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NANOPARTICLE-BASED THERAPEUTICS RECENT INNOVATIONS IN TARGETED DRUG DELIVERY AND DIAGNOSTICS

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ABSTRACT

Nano-particles are really small particles that range from 1-100 nm in size. The review describes nano-particles in a systematic way, from types, properties, and synthesis methods to various application. Therefore, ever-changing fields including medicine, electronics, energy, and environmental science perceive nano-particles as very vital and potential. Then there are discussions about advantages that can be attributed to properties of nano-particles, which are said to be enhanced due to a small size and very high surface-to-volume ratio. Thereafter are factors and challenges related to nano-particles, including toxic potentials and environmental impacts . This involves different production methods of nano-particles, including chemical, physical, and biological methods. The article also discusses different routes of administrations of nano-particles like parentrals, orals, intravenous injections etc. In application terms, it provides examples of how nano-particles have been used in areas such as drug delivery systems, imaging and diagnostics, environmental remediation, energy storage, and catalysis. It talks about the potential for nano-particles to revolutionize these fields through enhanced targeted delivery, improved capabilities for imaging, removal of pollutants, improved efficiency of energy conversion processes, etc. On the whole, it remarks how nano-particles have created a very significant impact on the various industries/disciplines, thereby emphasizing the potential need for future research and development to ensure further exploration of their potential and possible risks/concerns.

KEYWORDS: Nano-particles, targeted drug delivery, environmental remediation, personalized medicine, route of administrations.

INTRODUCTION

The word nano is a Greek prefix which means dwarf or something very small. Therefore, a nano-particle also called ultrafine particle is a particle of matter that ranges between 1-100nm in in diameter. A nano-particle can be either metal, ceramic, polymer or composite. Nano-technology focus on the development of devices that features at an intermediate scale between the larger particles and 100nm particles. The manufacturing of nano-particle is the essential component of nanotechnology. Richard Feynman the inaugural speaker of in 1959 and his address served as inspiration for the underpinning of nanotechnology. Since ancient times, nano-particles have been used in medicines & ceramics. There are several optimal ways to synthesize nano-particles. The way to synthesize nano-particle involves three key elements.

a) Cheap cost
b) Neutral ph
c) Environmentally benign method

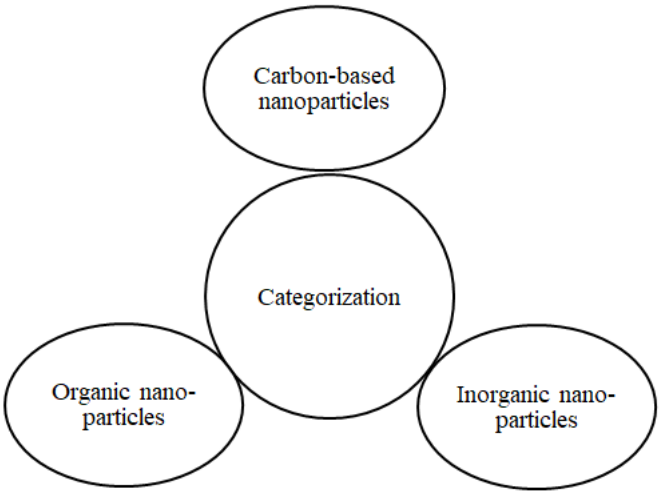
As compared to other organisms, plant creates nano-particles at a quicker rate of synthesis with great stability. (BS Murty et al. Textbook of nano-science and nano-technology)

Structure of Nano-particles

The structure of nanoparticle is intricate. There are two or three levels to them: -

a) A surface layer that has been functionalized by metal ion, surfactants, polymers, or a range of small molecules.
b) The chemically distinct shell layer, separate from the core& can be created on purpose.
c) The core material, which is the central component of NP.

