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BRIEF REVIEW ON THE NANOPARTICLE

Mayur Jadhav[1], Adinath Sangale[2], Dr. Megha Salve[3]

[1]Shivajirao Pawar College of Pharmacy, Pachegaon, Maharashtra, India.

[2,3]Department of Pharmacy, Maharashtra, India.

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ABSTRACT

A nanoparticle's size typically has one or more dimensions and ranges from 1 to 100 nm. When compared to the greater size of the corresponding materials, nanoparticles are often characterized as inorganic, organic, or particles based on carbon in the Nano metric scale. Due to their reduced size, they exhibit improved qualities including strength, sensitivity, high reactivity, stability, surface area, etc. Three categories of technologies—chemical, physical, and mechanical processes—were used to synthesis them for research and commercial applications, and they experienced significant advancements in these procedures. In order to provide an overview of nanoparticles, including their types, characterizations, production techniques, and environmental applications, we have written this article.

Keywords: Method of Prepaaion, Mechanism of Actions of NPs, Classification of NPs, Nanostars, Nanorods, Decahedral nanoparticles, Nanofibers.

1. INTRODUCTION

Materials with overall dimensions in the nanoscale, or less than 100 nm, are referred to as nanoparticles. These materials have become significant players in contemporary medicine in recent years, with uses ranging from carriers of genes into particular cells to contrast chemicals in medical imaging**.** (1) The term "nanotechnology" describes a young branch of research that deals with the creation and synthesis of diverse nanomaterials. Objects with sizes between one and one hundred nm that may differ from the bulk material due to their size are known as nanoparticles. Current methods for producing various metallic nanomaterials include the use of copper, zinc, titanium, magnesium, gold, alginate, and silver. Nanoparticles are being employed for a wide range of applications, including medicinal treatments, the production of solar and oxide fuel batteries for energy storage, and their widespread integration into common products like clothing and cosmetics. (2) The last few decades have seen tremendous advancements in the field of Nano medicine, both in terms of design and application reach. Nanoparticles (NPs) are characterized using a variety of approaches, and their final fates within the human body are predicted. The characterization is frequently carried out in a situation that does not accurately reflect the complexity of the physiological environment, which presents a challenge to existing technology. Furthermore, the majority of in vivo research using animal models still employ a "black box" methodology, with NP pharmacokineties and brodistribution determined by a variety of biological processes that are difficult to anticipate in vitro. To hasten the conversion of a bench-top endeavor to a clinically In the early stages of product development, it is critical that researchers use appropriate approaches to characterize Nano medicine, correlate its effects and biological repercussions, and forecast the therapeutic outcomes in clinical subjects. This review's objective is to provide an overview of existing methods for NP evaluation from a Critical viewpoint, go over possible dangers and advice, and present new Innovations in the realm of Nano medicine that demand careful consideration. (3)

2. CLASSIFICATION OF NANOPARTICLES

Carbon-based, inorganic, and organic nanoparticles are the three primary types of nanoparticles.

2.1. ORGANIC NANOPARTICLES

NPS composed of proteins, carbohydrates, lipids, polymers, or any other organic component fall under this class. Den trimers are among this class's most well-known representatives. Micelles, liposomes, and protein complexes like ferritin (displayed in These NPs are usually biodegradable and non-toxic, though occasionally they may include a hollow core, as in the case of liposomes. Organic nanoparticles are susceptible to electromagnetic and thermal radiation, including light and heat. Furthermore, they are frequently created by non-covalent intermolecular interactions, which increases their labile character and provides an exit path for the body.(4) An organic nanoparticle is a solid particle with a diameter between 10 nm and 1 um that is primarily made up of organic compounds, such as polymers or lipids Among the organic nanoparticles are liposomes, dendrimers, carbon nanomaterials, and polymeric micelles. Dendrimers are highly branching polymeric molecules that are nanosized and mostly utilized in the pharmaceutical and medical fields, including gene delivery.treatment with boron neutron capture, etc. Liposomes are spherical particles made up of one or more phospholipids. Due to their structure, they have lipophilic, hydrophilic, and ampiphilic properties. The liquid crystalline transition temperature is a special characteristic of phospholipids in liposomes. Liposomes have been utilized recently to add vitamins to dairy products. (5)

2.2. INORGANIC NANOPARTICLES

Non-carbon-based particles are known as inorganic nanoparticles. Typically, metal and/or metal oxide-based nanoparticles are referred to be inorganic.

