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Original Article

NANOPARTICLES: CURRENT DRUG DELIVERY AND TECHNOLOGY

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Abstract-
NPs are often created by reducing metal ions to uncharged nanoparticles using harmful reducing agents. However, there have been numerous recent efforts to develop green technology that utilizes natural resources rather than hazardous chemicals for nanoparticle productionThe importance of nanoparticles in technological progress stems from their adaptable characteristics and improved performance compared to their original material.. In green synthesis, biological methods are utilized for NP synthesis due to being eco-friendly, clean, safe, cost-effective, straightforward, and highly efficient. Many biological organisms, such as bacteria, actinomycetes, fungi, algae, yeast, and plants, are employed for the green synthesis of NPs. About its application in medicine, nanotechnology has the potential to greatly improve current therapies and diagnostics, as well as pave the way for unprecedented advancements due to its ability to work at a nanoscale level.

Keywords: Green-synthesis, Nanoparticles, Nanotechnology, Biological Synthesis, Microbial Nanotechnology, Bio-nanotechnology.

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INTRODUCTION

Nanotechnology has emerged as a significant scientific achievement in the 21st century. It encompasses the synthesis, management, and application of materials with a size smaller than 100 nm. Nanoparticles play a crucial role in various sectors including the environment, agriculture, food, biotechnology, biomedical, and medicine. The exceptional properties of nanoparticles (NPs), including their natural origins, biocompatibility, anti-inflammatory, and antibacterial activity, efficient drug delivery, bioactivity, bioavailability, tumor targeting, and bio-absorption, have fueled significant advancements in biotechnological and applied microbiological applications. NPs are revolutionizing wastewater treatment, environmental monitoring, functional food additives, and antimicrobial agents.[1,2,3]

A particle of matter with a diameter of one to one hundred nanometers (nm) is commonly referred to as a nanoparticle or ultrafine particle. Nanoparticles often display unique size-dependent characteristics due to their small size and large surface area. When the size of a particle approaches the nano-scale with a characteristic length scale close to or smaller than the de Broglie wavelength or the wavelength of light, the periodic boundary conditions of the crystalline particle are disrupted. Consequently, many of the physical properties of nanoparticles vary significantly from those of bulk materials, opening up a wide range of new and innovative applications.[4,5]

On the basis of dimensions NPs can be classified into four types[6]

1. Zero-dimensional (0D) objects have length, breadth, and height, with the corresponding author fixed at a single point. For example, nano dots.
2. One-dimensional (1D) objects possess only one parameter. For example, graphene.
3. Two-dimensional (2D) objects possess only two parameters, i.e., length and breadth. For example, carbon nanotubes.

4. Three-dimensional (3D) objects possess all three parameters, namely length, breadth, and height. For example, gold nanoparticles.[6,7]

Nanoparticles (NPs) can take on various shapes, sizes, and structures, such as spherical, cylindrical, tubular, conical, hollow core, spiral, flat, wire, and irregular forms. Their surfaces can be uniform or irregular, and they can exist in crystalline or amorphous forms, as single crystal solids or agglomerated multi-crystal solids. The physicochemical properties of these NPs are primarily influenced by their size and shape variations. With exceptional physical and chemical properties, NPs have demonstrated significant success in diverse applications, including medicine, environmental preservation, energy research, imaging, and chemical and biological sensing. Nanotechnology is increasingly recognized as a crucial factor for a clean and sustainable future, garnering significant attention from researchers.[6,7]

Structure of Nanoparticles[8,9]

Nanoparticles (NPs) possess a sophisticated structure, consisting of two or three layers: (i) a functionalized surface layer, modified by a variety of small molecules, metal ions, surfactants, or polymers, (ii) a purposefully added shell layer, chemically distinct from the core, and (iii) the core material, serving as the central component of the NPs.

The characteristic properties of NPs are generally due to the core material. Hence, NPs are often referred to by their core material only.