Categorization of Nano-particles (NPs)



NPs are usually categorized into three categories:- organic, inorganic, carbon based depending upon their composition

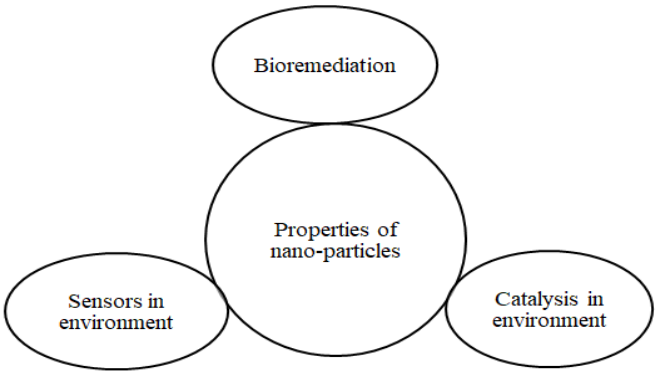
a) Organic NPs:- This class include NPs composed of any organic compound, including protein, carbohydrate, lipids, & polymers. The most well known members of this family are protein complexes like ferritin, liposomes, dendrimers, & micelles. These NPs are usually biodegradable & non-toxic, occasionally they may include a hollow core, as in the case of liposomes. Heat & light as well as other form of synchrotron radiation, can affect organic nano-particle. Furthermore, they are often formed through weak inter-molecular forces which increase their liability & provides an exit path from the body. The potential use of organic nano-particle in specific field are determined by their chemical makeup, physical structure, durability & ability to carry substance. Nowadays the organic biomedical field primarily organic NPs for cancer therapy & targeted drug delivery.

b) **Carbon based NPs**:- NPs in this class are exclusively composed of carbon atom. Fullerenes, acetylene black nano-particle &quantum dots of carbon are well known instance of this instance of this class. The carbon compounds known as fullerenes have a symmetric closed cage structure. Other. There have also been reports of fullerenes from C70 & C540. C60 fullerenes consist of 60 carbon atoms arranged in football configuration. Grape like clusters of strongly fused spherical particles make up carbon black nano-particle. Quantum dots are made up of quasi-spherical carbon nano-particle with diameter smaller than 10nm. At the nano-scale, carbon based NPs combine the unique physiochemical characteristics of sp2 hybridized carbon bonds with their distinctive feature. Because of their distinct optical,

thermal, sorption, high strength, electron affinity & electrical conductivity properties. Carbon based NPs have wide range of application such as medication delivery, energy storage, bio-imaging, photovoltaic devices, & environmental sensing application that track the ecology of microbes or identify their pathogens. More sophisticated carbon-based NPs are nano-diamonds. Their unique qualities of low toxicity and biocompatibility makes them useful in drug administration.

c) **Inorganic NPs** :- This class include NPs that are not composed of organic or carbon based components. This class include semiconductors NPs, metal, & ceramic example. Metal precursor make up metal nano-particle, which can be monometallic, bimetallic or poly-metallic. Bimetallic nano-particle (NPs) can be created using alloys or in different layers. These NPs localized surface pseudo-resonance characteristics provide them unique optical and electrical properties. Furthermore, several metal nano-particle have special biological magnetic & thermal characteristics. This makes them more & more crucial components for the creation of nano-devices with a wide range of chemical, physical, & biological uses. (M. Mohan Varma et al. 2021)

Properties of Nano-particles



Bioremediation:- Nano-particles can remove environmental pollutants including the removal of heavy metals from water or organic contaminants from soil. Several nano-particles are considered for the process of bioremediation including nano-scale zeolites, metal oxides etc.

Sensors in environment:- Nano-technology are already used in the improvement of water quality and the facilitation of environmental cleanup activities. Their further conceivable application as environmental sensors to monitor application pollutants are also becoming feasible NPs can be used as sensors for detecting certain compounds within the environment. These include heavy metals or other pollutants.

Catalysis in environment:- Nano-particles are used for the catalysis of the chemical reaction process, including those in bio-fuels and in process of environmental bioremediation. (Khadijah A. Altammar, a review on nano-particle 2023)

Benefits of nano-particle

Targeted drug delivery – These nano-particles can be designed to take drugs to precise cells or even tissues, resulting in minimal side-effects and increasing the efficacy of drug for the treatment.

Enhanced bioavailability – Nano-particles improve solubility and stability of a poor water soluble drug, hence enabling better absorption from body.

