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PROSPECTING APPLICATION AND CLASSIFICATION OF NANOPARTICLES: REVIEW

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ABSTRACT

Nanoparticles have been a part of our lives for approximately over 4000 year. This technology has flourished with time and has reached various scientific field of study like computers, electronics, food, agriculture, energy and medicine. But it is still not known to many due to its cost and technology barrier. This review has discussed various types of nanoparticles and nanomaterials synthesizedlike Fullerenes (C60), carbon nanotubes (CNTs), magnetite (Fe3O4), polylactic acid (PLA) and polyethylene oxide (PEO) along with their application in various field of science medicine, health care, diagnoses, environmental remediation, clean energy and others.

Keywords: Nanoparticles, Nanomaterials, Carbon nanotubes (CNTs)

INTRODUCTION

Early Egyptians have been using nanomaterials for more than 4000 years these people used chemical process to synthesize nanoparticles of size as small as ≈5 nm in diameter. PbS NPs were used as hair dye **[1]**. The widespread of nanotechnology and its interdisciplinary applications with other fields such as biomaterial science, cell and molecular biology and nanomedicine, have gathered the attention of biomedical researchers due to its potential uses in the treatment and diagnosis of various disease. Nanoparticles (NPs) developed as a centre of focus for further research system used in nanomedicine, as the ranostic agents with high molecular specificity **[2–3]**. The high multi functionality of noble metal nanoparticlesis achieved exclusively by physical–chemical properties varying according to their size **[4]**. AuNPs, PtNPs and AgNPs being noble metallic nanoparticles offer easy chemical synthesis, tuneable surface functionalization and high stability **[5]**.

In times, NMs have been described as materials having lengthof approximately 1–1000 nm in at least one perimeter; whereas according to international standards they are defined as particles having diameter between 1 to 100 nm. A nanometre (nm) is an International System of Units (SI) unit that is equals 10^{-9} meter in length. Various legislationsare available in USA and European Union (EU) with specific references to nanomaterials or smart materials. However, with a lot of differences in technology around the globethere is not just one acceptable definition for nanomaterials worldwide. Different scientific communities define nanomaterials differently **[6]**. As per Environmental Protection Agency, Nano-materials exhibit unique characteristics dissimilar to their equivalent chemical compound in larger particle size **[7]**. The US Food and Drug Administration (USFDA) alsorefer to NMs as "materials that have at least one dimension inthe range of approximately 1 to 100 nm and exhibit dimension dependent phenomena" **[8]**. ISO has certainly issued some regulations for defining nanofibers, nanowires, nameplates and quantum dots **[9]**.

Since past decade nanoparticles of metallic nanoparticles, including gold (Au), silver (Ag), palladium (Pd) and platinum (Pt) have been thoroughly studied as compared to bulk metals or metal ions because of their unique properties at Nano scale such as particle size and enhanced surface properties. The bio compatibility of metallic nanoparticles makes them easily available and part of the biological system, which enables them to be used for diagnostic imaging, drug delivery, developing biosensors and labelling **[10]**.

Classification on nanoparticles

Nanoparticles are classified on the basis of carbon based, organic based and inorganic based nanoparticles. Nanomaterials and nanoparticles are regulated in one form or other in environment as shown in **Figure 1**. Nanoparticles cannot be destroyed; nanoparticles coagulate or react with other metals forming precipitates.

Carbon based nanoparticles

A major range of carbon based NPs is inherited by Carbon nanotubes (CNTs). Globular hollow cage of allotropic forms of carbon make a class of nanoparticles known asfullerenes. They have gained importance infield of commercial applications such as nanocomposites which are widely used as fillers **[11–12]**, work as efficient gas adsorbents for pollution control **[13]**, and support different inorganic and organic catalysts **[14]**. Dendrimers, liposomes ferritin and micelles are few currently available organic nanoparticles or nanomaterials. These nanoparticles are eco-friendly, non-toxic and sustainable. Due to hollow core so such nanoparticles like micelles and liposomes they are also known as nanocapsules which show sensitivity towards electromagnetic and thermal radiation from heat or light **[15]**.