A. Metal Nanoparticles

One element makes up metal nanoparticles, which are single-element nanomaterials. There can be single atoms or collections of several atoms. The most often produced nanoparticles include those made of Au, Ag, Pt, Cu, Pd, Re, Zn, Ru, Co, Cd, Al, Ni, + Fe. Metal nanoparticles can be produced as solid nanoparticles or colloidal fluids using straightforward techniques including the hydrothermal process, microwave-assisted method, and bio-assisted method. Their broad electromagnetic spectrum absorption, strong reactivity, and localized surface plasmon resonance (LSPR) are among their noteworthy qualities. Because of their enhanced optical, optoelectrical, catalytic, antibacterial, anticancer, and viral properties, metal nanoparticles are highly intriguing materials for a range of practical applications (Chakraborty and Pradeep). (3)

B. Ceramic Nanoparticles:

The main constituents of ceramic nanoparticles are metal oxides, carbides, phosphates, and carbonates, which include calcium, titanium, silicon, and other metalloids. Their many advantageous qualities, including strong heat resistance and chemical inertness, give them a broad range of applications. The biological industry is the most studied application area for ceramic nanoparticles. Ceramic nanoparticles are thought to be effective transporters of medications, genes, proteins, imaging agents, etc. in the biomedical area. Many aspects of nanoparticles, including size range, surface features, porosity, surface area to volume ratio, etc., must be regulated in order for them to function as an effective and efficient drug delivery vehicle. In order to obtain these advantageous characteristics, theAn effective preparation strategy and strong control over process factors are essential. Effective drug delivery systems can be developed by selecting an appropriate nanoparticle preparation technique and loading a substantial amount of medication(s). This approach is now the subject of extensive research and development. Ceramic nanoparticles have proven to be effective drug delivery agents for a variety of illnesses, including glaucoma, bacterial infections, and cancer. This study provides an overview of recent developments in the field of drug delivery research as well as a thorough description of widely used techniques for synthesizing nanoparticles of different ceramic materials.(6)

C. Semiconductor Nanoparticles

Nanometer-sized light-emitting particles are known as semiconductor nanocrystals. After extensive research, scientists have created these particles for a variety of uses, including solar energy conversion, optoelectronic devices, imaging of molecules and cells, and ultrasensitive detection. The quantum confinement phenomenon, which causes the electronic charge carriers within the nanocrystal to be spatially enclosed, is a key characteristic of semiconductor nanocrystals. This technique allows researchers to precisely and widely modify the energy of discrete electronic energy levels and optical transitions using the size and form of these “artificial atoms. “Consequently, light emission from these particles can be tuned by researchers across the visible, near-infrared, mid-infrared, and ultraviolet spectral ranges. Along with bridging the gap between bulk crystals and small molecules, these particles introduce novel optical features as spectrum diffusion, single-particle blinking, and carrier multiplication. Furthermore, semiconductor nanocrystals offer a flexible building block for the creation of intricate nanostructures like super lattices and multimodal agents for targeted therapy and molecular imaging. (8)

D. Polymeric Nanoparticles

Polymeric nanoparticles have completely changed the way medicine is practiced and approached. Block copolymer micelles, polymeric medicines, polymer conjugates of proteins, pharmaceuticals, and aptamers, and multicomponent nonviral vectors with covalent lambda lambda are all considered “polymer therapeutics,” according to Duncan and Vicent Because of their versatility in design based on functionalization, macromolecular synthesis techniques, and polymer diversity, polymers are interesting for use in therapeutic applications.The nonbiodegradable polymers poly polyacrylamide, polystyrene, and polyacrylates formed the basis for the first applications of polymeric nanoparticles for nano-based applications. Systems for nonbiodegradable particles must be created so that they are physically removed, do not accumulate or distribute in tissues at a toxic level due to their inability to be readily broken down and expelled, and show quick and effective clearance through carriers like feces or urine. Nonbiodegradable polymeric particles have been applied to a number of processes, such as antibacterial activity, wound healing, and drug delivery13,14, and 15.8 The usage of nonbiodegradable materials was linked to inflammation and chronic toxicity, which led to a shift in emphasis toward biodegradable polymers. Degradable in nature.(8)