Nanoparticles (NPs) are typically categorized into various classes based on their morphology, size, and physical and chemical properties. They are mainly grouped as organic, inorganic, and carbon-based NPs.

A. Organic Nanoparticles[8]

Organic nanoparticles, ranging from 10 nm to 1 μm in diameter, consist of solid particles made of organic compounds like lipids or polymers.

Some commonly known organic nanoparticles include dendrimers, liposomes, micelles, and ferritin. These organic nanoparticles are environment-friendly, biodegradable, non-toxic, and more suitable in the biomedical field. Both micelles and liposomes have a hollow core, also known as nanocapsules, and are sensitive to thermal and electromagnetic radiation. These unique properties make organic nanoparticles an ideal choice for drug delivery as they are highly efficient in targeted drug delivery.

B. Inorganic Nanoparticles[8,9]

Inorganic nanoparticles are the particles that are not made of carbon. It includes metal and metal oxides As compared with organic NPs in inorganic NPs enormous research and commercial investments has been made.

1) Metal Based Nanoparticles[8]

Organic nanoparticles (NPs) like dendrimers, liposomes, micelles, and ferritin offer numerous advantages. These environment-friendly, biodegradable, and non-toxic NPs are cost-effective and well-suited for biomedical applications. With unique properties such as a hollow core, sensitive to thermal and electromagnetic radiation, these NPs are ideal for efficient drug delivery to targeted areas. Metal-based nanoparticles (NPs) ranging from 10 to 100 nm in size exhibit unique properties such as high surface area to volume ratio, pore size, surface charge and charge density, crystalline and amorphous structures, high reactivity, and sensitivity to environmental factors like air, moisture, heat, and sunlight. These exceptional properties make them highly promising for applications across various research areas.

2) Metal Oxides Based Nanoparticles[8,9]

Metal-based nanoparticles can be transformed into their corresponding oxides, known as metal oxide-based nanoparticles. Metal oxide-based nanoparticles have exceptional properties compared to their metal counterparts. Some examples of metal oxide-based nanoparticles include iron oxide (Fe2O3), magnetite (Fe3O4), aluminum oxide (Al2O3), cerium oxide (CeO2), silicon dioxide (SiO2), titanium oxide (TiO2), and zinc oxide (ZnO) These metal oxides based NPs found to be more reactive and efficient.

C. Carbon Based Nanoparticles[9]

Carbon-based nanoparticles (NPs) are composed of carbon and can take on various shapes, including tube-shaped, horn-shaped, spherical, or ellipsoidal. The two main classes of carbon-based NPs are fullerene and carbon nanotubes (CNTs). Other classes include graphene, nanofibers, and carbon black.

Advantage of Nanoparticles [10-15]

1. Modifying the surface characteristics and size of nanoparticles to target pharmaceuticals passively or actively following parenteral injection is a simple process.
2. Tagging certain bacteria with nanoscale quantum dots based on immunofluorescence to facilitate their identification and elimination.
3. Aquaculture is one of the many industries where nanotechnology is expanding. It has several uses in fields including nutrition.
4. Reproduction, fishing, disease prevention, water purification, and a decrease in toxicity and adverse effects.
5. Long-lasting medication release at the target location over several days or even weeks is made possible by the use of biodegradable ingredients in the creation of nanoparticles.
6. Due to their small size, nanoparticles are quickly absorbed by cells and can easily travel through tiny capillaries, allowing drugs to accumulate effectively at the body's target sites
7. Because NPs have a high surface energy and a big surface area to volume ratio, nanotechnology can increase the durability of fabrics.
8. The encapsulation technology makes it simple to incorporate nano supplements for efficient medication and nutrient delivery.
9. Food products are labeled with nanobarcodes to ensure their safety and to monitor their distribution.