NMs containing carbon are found in different surface characteristics such as ellipsoids, spheres or hollow tubes. Fullerenes (C60), carbon nanotubes (CNTs), carbon nanofibers, carbon black, graphene (Gr) and carbon onionsare classified under the carbon-based NMs category. Fullerenes (C60) are spherical carbon molecule having structural unit of carbon atoms held together by sp2 hybridization. Containing approximately 28 to 1500 atoms of carbon spherically bind to form single layer and multi-layer fullerenes having diameters up to 8.2 nm and 4 to 36 nm respectively.

Metal based nanoparticles

Most metals can be converted into nano scale forms which are nanoparticles. Metal nanoparticles are synthesised from constructive or destructive methods by converting metals to nanometric sizes based nanoparticles **[16]**. Metal NPs are saturated products of the metals precursors. Metal NPs synthesized byusing localized surface plasmon resonance (LSPR) have extraordinary optoelectrical properties. Nanoparticles of the noble and alkali metals have wider absorption wavelengths in the visible range of the electromagnetic solar spectrum. Nanoparticles controlled synthesis for attaining optimum size and shape is important in present day materials study **[17]**.

Non-metal based nanoparticles

Non-metal nanoparticles like ceramics NPs are inorganic solids, synthesized by heat and successive cooling. These NPsare found in various states like polycrystalline, dense, amorphous, hollow or porous forms **[18]**. There are various applications of ceramic nanoparticles due to semiconductor properties which possess properties between metals and non-metals **[19–20]**. Using bandgap tuning, semiconductor NPs possess wide bandgaps which therefore made significant alteration in their electrical properties. This variation makes them excellent materials for making photo optics, electronic and photocatalysis devices **[21]**. Like various semiconductor NPs having their steady bandgap and bandedge positions are found exceptionally capable in water splitting **[22]**.