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E. Lipid-based Nanoparticles

Because liposomes are biocompatible and biodegradable, they are the most researched delivery mechanism. Phospholipids, the primary constituents of these nanoparticles, are arranged in a bilayer configuration because of their amphipathic characteristics. When anticancer medications are loaded into their structure, they form vesicles in the presence of water, which increases the drugs' solubility and stability. They can contain medications that are hydrophilic or hydrophobic Other substances, such as cholesterol, can be added to their formulations in addition to phospholipids to improve the stability of the nanoparticles in blood by decreasing the fluidity of the nanoparticle and increasing the penetration of hydrophobic medicines through the bilayer membrane. Cholesterol-modified liposomes can exhibit three different bilayers: a single bilayer above 100 nm, known as Large Unilamellar Vesicles; an intermediate size (10–100 nm), known as Small Unilamellar Vesicles; and a multiple bilayer between 0.5 and 10 nm, known as Multilaminar Vesicles.The two general approaches for achieving nanocarrier vectorization are widely recognized. One of these is passive targeting, in which liposomes only penetrate the tumor cell through the cellular membrane on a molecular level. The other is active targeting, which is encapsulating tumor cell-recognizing antibodies in structurally altered liposomes For liposomes, a third preparation technique that takes into account stimulus-sensitive components can be used. By employing an external trigger, one can alter parameters such as temperature, pH, or magnetic fields to administer anticancer drugs in a controlled manner. (9)

F. Carbon-based Nanopartical

In recent years, there has been a significant exponential development in the use of carbon-based nanomaterials, including carbon nanotubes, graphene and its derivatives, nanodiamonds, fullerenes, and other nanosized carbon allotropes. Because of their small size—which makes them comparable to many basic biomolecules—large specific surface area, high electrical and thermal conductivity, special optical properties, and superior mechanical properties, carbon nanomaterials offer virtually limitless opportunities for modification and customization. These attributes have opened the door to a wide range of applications. Specifically, fullerene derivatives have been used for scavenging solar energygraphene has been widely used in flexible electronics, carbon nanotubes have been tailored to have molecular recognition capability, graphene quantum Because of their photoluminescence, dots have found widespread application in bio-imaging and sensing. Similarly, nanodiamonds have shown promise in super-resolution imaging and nanoscale temperature sensing.(10)

Among the elements with the greatest abundance and versatility in the universe is carbon. The way neighboring carbon atoms are arranged can create compounds with entirely different properties from carbon due to its allotropic features. Graphite and diamond are two common examples. Graphite is brittle and delicate, while diamond is recognized as the material with the highest hardness. Due to its versatility, carbon nanostructures are considered to be among the most promising in the field of nanotechnology. Carbon nanostructures can be utilized in electronics to produce novel devices because of its molecular-sized diameter (about 1 nm), microscopic-scale length, and optical and electrical characteristics. Composites made from these nanostructures could have mechanical characteristics, In new engineering goods, the thermal and electrical conductivities are beneficial for applications, and there are desirable aspects for corrosion prevention.(15)

3. APPLICATION OF NANO PARTICLES

3.1. PARTICLES AS CHEMICALLY INERT ADDITIVES:

In addition to bulk applications like ceramics, small, chemically inert particles have been widely used in pigments, polymer fillers, and surface finishing. None of these were previously referred to as "nano," and the majority of scientists are unaware of the widely accepted applications for tiny particles. The employment of different carbon soot pigments in cave and ceramic paintings, as well as meticulously reduced iron oxide colloids as red and yellow colors, are the most fascinating historical examples.

