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Nanoparticles and Their Applications – A Review

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Abstract:

Aim:
To spread awareness about the insight of nanoparticles and its various uses.

Objective:
Nanoparticles synthesis and the study of their size and properties are important in medicine as well as biological fields. So, it's necessary to have an insight about the nanoparticles and its applications.

Background:
For the past few decades, there has been a considerable research interest in particulate delivery systems. So, particulate systems like nanoparticles have been utilized as physical approaches to change and improve the pharmacokinetic and pharmacodynamics properties of various types of drug molecules.

Reason:
To create awareness regarding the knowledge of nanoparticles and its uses in industrial and medical fields.

Keywords: Nanoparticles, awareness, particulate, nanotoxicity, drug delivery systems.

INTRODUCTION:

Nanotechnology is associated with nano-meter sized objects[1]. Living organisms are made up of cells. These cell parts, however, are nano sized[2]. Nanotechnology basically deals with design, production and characterization on nano sized particles[3]. Nano sized particles are basically small objects that act as a whole unit in accordance with their transport and properties. Fine particles have the range of 100-2500nm and ultrafine particles have the size of 1-100nm[4]. They can also be designed to improve the pharmacological and therapeutic effects of the drugs[5]. They also have a very high surface area and they permit many functional groups to be adhered to them which in turn, can bind to tumor cells[6]. They have proven to be an excellent replacement for radiation and chemotherapy as they can easily assemble in the micro environment of the tumor. Recent studies have developed a number of nano-sized particles such as metals, semiconductors and polymeric particles utilized in molecular imaging and particulate delivery vehicles[7-9]. Polyethleneimine liposomes, silica nanoparticles, micelles and chitosans play an important role in drug delivery with minimized side effects[10,11]. They have also been utilized as anticancer agents[12]. So, basically, nanotechnology deals with construction of artificial cells, enzymes and genes or repair in the synthesis of protein[13]. In this review, we discuss the synthesis, types, applications, advantages and limitations of nanoparticles.

SYNTHESIS OF NANOPARTICLES:

They are synthesized either biologically or chemically. Many harmful effects were associated with chemical synthesis method due to presence of some toxic chemicals absorbed on the surface. Biological synthesis method utilizes microorganisms, enzymes, fungus and plants or plant extracts.[14-19]. They can be prepared from materials such as proteins, polysaccharides and synthetic polymers. Moreover, the presence of large secretory parts in fungi is the reason for their extracellular synthesis of nanoparticles[20]. The matrix material selection depends on many factors such as size of nanoparticles, drug's inherent properties, aqueous solubility and stability, charge, permeability, biodegradability, biocompatibility, toxicity, drug release and antigenicity of the final product[21].

TYPES OF NANOPARTICLES:

Silver Nanoparticles

Under atmospheric condition, silver ions are reduced by ethanol at 800°C to 1000°C to obtain the silver nanoparticles[22]. They are the most commonly used type of nanoparticles. They have good antimicrobial efficacy and so they are used in textile industries for sunscreen creams and water treatment[23,24]. Research studies have revealed the advantageous biosynthesis of silver nanoparticles by plants like *Azadirachta indica*[25], *Capsicum annuum*[26] and *Carica papaya*[27].

Gold Nanoparticles

Liquid chemical method is used to produce gold nanoparticles by Chloroauric acid ($HAuCl_4$) reduction[28]. They are utilized in immunochemical studies and detection of protein interactions. They are also used for detecting the presence of DNA in a fingerprint sample, aminoglycoside antibiotics like grentamycin, streptomycin and neomycin. Cancer stem cells and different classes of bacteria can also be detected by gold nanorods[29,30].

Copper Nanoparticles

Under microwave irradiation, reduction of copper sulphate with hydrazine in ethylene glycol is a new method for preparing copper nanoparticles[31]. Polyvinylpyrrolidone plays a crucial role on the size of the copper nanoparticles, and increase in its concentration elicits smaller dimension particles[32]. They are basically 1 to 100 nanometers in size[33]. They can be applied to biosensors and electrochemical

sensors[34]. They also serve as antifungal or antibacterial agents[35].