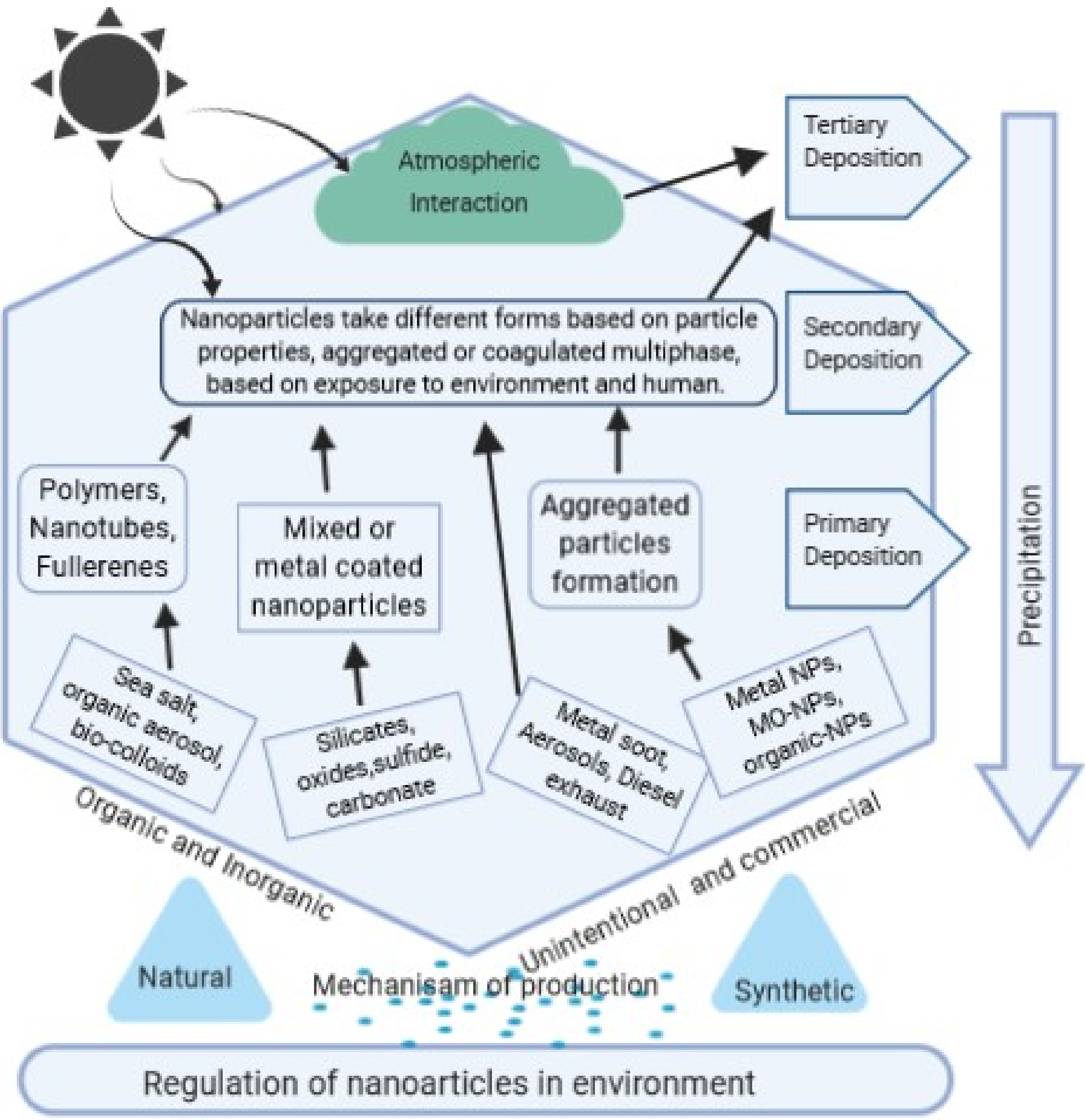

Figure 1: Types of nanoparticles and regulation in environment

Applications of nanoparticles

Nanoparticles have a upper hand over large particles of bulk material because of very small size and high surface-to-volume aspect ratio, and depict novel properties as contrast to bulk material which has created a huge interest in extensively studying various applications of nanoparticles in biomedical devices, cancer treatment, diagnostic tools, drug and gene delivery and food technology **[23]**. Recently research on nanoparticles has gained significance in the field of Biomedicine **[24]**. Further case studies have shown applicable application in biomedical field include therapeutics and diagnostics **[25]**.

Application in drug and medication

Silver nanoparticles possess unique antimicrobial properties against wide spectra of bacteria and fungi which enables them to be used as coating materials for medical devices. AgNPs not only protects surfaces of the devices butthey also facilitate release of silver ions to induce antibacterial activity for a longer period of time **[26]**. AgNPs can also be facilitated by dispersion in various carriers like chitosan-alginate composites **[27]** and chitosan **[28]** to attain a consistent and effective enhanced antibacterial activity.

Nanoparticles help in delivering optimum dosage of drugwhich ultimately increases therapeutic efficiency of the drugs andreduces side effects, and improved patient compliance has drawn lot of attention in recent years in the field of drug discovery **[26]**. Iron oxide nanoparticles like magnetite (Fe_3O_4) or maghemite (Fe_2O_3) are the most commonly used iron nanoparticles for biomedical imaging devices and drug delivery **[20]**. Optical properties of nanoparticle help in efficient contrast for photo thermal therapeutic applications and biological imaging. Various polymers have been studied for potential drug delivery system; polymers likepolylactic acid (PLA) and polyethylene oxide (PEO) NPs have shown very promising results for the intravenous drug delivery **[27]**.