3.2. CHEMICALLY ACTIVE PARTICLES:

Catalysts, biomaterials and Antimicrobial additives:

Solids with active surfaces exhibit chemical reactivity, which is used in heterogeneous catalysis in industry. Bioactivity, or the safe interaction of biomedical implants and devices with living tissue or cells, is a necessary prerequisite. The product definition includes the inhibition or killing of microorganisms in the case of activity against tiny organisms, such as antimicrobial activity. For apparent geometrical reasons, the surface effect is directly correlated with particle size in all areas, and smaller particles are now preferred due to their superior mass or volume related performance (effect per volume or mass of material). The most sophisticated active surfaces in academia are related to catalysis, which in the middle of the 20th century emerged as a distinct field of study. Once more, at that time, the word "nano" was not frequently used.(11)

3.3. OTHER APPLICATIONS

Nanopartical in biosensing:

Forensic analysis, environmental monitoring, and biomedical diagnostics all depend on the ability to detect biological agents, illnesses, and hazardous materials. A recognition element for target binding and a transduction element for transmitting the binding event are the two main parts of a sensor. Miniaturization naturally increases the signal-to-noise ratio, which when combined with the distinct physicochemical features of NPs makes these systems attractive candidates for sensing applications. For instance, depending on their size and form, gold nanoparticles display distinctive optical and electrical characteristics.

The SPR band signals variations in solvent and binding because it is sensitive to the environment. The plasmon band's redshift (to around 650 nm) and broadening as a result of the interparticle plasmon interaction are two especially helpful results. This phenomena gives rise to colorimetric sensing, which is widely used and popular. Under some circumstances, metallic nanoparticles can also exhibit excellent quenching ability and photoluminescence. (12)

Nanoparticals In Fluorescence Sensing:

Because of their remarkable capacity to quench, metallic nanoparticles are a great choice for FRET-based biosensors, such as those that are used to create molecular beacons that detect DNA . This method causes fluorescence quenching because the dye molecule is near the nanoparticle surface in the absence of the target DNA strand because of the hairpin structure of the attached DNA . The target DNA's hybridization opens up the hairpin structure, leading to a notable rise in fluorescence.(13)

Research on fluorescence detection of chemical and biological analytes is ongoing. The goal of this research is to get rid of radioactive tracers because they are expensive to use and discard. Furthermore, quick and inexpensive testing techniques are required for a variety of environmental, bioprocess, and clinical applications.(13)

Nanoparticals In Electrochemical Sensing:

Metal nanoparticles can function as “electronic wires” to improve electron transport between redox centers in proteins and electrode surfaces and as catalysts to speed up electrochemical reactions since they typically have great conductivity and catalytic characteristics. Because oxide nanoparticles are biocompatible, they are frequently utilized to encapsulate biomolecules, whereas semiconductor nanoparticles are frequently used as labels or tracers for electrochemical investigation. Although the significant roles of nanoparticles have been emphasized in a number of publications pertaining to electrochemical sensors and biosensors based on nanomaterials, very few of them have methodically examined the functions of nanoparticles This minireview aims to provide an overview of the latest developments in nanoparticle-based electrochemical and biosensors, as well as the roles played by nanoparticles in these sensing systems.(14)

Due to their special physical and chemical characteristics, nanomaterials have drawn more attention recently. These traits make them highly desirable for applications in a wide range of industries, including biotechnology, electronics, optics, and catalysis. The creation of smart electrochemical sensors for use in a variety of application areas, including food analysis, environmental monitoring, and biomedicine, has been made possible by the advancement of nanomaterials. Indeed, they demonstrated excellent sensitivity and selectivity. We provide an overview of the use of various nanomaterials and nanocomposites with customized morphological characteristics as sensing platforms for food analysis in this research. A significant amount of focus has been placed on sensors that are created using nanomaterials, including metallic, carbon-based, and related nanocomposites. Lastly, a few illustrations of sensors for the detectionof various analytes found in food and drink, including nitrite, ascorbic acid (AA), caffeine (CAF), and many hydroxycinnamic acids (caffeic acid, chlorogenic acid, and rosmarinic acid), are documented and supported.(16)