Improve diagnostics – Nano-particles are utilized in imaging techniques to enable early and more precise disease diagnosis.

Anti-cancer therapy – Traditional anti-cancer therapies may cause substantial systemic toxicity results in drug resistant phenotypic growth. The investigation of tumor specific thermal scalpels to heat and burn tumors is an intriguing possible application of nano-particle in cancer therapy.

Biocompatibility – Most of nano-particles are biocompatible in nature thus capable for medical applications with no or very less adverse reactions

Versatility – Due to their versatility these nano-particles can unique properties can be tailored for various applications across different fields. (Nadeem Joudeh et al. 2022, Maureen R. Gwinn et al. 2006)

Different administrative route for nano-particle

There are several ways for nano-particle administration through various routes offering distinct advantages for drug delivery.

Oral administration – Nano-particles can be used to improve the bioavailability of poor soluble drugs. Nano-particles can protect drugs from getting degraded in the gastro-intestinal tract. Because of its increased convenience, ability to prevent pain, effectiveness, high patient compliance and less risk of cross infection of needle-stick accidents the oral route is popular method for administration.

Inhaled administration – As compared to other alternative delivery methods like oral or injection, pulmonary administration offers a number of crucial advantages. By avoiding first pass hepatic metabolism, it lowers the need for a dose and minimizes adverse effect. It also includes large surface area, quick absorption.

Intravenous administration – There are several ways to administer the nano-particle including intra-peritoneal, intra-venous injections etc. The intravenous approach offers a nearly immediate response and broad control over the rate at which drug enters the body. It is also appropriate for medication that cannot be injected into muscles or other tissue or absorbed by GI route. (Dhrisya chenthamara et al. 2019)

Ophthalmic administration - Facilitates improved drug delivery to the eyes while maximizing therapeutic effect with minimal systemic exposure. Nano-particles can also improve the retention time of drugs on ocular surface. (Dawin Kheiv et al. 2021)

Application of Nano-particles

Specific physical & chemical characteristics including mechanical, optical, magnetic, & thermal characteristics are displayed by nano-particles. Its versatility has led to its use in a variety of context. These are few uses of NPs that are covered below:-

a) Medicine

Clinical medicine has greatly benefitted from the use of nano-particle in the fields of medication& gene delivery & medical imaging. The majority of iron oxide particle applications are in biomedical field. Ex of this includes magnetite (Fe3O4) & its oxidized counterpart, hametite (Fe2O3). Ag NPs antibacterial action has led to an increase in their use in catheters, wound dressing, & other home items. As medication transporters, photo-thermal

agents, contrast agents, & radio-sensitizers, gold nano-particle are showing promise in the treatment of cancer. Over the past few decades, there has been a lot of attention in developing biodegradable nano-particles as efficient drug delivery system. Drug delivery has made use of variety of polymers because they can more efficiently transport the medication to the intended location thus reducing the ADR.

b) Environmental remediation

Since nano-particles can be applied both in-situ & ex-situ in aquatic environment, they are frequently utilized for environmental remediation. Ag NPs have been widely used as water disinfectants because of their anti-viral, antifungal & antibacterial properties. Given their well-established low cost, non toxicity, semiconducting, electrical, gas sensing, photo-catalytic and energy conversion properties,TiO2, nano-particle have drawn increasing attention in the field of waste treatment, air purification etc.

c) Mechanical industries

Due to their superior young modulus, tension, &pressure characteristics, nanoparticles are used in mechanical industries, particularly in the coating, lubricants, adhesives, & the production of mechanically stronger nanodevices. Pal et al (2021) described a two step dip coating technique that used fluorine-free silane monomer & Ag NPs 3 trimethoxysilyl propyl methacrylate to create a hydrophobic layer on cotton textile.

d) Electronics

One dimensional semiconductors & metals have special structural, optical, & electrical features that make them the primary building component for a next generation of electronic, sensor, & photonic material. (Kumari. B 2018: A review on nano-particle their preparation methods and their applications)

CONCLUSION

Nano-particles are a new area of scientific study that could completely transform a variety of industries. We can harness the power of these tiny particles to improve the society while carefully managing the potential & challenges.

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