Disadvantage of Nanoparticles[8,9,10]

Despite these benefits, nanoparticles do have some drawbacks, such as the following:

1. In the cellular milieu, nanoparticles exhibit strong reactivity due to their small size and large surface area.
2. Non-biodegradable particles may build up at the medication delivery site when they are utilized, which could result in a persistent inflammatory response [2].
3. The therapy cannot be stopped because of the restricted targeting capabilities of nanoparticles.
4. The cost of nanotechnology is high, and its development can be considerably more costly.
5. Nowadays, atomic weapons are more readily available, more powerful, and more devastating to use.

Application of nanoparticles[11-15]

Nanoparticles exhibit certain physical and chemical properties, such as mechanical, magnetic, optical, and thermal properties.

1. Medicine

The contributions of nanoparticles to medical imaging and medication and gene delivery have been very beneficial to clinical medicine. Ion oxide particles such as magnetite (Fe3O4) or its oxidized counterpart, hametite (Fe2O3), are most commonly used in biomedical applications. Ag NPs are becoming more and more common in home goods, wound dressings, and catheters due to their antibacterial action. Gold nanoparticles are showing considerable promise in cancer treatment as drug transporters, photothermal agents, and contrast agents. Over the past few decades, a lot of research has been focused on the creation of biodegradable nanoparticles as effective drug delivery vehicles. Many polymers have been used in drug delivery research because they effectively transfer drugs to their target site, enhancing therapeutic advantages while reducing unwanted effects.[11]

2. Diagnostics

NPs can be employed as imaging agents to help visualize specific bodily parts. To enhance the visibility of organs and tissues during magnetic resonance imaging (MRI), iron oxide nanoparticles, or Fe3O4NPs, have been utilized as contrast agents. Au NPs have special optical, electrical, and catalytic capabilities and are being researched for use in diagnostics because they can accumulate in some malignant tumors.

3. Tissue engineering

NPs can encourage the growth and repair of tissues and organs. For example, titanium dioxide nanoparticles (TiO2) have been studied for tissue engineering applications because of their ability to stimulate bone cell development.(11)

4. Antimicrobials

Some nanoparticles (NPs), such as silver NPs (Ag NPs) and copper nanoparticles (CuNPs), have strong antibacterial properties and are being researched for use in bandages and other medicinal goods. All things considered, NPs are the subject of current research for a wide range of uses and hold great promise for the medical industry. However, it is crucial to carefully consider the advantages and potential hazards of doing so in order to ensure the safe and responsible use of NPs in medicine.(12)

5. Cosmetic and sunscreens

The conventional UV sunscreen does not contain long-lasting medications. There are several advantages to sunscreen that contains nanoparticles, such as titanium dioxide. Titanium oxide and zinc oxide nanoparticles have been used in sunscreens because of their dual properties of being transparent to visible light and able to absorb and reflect ultraviolet radiation. A pigment called iron oxide nanoparticles is found in certain lipsticks.(37)

6. Time release of the drug(11)

To avoid nonspecific toxicity, the drug must remain encapsulated until the particle attaches to the target. While the particles are still in the circulatory system, it cannot diffuse them out. Targeted medication administration at the site of disease is a huge prospective application for nanoparticles, which has various crucial consequences, such as:

1. The bioavailability of drugs can be improved by using nanoparticles. medication that is intended for a specific area.
2. To improve the absorption of poorly soluble drugs.
3. Nanomaterials have been used to successfully formulate chemotherapeutic
4. Medications, such as paclitaxce, doxorubicin 5-fluro-uracil, and dexamethasone.

7. Cell specificity

Conjugation of antibodies to carbon nanotubes with fluorescent or radiolabelling to increase cell specificit.(13)

8. Protein detection

For human cells to continue developing, it is imperative that we comprehend the roles played by proteins, which are fundamental to the language, mechanism, and structure of cells. Gold nanoparticles are widely used in immunohistochemistry to identify protein-protein interactions. surface enhanced The capacity of Raman scattering spectroscopy to identify and detect individual dye molecules is a widely acknowledged method. Combining the two methods into a single NPs probe can greatly boost the multiplexing power of protein probes. The NPs are coated with hydrophilic oligonucleotides that have a Raman dye at one end and a small molecules recognition element terminally capped.(14-15)

