pathogens in humans, the separation and purification of molecules and cells, and detoxifying agents. Future nanomachine (respirocyte) is the nano-on-board mini-computer,that can be used for the detection of disease-causingmarkers or antigens, to view the diseased site, and to deliver the therapeutic agent at the site. Pharmaceutical nanotechnology has important applications in the discovery of new drugs. It helps to detect the biomarkers associated with specific diseases or mechanisms of action of a drug. Nanotechnology helps to improve the drug discovery process through automation, speed, and reliability of assay [21].

Basic characters of a Biosensor :

1) Linearity: - Maximum linear value of the sensor calibration curve. The linearity of the sensor must be high for the detection of high substrate concentration
2) Sensitivity: - The value of the electrode response per substrate concentration
3) Selectivity: - Interference of chemicals must be minimizedto obtain the correct result
4) Response time: - The necessary time for having 95% of the response

II. CONCLUSION

Pharmaceutical nanotechnology has emerged as a discipline having enormous potential as a carrier for spatial and temporal delivery of bioactives and diagnostics and provides smart materials for tissue engineering. It offers new tools, opportunities, and scope, which are expected to have a great impact on many areas in disease, diagnostics, prognostics, and treatment of diseases through its nano-engineered tools. Pharmaceutical nanotechnology provides opportunities to improve materials, and medical devices and help to develop new technologies where existing and more conventional technologies may be reaching their limits. It raises new hope to industries by providing new patentive technologies giventhe revenue loss caused due to off-patent drugs. Pharmaceutical nanotechnology has a profound influence on disease prevention efforts because it offers innovative tools for understanding the cell as well as the difference between normal and abnormal cells. It could insights into the molecular basis of disease. Some of the advantages are:- 1. Identifying, defining and characterization of model nanomaterials. 2. Developing toxicity testing protocol. 3. Detecting and monitoring exposure levels. 4. Assessing the impact of the environment. 5. Developing the biocompatible hybrid system. But still we lack the sufficient data and guidelines regarding safe use of these nanotechnology-based devices and materials. There are several confounding unresolved issues, which warrant the application in its full boom.

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