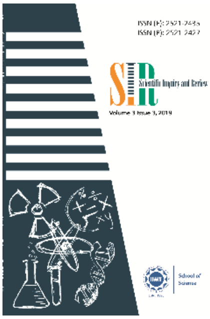

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The Role of Nanoparticles in the Diagnosis and Treatment of Diseases

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Abstract

Nanotechnology is involved in the diagnosis and treatment of infectious and inflammatory diseases. It has shown a good role in regenerating, restoring and repairing damaged body parts, such as the heart, lungs and blood vessels. Nanoparticles (NPs) are helpful in osteoblasts formation and also used in the treatment of bone inflammation, skin infections, tuberculosis (TB), human immunodeficiency virus (HIV), Parkinson's disease, atherosclerosis, cardiovascular and pulmonary diseases. They also assist the anti-inflammatory drugs in penetrating the skin. Platinum nanoparticles (NP) are used in bone allograft and dentistry while silver NPs possess an excellent potential against viruses, fungi and bacteria. For diagnostic purposes, nanoparticles are mostly used in the form of nanorobots, microchips and biosensors. Quantum dots give information about the tumor; the gold nano-particles are ideal to detect the antibodies of hepatitis and also for RNA and DNA delivery. Nanomaterials play an important role in the management of plant diseases and the activation of their defense mechanisms. The NPs of copper and silver are directly toxic to microorganisms while those of zinc, silicon, manganese, copper and boron have a function in host defense as a fertilizer and alter the nutritional status of the crop. Enzyme-based biosensors coated with Ti, Cu, Ag or Au-NPs greatly enhance the sensitivity of diagnostic probes for the detection of plant infections. The nano-Zn products have been effectively used to control viral, fungal, phytoplasma or bacterial diseases in crop plants. Nanoparticles are also used in packing edible food films.

Keywords: diagnosis, diseases, nanomaterial, nanoparticles, treatment

Introduction

Nanoparticles (NPs) include a huge class of materials having small discrete masses, ranging in size from 1-100 nm [1] and having a large number of applications in various fields [2-5]. They may exist in zero, two or three-dimensional forms. The Nanoscale size is an important property of matter. The 20-nm platinum, gold, palladium and silver nanoparticles have characteristic yellowish gray, wine red, dark black and black colors, respectively [6]. NPS are complex molecules that are formed from 3 layers: (a) The outermost layer, which may be functionalized with many biomolecules like proteins, DNA and other polymers and surfactants, (b) the middle layer, which varies chemically from the inner layer in all characteristics, and (c) the inner core which is essentially the inner part of the NPs [7]. Figure 1 [6] shows the color dependence on the size and shapes of nanoparticles. Gold nanorods (a), silica-gold core-shell nanoparticles (b) and gold nanocages (c) are commonly applied in biomedical applications. Their intense color depends upon the collective excitation of their conduction electrons, or surface plasmon resonance modes [6, 8, 9].

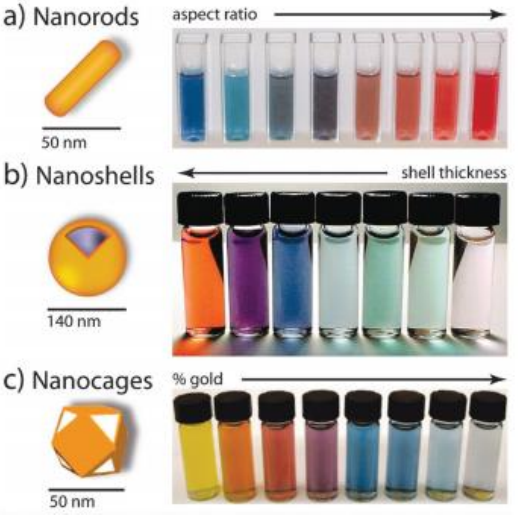

Figure 1. Color dependence of gold NPs on their shapes [6, 8, 9]

The nanoparticles can be classified into ceramic nanoparticles, metal nanoparticles, carbon-based nanoparticles, semiconductor nanoparticles, lipid-based nanoparticles, polymeric nanoparticles, *etc* [10].