4. SAFETY AND TOXICITY OF NANOPARTICLES

Using nanoparticles for diagnostic and therapeutic purposes is known as nanomedicine. Over the last twenty years, an increasing number of nanomedicines have been approved by regulatory bodies, and many more have the potential to be clinically translated in the future. In this situation, determining a nanoparticle's safety is crucial to achieving the required activity and biocompatibility. However, as the field of nanomedicine includes a wide variety of created nanoparticles made from different materials, it is improper to make generic claims regarding the safety of nanoparticles. In fact, compared to their small molecule counterparts, a number of recently licensed nanotherapeutics, such Abraxane and Doxil, show less adverse effects; however, some nanoparticles, like metallic and carbon-based particles, tend to be poisonous.(17)

Environmental regulators and consumer advocates are becoming increasingly concerned about metal nanoparticles in general and silver nanoparticles in particular due to their growing presence in consumer goods like pesticides, toothpaste, toothbrushes, socks, washing machines, filters, creams, air purifiers, mobile phones, and so forth122 due to their antimicrobial qualities. Although it is anticipated that AgNPs released from consumer products will find their way into terrestrial ecosystems, little is understood about what will happen to these nanoparticles, how they will change over time in a real, complex environment, and how they will affect the planet. Concerns have been raised by the general public concerning the potential effects of AgNPs on aquatic life types. Silver nanoparticles' inability to discriminate between beneficial bacteria is another issue[18].

5. NANOPARTICALS IN THERE DAILY LIFE

5.1. ZINK OXIDE NANOPARTICLES :

Zinc oxide nanoparticles (ZnONPs) are widely used in food additives, sunscreens, biosensors, and pigments. Numerous scientists have investigated these modified ZnONPs' harmful effects using various cell lines and animal models. ZnONPs have demonstrated their cytotoxicity and genotoxicity potential in both vitro and in vivo settings. Subsequent research has shown that ZnONPs decrease cell viability in a time- and dose-dependent way.One biomarker for metal-induced toxicity is the metallothionein gene, whose expression may be elevated by ZnONPs. Research has verified the hepatotoxicity in response to varying doses and a noteworthy rise in oxidative stress, as seen by elevated levels of malondialdehyde (MDA) and decreased liver enzyme activity of superoxide dismutase (SOD) and glutathione peroxidase (GPx).(19)

5.2. SILICA NANOPARTICLES:

When silica nanoparticles are administered intraperitoneally, they biodistribute to many organs, including the liver, kidney, spleen, and lung . Silica nanoparticles have been used in diagnostics and drug delivery . Commercial silica particles are also available in both micro- and nano-sizes. In this work, we used silica particles as a model material to examine the effects of nanomaterials on key organs, including the liver, kidney, spleen, and lung. Only the 70-nm silica particles caused immediate and long-term liver damage when they were given intravenously, out of particles with diameters of 300, 1000, or 70 nm.

The Impact of breathing in nanoparticles on human health has been thoroughly studied. Inflammation, fibrosis, and cytotoxicity are caused in the lungs by quartz, mineral dust particles, and asbestos exposure at work . In animal models, inhaled nanoparticles are not retained locally in the lung but instead enter the bloodstream and spread to other organs, including the brain, heart, liver, and kidney . Furthermore, intravenous, subcutaneous, or intramuscular injection will be necessary for biomedical applications for diagnostic and therapeutic purposes. Confirming the impact of nanoparticles in systemic flow on different organs is therefore imperative.(20)

5.3. SILVER NANOPARTICLES:

AgNPs are effective antiviral and antibacterial medicines that have been used to treat acne, eczema, trophic sores, chronic ulcers, open wounds, and infection in the buttocks.45 It has also been shown that AgNPs are used as an antibacterial agent in detergents, soaps, toothpastes, shampoos, and air sanitizer sprays. AgNPs have also been widely utilized in food product packaging and storage to extend shelf life. Medical equipment, including dental implants, have been coated and filled with resin composites based on silver. It has been indicated by experiments that AgNP might be utilized as a safe preservative in cosmetics; nonetheless, they might permeate human skin when the skin's barrier function is compromised.46 Researchers have confirmed that ammonia and PVPs stabilized AgNPs at reduced doses in mice are not harmful.(19)