APPLICATIONS OF NANOPARTICLES:

IN DRUG DELIVERY

Firstly, the most significant advantages of nanoparticles used on drug carrier are high stability, high carrier capacity, expediency of accommodation of both hydrophilic, hydrophobic substances and various routes of administration including oral application and inhalation[36]. Certain drugs cannot pass the first pass metabolism. The nanoparticles can be modified to overcome this and they also allow controlled sustained drug release from the matrix. These attributes can enhance the bioavailability of the drug and also in the reduction of the dosing frequency[37]. Quantum dots are miniature semiconductor particles of few nanometers in size. They are also called as artificial atoms with distinct electronic states. When light or electricity is applied to them, they emit light of variable frequencies. These frequencies can be altered by changing the dots' sizes, shapes and materials eliciting many applications in the process[38,39]. The most advanced approach of quantum dots technology associated with anticancer drug therapy is called ZnQ Quantum dots. The essence of this technology is that the quantum dots are loaded with anti-cancer agents and are encapsulated with biocompatible polymers. This is how the tumor targeted drugs are delivered and this is one of the important applications of Quantum dots technology[40]. Verdun et al established that when mice were treated with doxorubicin integrated into isohexylcyanoacrylate nanospheres, there were higher concentrations of doxorubicin in liver, spleen and lungs than in mice which were treated with free doxorubicin[41]. The greatest objection of using nanoparticles for tumour targeting is the prevention of particle uptake by mononuclear phagocytic system in liver and spleen. This was demonstrated by Bibby et al through the biodistribution and pharmacokinetics of a cyclic doxorubicin-nanoparticle formulation in tumour-bearing mice. These nanoparticles are been modified as delivery vehicles for many more therapeutic pharmaceuticals such as liposomal nanoparticles, layered double hydroxide, water soluble polymers drug conjugate to enhance half life with potent anticancer effect[42-46]. It is more difficult to deliver drugs to the central nervous system and brain but the nanoparticles can overcome these obstacles ensuring the success rate of the drug delivery in the brain.

IN FOOD

The major areas where nanotechnology has potential utility in the food sector are encapsulation and emulsion formation, in food contact materials and sensor development. Cultivation, producing, packaging and processing of food using nanoparticles is demonstrated as nanofood by Garber. FSAI determined some applications of nanofood which include sensory improvements (flavor/color enhancement and texture modification), increased absorption, targeted delivery of nutrition bioactive compounds, stabilization of active ingredients such as nutraceuticals in food sources, packaging and product improvement to extend shell life, sensors for food safety and antimicrobials to eradicate pathogenic microbes in food[47,48]. Bionanocomposites are hybrid nanoparticles with enhanced mechanical, thermal and gas attributes. They are utilized in packaging of food, increase its shelf. This is environment friendly as it reduces reliability on plastics for packaging. An example is zein which is a prolamin and a major component of corn protein which, when dissolved in ethanol or acetone can produce a biodegradable zein film with improved tensile and water barrier properties[49]. In Australia, nanocapsules are utilized to accommodate omega-3-fatty acids to white bread. In Asia, the development of non-toxic nanoscale herbicides to intervene weed's seed coating and prevention of germination is in progress[50]. So, the application of nanotechnology in food is emerging rapidly and is involved in all areas of food chain.