There are many methods for the preparation of nanoparticles, but the following two methods are the most commonly used:

1. Top-down approach
2. Bottom-up approach [11]

Characterization of nanoparticles involves the study of many facts like the structure and properties of nanoparticles and the material from which nanoparticles are formed [12]. Nanoparticles can be characterized by various techniques including X-ray diffraction, scanning electron microscopy, atomic force microscopy, transmission electron microscopy, Fourier transform infrared spectroscopy, Raman spectroscopy, X-ray photoelectron spectroscopy and particle size analysis [13] . SEM and TEM are essential techniques. SEM depends on the electron scanning method [14] whereas TEM depends on electron transmittance properties [15]. XRD is based on structural properties [10].

The current study was performed to evaluate the role of nanoparticles in the diagnosis of a disease and its treatment.

2. Role of Nanoparticles in Disease Diagnosis and Treatment

Material science is directly related to nanotechnology. Nanotechnology deals with small-sized particles which find applications not only in research but also in daily lives. Nanotechnology when used for the diagnosis and treatment of diseases is known as nanomedicine. Nanotechnology has been used in different fields, but its use in medicine is the most recent [16, 17]. Nanostructures are prepared in various shapes, sizes and material properties and find a lot of applications in therapeutics, clinical diagnostics and biomedical imaging. However, there is still not a complete understanding of how cells interact with nanostructures at the molecular level. The membrane receptor internalization can be regulated by silver and gold nanoparticles coated with antibodies. The size of nanoparticles governs the activation of membrane receptors, their binding and protein expression. Although the signaling processes is essential for basic cell functions (including cell death), it can be altered by nanoparticles of 2–100 nm size range; however, the greatest effect has been shown by nanoparticles of 50-, 40- and 7-nm sizes. Nanoparticles may play an important role as simple carriers for biomedical applications and play a role in mediating biological effects [18]. A bigger purpose of nanomedicine is finding health issues and providing suitable treatment. If nanotechnology is connected with medicine then the treatment of disease becomes more effective [19]. The tempo of the modern world revolves around the major problem of health. Cancer, diabetes, depression and many other diseases are commonalities in fast-moving life. Nanoparticles in the form of nanorobots, microchips and biosensors are mostly used for diagnostic purposes [20].

In simple chemotherapy, where nanoparticles are not involved, the pharmacologically active drugs move towards the tissues which are damaged by cancer. In these old methods, many problems are associated. Such drugs can kill healthy tissues owing to their toxicity. But nanoparticles using biodegradable polymers are more effective in eradicating problems [21]. Quantum dots are a nanoparticle fabrication that glows when placed in UV light. When these nanoparticles (quantum dots) are moved towards the inner cancerous cells, they start glowing and map out the tumor. According to recent studies, the antibodies are linked with the magnetic poly-(D, L-lactide-co-glycolide) nanoparticles with doxorubicin (DOX). Magnetic nanoparticles and DOX are integrated into the poly-(lactic-co-glycolic acid) (PLGA) nanoparticles for targeting diseased cancerous cells. For targeting the breast cancer antibody, Herceptin is more effective [22].

Many imaging techniques like ultrasound imaging (USI), magnetic resonance imaging (MRI) and optical imaging (OI) are used to study human beings internally and externally. These techniques involve numerous nanoparticles which can help in *vivo* and *vitro* studies [23]. Many nanoparticles are used in the diagnosis and treatment of infectious and inflammatory diseases. Hepatitis is an infectious disease that is caused by a virus. It is a chronic disease that may be associated with the whole life. Nanoparticles, in particular Gold nanoparticles, can be used for the diagnosis of this disease. Gold nano-protein chips are formed which detect the antibodies of hepatitis making them effective for diagnostic purposes. For treatment purposes, DNA vaccine coated SiO_2 (LDH) nanoparticles induced antibody is mostly used [24].

Nanomaterials (especially those of metals) are effective in osteoblasts formation and the treatment of bone inflammation. They provide more surface area for osteoblasts formation. Titanium (Ti) nanoparticles are generally used for the treatment of bone inflammation. Superparamagnetic iron oxide nanoparticles are linked with the PLGA particles and are used in joint inflammation [25]. Nanotechnology is also effective in the treatment of skin infections. One of the medicines used for the treatment of skin infection is nitric acid-coated nanoparticles. Iron oxide nanoparticles have a direct link with protein thrombin. Thrombin protects anti-thrombin and takes part in the process of tissue repair. Nanoparticles help anti-inflammatory drugs in penetrating the skin [26].