5.4. GOLD NANOPARTICLES:

Within the field of colloids and surfaces, a large new subdiscipline known as gold nanoparticle chemistry and physics has evolved. Small gold particles have unique optical characteristics, size-dependent electrochemistry, and high chemical stability, which have made them the preferred model system for studying a variety of phenomena, such as phase transfer, biolabeling, electron-transfer theories, phase transfer, self-assembly, and crystal growth.

A catalytic nanoparticle made of gold. Despite the fact that gold nanoparticles have been applied in a wide range of applications, their catalytic capabilities were long thought to be minimal or nonexistent. When Haruta and Hutchings independently and simultaneously9a,9b demonstrated that gold may be very active, especially for the heterogeneous low-temperature oxidation of CO, it was an intriguing discovery.(21)

6. ENVIRONMENTAL IMPACT OF NANOPARTICALS

6.1 Nanoparticals in aquatic system:

NP are ultrafine particles in two or three dimensions that range in length from 1 to 100 nm. In the past ten years, the majority of the research and discussion surrounding particles in aquatic systems has concentrated on synthetically designed nanoparticles, or produced or engineered nanoparticles (ENP). ENP are extensively and advantageously employed in industrial, technical, medical, pharmaceutical, cosmetic, and life science applications because of their exceptional qualities . ENPs in particular show promise for enhancing environmental quality when applied, for example, in remediation or water treatment procedures . Without a doubt, this research greatly inspired analytical chemistry. Consequently, strong analytical tools and techniques are being created to identify and describe NP and colloids in aquatic systems. Nevertheless, compared to the majority of other chemical compounds, we currently lack almost all environmental data concerning the presence of ENP in aquatic environments . Given the almost unmanageable amount of research publications, reviews, and textbooks on NP and colloids in aquatic systems, the fundamental and extreme lack of trustworthy environmental data is striking.(22)

6.2 Nanoparticals In Air :

Trace amounts of particles ranging in size from approximately 1 nm to 100 μm are found in the atmosphere. Ultrafine particles are another name for particles that are smaller than 100 nm. According to Wang et al. (2005), these nanoparticles are essential for the production of cloud droplets, precipitation, atmospheric visibility, stratospheric ozone depletion, and the earth's radiation balance. Particle concentrations in contaminated air can reach over 104 particles per centimeter, which is a significant factor that negatively impacts materials, flora, ecosystems, and human health (Seinfeld and Pandis, 1998). Particles originating from biogenic, geogenic (soil dust, volcanic ash), oceanogenic (mostly sea sprays), and astrogenic (burning of falling meteoroids) sources are examples of natural sources of particles. Mass transfer of either gaseous species or particles is a component of both methods.

When supersaturated vapors cool or when chemical processes produce products with extremely low saturation vapor pressures, nucleation takes place. As a result, stable nuclei and nanoparticles are formed. Due to their Brownian motion, these particles clash once they have formed. Brownian Larger particles are formed during coagulation, which also lowers the concentration of all particles. These processes produce ambient ultrafine particles, or nanoparticles, which can exist as agglomerates, compact solid particles, or liquid droplets with varying morphological characteristics.(22)

6.2 Nanoparticals In Soil System :

By applying them to land or wastewater treatment products like sludges or biosolids, nanoparticles can enter soils directly through fertilizers or plant protection products, or indirectly through other means. These nanoparticles can have a variety of harmful consequences on soil organisms by bioaccumulating, trophically transferring, and even biomagnifying in some situations. Additionally, their detrimental effects on plant-fungi and plant-bacteria have previously been documented; in order to evaluate potential hazards, more research on other potential interactions (such as competition and predation) is required. Numerous studies have demonstrated the detrimental impact of nanoparticles on the nitrogen cycle and other biogeochemical processes.(19)

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