IN MEDICINE

Nano medicine aids in early detection and prevention, enhanced diagnosis and follow up of diseases. Invention of nano devices like gold nano particles has made gene sequencing less difficult. They are also used to detect genetic sequences when they are adhered with the short DNA segments. Damaged tissue can be repaired or reproduced using nanotechnology. Organ transplantation or artificial implantation can be revolutionized using nanotechnology. Magnetic nanoparticles have proven to be successful in isolating and grouping stem cells. Quantum dots on the other hand, have been used for molecular imaging and tracing of stem cells etc. Controllable regulation of proliferation and differentiation of stem cells is made possible by designed unique nano particles[51]. Another added benefit of nanotechnology is regeneration and neuroprotection of Central Nervous system. Parkinson's disease is one of the most known neurodegenerative disorders. Intracranial nano-enabled scaffold device (NESD) for the site specific drug delivery of dopamine to the brain is an excellent method to reduce the peripheral side effects of Parkinson's disease therapy. Novel methods include activation of signaling cues for controlled axon growth and peptides and peptidic nano particles as novel tools for various Central Nervous system diseases. They can also provide functional regeneration of damaged neurons so as to provide neuro protection and facilitation of drug delivery and molecules across the blood brain barrier. Amyloid beta plaques are mainly found in the brains of Alzheimer patients. These nanoparticles may suppress these plaques as they have high affinity for them, thereby improving the Alzheimer's disease condition. Tuberculosis is a deadly infectious disease. A more effective and an affordable TB pharmacotherapy was made possible due to the recent improvements in nano-based drug delivery systems for encapsulation and release of anti-TB drugs[52]. In par with operative dentistry, nano filled composite resin materials provide effective wear resistance, tenacity and excellent aesthetic values as a result of their unique luster retention and polishability. Spherical silicon dioxide nano fillers elicit the possibility of modifying the load of inorganic phase in operative dentistry. These nano composites have extreme hardness, great bend strength, good elasticity, reduced polymerization shrinkage[53,54].

Some of the applications of nanotechnology in ophthalmology include treatment of oxidative stress, intraocular pressure measurement, treatment of choroidal new vessels, prevention of scar formation post glaucoma surgery, prosthetics etc[55]. Treatment of severe evaporative dry eye is done by nanoscale dispersed eye ointment (NDEO) in the recent times. Histological evaluation suggested that the normal corneal and conjunctival morphology was restored through NDEO[56]. The resistance to antibiotics can be minimized by using Zinc Oxide nanoparticles thereby enhancing the antibacterial activity of Ciprofloxacin against microorganisms. This is brought about by intervention of these nano particles with the proteins interacting in the antibiotic resistance[57]. The nano device buckminsterfullerenes (bucky balls) can change the immune response by preventing the release of histamine from mast cells into the blood and the tissues[58]. Nano pharmaceuticals minimize toxic systemic side effects to an extent resulting in better patient compliance. They play a crucial role in detecting the failure of traditional therapeutics which provide site-specific targeting of active agents. Nanoparticle based thrombocytic agents have enough potential to accelerate the clot removal effect. In nanodentistry, treatment possibilities include the application of nanotechnology to dentition renaturalization, the permanent solution for hypersensitivity, complete orthodontic realignments etc. Eradication of Caries-causing bacteria and reparation of tooth blemishes where decay has adhered to, are made possible with the help of nanorobots in accordance with a computer to control them[59].

LIMITATIONS OF NANOTECHNOLOGY

A major drawback is that the nanoparticles might be undetectable after releasing them into the environment, whereby can cause problems if remediation is needed. Therefore, analytical techniques are needed to be improved to detect nanoparticles in the environment. Sufficient information is needed regarding the relationship of surface area and chemistry to the functioning and toxicity of nanoparticles. Moreover, novel nanoparticles elicit a risk of exposure during manufacture or usage. So, complete risk assessments have to be taken into consideration. When there is a need to use the scarce material for the elaboration of the nanoparticles, an efficient strategy for recycling and recovery is needed. Therefore, further investigation is required to fill the wide knowledge gap in the area of nanotoxicity as this will aid to improve risk assessment[60].

CONCLUSION

Poorly soluble, poorly absorbed and labile biologically active substances are re-modified to promising deliverable drugs through the recent advancements of nanotechnology. The knack of nanotechnology to engineer matter at the smallest scale is re-developing areas such as information technology, cognitive science and biotechnology. Further research studies in nanotechnology, can be useful for every aspect of human life.

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