Noble metals and their composites were used in earlier times as healing agents and medicines for many diseases. The nanoparticles are used for the treatment of many diseases like HIV, TB and Parkinson's disease. Nanotechnology also finds applications in dentistry; it helps in the production of Nano-filled resin composites whose nanosized filler particles dissolve in high concentration, thus enabling the deposition of hydroxyapatite on enamel; it helps to improve the bond durability between adhesive resin and tooth structure. Platinum (Pt) particles are especially useful in bone allograft and dentistry. Noble metal nanoparticles are used in several technological applications and have attracted great interest from the scientific community. They are considered powerful tools against cancer. Being natural materials, platinum, gold and silver have either no or very few side effects or are considered safe when they are applied for disease treatment. Silver NPs possess excellent antimicrobial potential against a wide range of viruses, fungi and bacteria. The characteristic properties of platinum and silver NPs make them ideal for the diagnosis of a disease and its treatment [27]. Nanotechnology also plays an important role in curing cardiovascular and pulmonary diseases. Its role in regenerating, restoring and repairing damaged body parts, such as the heart, lungs, blood vessels has also been reported. Carbon nanotubes are the more advanced form due to their unique electrical, thermal and mechanical properties; they are especially functionalized for the transport of drugs [28]. Atherosclerosis is the most common coronary disease which occurs mostly at a young age. The major cause of this disease is the progressive plaque deposition in the major arteries of the body that causes the blockage of arteries. For this purpose, drug-eluting stents (DES) are performed. Therefore, anti-proliferative drugs can be delivered using nanoparticles which help in drug delivery [29].

Drug delivery is one of the most important aspects in the field of research. It finds more applications in the clinical field. Many nanoparticles are used for the delivery of drugs in the diseased part of the body, with preference is given to gold nanoparticles (Au NPs). We can use gold nanoparticles in drug delivery due to many advantages: (1) they can easily be synthesized in various forms such as rods or cages (2) they can easily functionalize with any biomolecules due to the presence of negative charge on the surface of the nanoparticles (3) less toxic and so on. For proper delivery of drugs, nanoparticles are functionalized with biomolecules such as DNA, *etc*. There are two types of interactions through which nanoparticles are functionalized (1) through covalent interaction (2) non-covalent interaction. After the modification of nanoparticles, the antibody or transport drug is attached with Au NPs through ionic and covalent interactions. Drug delivery is more preferable for endocellular diseases. Methotrexate like folic acid controls diseases and acts like anti-cancer drugs. But in some cases, DOX is attached with nanoparticles. After the attachment, this enhanced modification is targeted into the receptor cells [30].

Gene therapy is an approach for the treatment of genetic diseases. For this, oligonucleotides like DNA, RNA and plasmids have healing effects. Gold nanoparticles are ideal for RNA and DNA delivery. Oligonucleotide acts as an intracellular regulatory agent. The surface of gold nanoparticles is modified with the attachment of oligonucleotides to improve their properties. These modified gold nanoparticles act as intracellular gene regulation agents [31]. Alzheimer's disease (AD) is one of the most common diseases in early aged people and it is a highly serious issue in 35 million people all over the world. The effects of this disease are increasing every year. It has neurological effects and can also cause loss of memory. For this purpose, a dual-function nanoparticle drug delivery system based on PEGylated poly(lactide) (PLA) has been prepared, which may be helpful in the diagnosis and treatment of AD [32]. Photothermal ablation therapy mediated by the gold nanoparticles is a new minimally invasive therapeutic approach that has been shown *in vitro* and *in vivo* to be highly effective at killing tumor cells [33]. Studies have been reported on the efficient iron oxide labeling, without the use of cell-penetrating peptides or transfection agents, in a clinically relevant non-phagocytic cellular system [34]. The role of quantum dots (QDs) in the diagnosis of cancer has been reported. They are also important in unlocking complex neurological phenomena, such as molecular activities at synapse during neurotransmission [35]. AuNPs have an average width of 50nm which is quite consistent for their entry into the cancerous tissue or any type of cells. Because cancerous cells have a high metabolic rate, there is more probability of transporting a higher number of AuNPs into them as compared to usual tissues and they also get detached from the body by any mechanism of secretion without causing any trouble [18].