9. Cancer therapy

The cytotoxic atomic oxygen generated by lasers, which kills cancer cells, is the cornerstone of photodynamic cancer therapy. Cancer cells absorb more of a certain dye—which is used to create atomic oxygen—than do healthy cells. So, the only radiation coming from cancerous cells Unfortunately, the residual dye molecules migrate to the patient's skin and eyes, making them extremely sensitive to sunshine. It could take up to six weeks for this effect to go away. To avoid this negative effect, the hydrophobic color molecules were encapsulated in porous nanoparticles. The dye stayed confined inside the cromosil NPs and did not spread to other parts of the body.(41,42)

10. Biological application

Nanoparticles have been demonstrated to initiate both intrinsic and extrinsic apoptotic pathways for the killing of malignant cells, and copper has demonstrated potential in the fight against cancer. Hela cells, Md A-MB-231 human breast cancer cell lines, Caco-2 human colon cancer cells, HepG2 human liver cancer cells, and McF-7 human breast cancer cells are all susceptible to the anticancer effects of copper and copper oxide nanoparticles. Copper nanoparticles demonstrated their anti-inflammatory and anti-arthritic capabilities in rats administered Complete Freund's adjuvant (CFA), which mimics the course of human arthritis. These nanoparticles boosted antioxidant enzymes and lowered pro-inflammatory indicators. In an in vivo investigation on mice, the capacity of CuNPs to heal wounds was demonstrated by a significant increase in the concentration of fibrocytes that finally generated collagen for.[16-17]

11. Nanobiosensors

Some examples of organic chemicals that have been used as antimicrobial packaging materials are essential oils, organic acids, and bacteriocins.Nanobiosensors are used in the food sector to identify infections during processing. Antimicrobial characteristics are exhibited by a variety of nanoparticles (NPs), such as Ag, chitosan, copper, and metal oxide NPs such as titanium oxide (TiO2). Conventional techniques of diagnosing infectious diseases are sluggish, tedious, and require a lot of work, especially during an emergency. The rapid, inexpensive, and accurate identification of infectious pathogens, hormone imbalances, and DNA has been made possible by the development of microbial biosensors. In forensic identification, microbial biosensors have been used to examine bodily fluid traces that contain DNA and miRNA as proof.[17]

12. Future Perspectives

Nanotechnology has been rapidly advancing and is useful in a wide range of industries. NPs can cause a range of health problems with the kidneys, lungs, and other organs in both humans and animals.However, more work has to be done to address the lack of awareness about the risks associated with prolonged usage. A safe technique for producing non-toxic NPs with additional beneficial features is green synthesis. Currently, one of the most fascinating areas of research is nanomedicine, which includes therapeutic alternatives, medication delivery, and cancer diagnosis. Producing NPs with uniform sizes, characteristics, biocompatibility with drug loading, and restricted release to the targeted cells is essential. It is acknowledged that NPs have significantly advanced the disciplines of diagnosis and therapy. Other areas, such the control of parasite infections and the reaction to cancer therapy, which has been reduced and is still insufficient, need to be included in their expectations.[17-22]

Conclusion

Targeted drug delivery is being studied using a variety of nanomaterials, including carbon-based, gold, titanium, dendrimers, and liposomes. Because of their greater surface-area-to-volume ratio, nanostructured scaffolds can be used as selective substrates to absorb specific proteins and promote cell adhesion.There are several uses for NPs based on metal and carbon in the biomedical and agricultural industries for the development of biosensors. Nanoparticles offer an incredibly attractive platform for a variety of biological applications. Nanomaterials are fascinating materials because of their superior and versatile physical, chemical, and biological capabilities over bulk materials. In this overview, we covered nanoparticles in brief, covering both their advantages and disadvantages. NPs are prepared using many methods, including top-down and bottom-up synthesis. Different nanomaterials are discussed individually with regard to their many characteristic properties, antibacterial activities, protein detector, drug release time, and waste water treatment activities.

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