Nanomaterials also play an important role in the management of plant diseases and the activation of their defense mechanisms. The NPs of copper and silver are directly toxic to microorganisms while those of zinc, silicon, manganese, copper and boron have a function in host defense as a fertilizer and alter the nutritional status of the crop [36]. Efforts are being made to design phytopathogen detection devices with smart sensing capabilities for field use [37]. The Nanosensors and nanoparticles have a broad range of applications in the diagnosis of plant diseases and detection of microbial infections. Enzyme-based biosensors coated with Ti, Cu, Ag or Au-NPs may greatly enhance the sensitivity of diagnostic probes for the detection of plant infections. A higher concentration of active ingredients of pesticides, etc. can be efficiently carried by Nanocapsules, nanotubes and other nanomaterials with its controlled release and regulation in the target plant [38]. For the treatment of plant diseases, they are used either by controlled delivery of functional molecules or as a diagnostic tool for disease detection [35]. The Nano-based diagnostic kits have been applied to monitor plant health [39] and to quickly detect potential serious plant pathogens to control the epidemic diseases; these kits not only increase the accuracy of the diagnosis but also increase the speed of pathogen detection. The use of nanotechnology with microfluidic systems finds applications in molecular plant pathology; it can be adapted to detect specific toxins and pathogens. The Nano-scale devices with novel properties are expected to build future smart agricultural systems for the protection of the crops and early warning; they will identify plant health issues before they are observed to the grower and will take an appropriate disease management action. New methods for crop protection will be developed by applying Nano phytopathology to understand plant–pathogen interactions [40]. The Nano-Zn products have been effectively used to control viral, fungal, phytoplasma or bacterial diseases in crop plants. They can be applied through numerous application modes and are useful in both open fields and closed greenhouse/screen-house conditions. They can be used to develop an affordable sensor system for sensitive and early detection of the pathogen attack so that the crop losses can be predicted on time to take important measures. and for surveillance purposes [41]. Engineered nanoparticles (1 and 100 nm) can be applied as Nano fertilizers and bactericides/fungicides due to their high reactivity, large surface area and small size; they exist as and quantum dots, liposomes, functionalized dendrimers, carbon nanomaterials, nonmetals, metallic oxides and metalloids. Nanoparticles can be designed as delivery vehicles for agrichemicals, probes and genetic material [36]. Efficient pesticides in the form of alumino-Silicate nanotubes with active ingredients have been developed, which are easily picked up in the insect hair; the insects actively consume the pesticide-filled nanotubes and are killed. These sprays are relatively safer for environmental health and are highly active as well. Nanoparticles are also used in packing edible food films [42].

3. Conclusion

Nanostructures play an important role in regenerating, restoring and repairing the damaged body parts, such as the heart, lungs and blood vessels and also used in the treatment of bone inflammation, skin infections, tuberculosis (TB), human immunodeficiency virus (HIV), Parkinson disease, atherosclerosis, cardiovascular and pulmonary diseases. They also assist the anti-inflammatory drugs in penetrating the skin. For diagnostic purposes, nanoparticles are mostly used in the form of nanorobots, microchips and biosensors. They also find applications in imaging techniques like ultrasound imaging (USI), magnetic resonance imaging (MRI) and optical imaging (OI) for in *vivo* and *vitro* studies of human beings. Nanomaterials also have a considerable role in the management of plant diseases and the activation of their defense mechanisms. The NPs of copper and silver are directly toxic to the microorganisms while those of zinc, silicon, manganese, copper and boron have a function in host defense as a fertilizer and alter the nutritional status of the crop. The Nano-based diagnostic kits have been applied to monitor the plant's health and to quickly detect potential serious plant pathogens. The Nano-Zn products have been effectively used to control viral, fungal, phytoplasma or bacterial diseases in crop plants. Engineered nanoparticles (1 and 100 nm) can be applied as Nano fertilizers and bactericides/fungicides due to their high reactivity, large surface area and small size. Efficient pesticides in the form of alumino-silicate nanotubes with active ingredients have been developed. These sprays are relatively safer for environmental health and are highly active as well. Nanoparticles are also used in the packing of edible food films.

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