Iron oxide NPs possessing super paramagnetic properties having significant surface chemistry can be employed for many applications like tissue repair, immunoassay, drugs delivery, detoxification of body fluids, cell separation and MRI contrast enhancement. Certain medical applications are only possible with NPs having high magnetic properties, narrow intra particle spacing and small size **[28]**. Plenty of metallic NPs have shown promising results for cancer therapy and diagnosis depending on their surface plasmon resonance (SPR) which enhances absorption and light distribution. Gold nanoparticles potentially transform the localized incident light absorbed into heat which is engaged for the selective laser photo thermal therapy of cancer **[29]**. Few nanoparticles are also known for antineoplastic effect which is also competently used to obstruct the tumour growth.

Conventional ultraviolet (UV) protection sunscreens are highly unstable during longer usage. The sunscreen blended with proportion of titanium dioxide nanoparticles has provided numerous advantages. Similarly nanoparticles of titanium oxide and zinc oxide possess high UV protection properties and due to small size they are transparent to visible range, absorb and reflect UV rays,due to these unique properties they have found way cosmetic industry like sunscreens containing zinc oxideand lipsticks having iron oxide nanoparticles as a pigment **[30]**. Engineered NPs are produced synthesised by various physical, chemical and biological methodsto meet various commercial demands **[31-32]**. Immobilized nanoparticle over a firm surface without risk of detachment reduces a lot of health and environmental issues **[33]**. Targeted drug delivery is new era of medicine with specific target like cells or part of body.Nanoparticles can help in treating cancer where the medicines can be delivered directly to the affected cells without damaging healthier cells in any way. This minimizes the side effects of drugs.Fe_3O_4 and ZnO **[34]** nanoparticles are effectively explored for targeted drug delivery.

Bone transplants made from ceramics had plain surface which resulted in formation of fibre muscles around the transplant. The muscles activated immune response on failing to adhere to the surface of implant. Natural bones have nanostructures over the surface for cells to adhere and function normally **[35]**. Recent developments have shown significant improvement in coating bone transplants with nanostructures for better chances of acceptability. Modified titanium implants have been used for most of the knee and hip implants.Due to highly dynamic structure of spherical Se NPscan be easilyconverted into one-dimensional (1D) anisotropic structures even after 24 hrs of their synthesis. Therefore, Se NPs have high adhesive ability, biocompatibility and surface-to-volume ratio which are employed for building HRP (horseradish peroxidase) biosensor **[36]**.

Iron oxide NPssuch as Fe_2O_3 (maghemite) and Fe_3O_4 (magnetite) have significant magnetic properties are well known for biocompatibility. Further research is going on actively to investigate promising applications for targeted cancer treatment (magnetic hyperthermia), gene therapy, drug delivery, DNA analysis, stem cell sorting and manipulation, and MRI **[37]**. These nanoparticles having magnetic properties can be used for hyperthermia cancer treatment. In a study magnetic nanoparticles were injected at cancer tissue sites for inhibiting and restricting the growth of hyperthermia cancer cells. External magnetic field is applied for localized heating at specific sites **[38]**. AuNPs shows affinity towards various functional groupssuch as ligands containing functional groups like phosphines, amines, and thiols increases their chance of bioavailability and applications in various biomedical field of study **[39]**.

Application in environment

Nanoparticles or nanomaterials are efficiently employed to decontaminate the water, soil and airfor long period of time also known as environmental remediation **[2]**. Due to the adverse effects of various heavy metals like lead, mercury, thallium, arsenic and cadmium on human health present in natural water sources has gained considerable attention in environmental remediation. Studies show that these toxic soft materials can be recovered using super paramagnetic iron oxide NPs as effective sorbent material. Before time we were unable there was no analytical technique to study the traces of these heavy metals but with the help of nanotechnology, engineered nanoparticles studies are been conducted to measure traces of these heavy metals **[40]**.

Oil extraction from ocean bed is a tedious task and oil spill is a problem of this process causing damage to marine life and it may spared over very long distances. Controlling this situation in minimum time and reducing damage is main concern but damage control by conventional methods is very tedious and takes lot of time which further deteriorates the situation. Cleaning oil spills with the help of nanoparticles have proven very efficient in controlling the spread and reducing damage to marine life **[41]**. These days nanoarticles are also been used for treating industrial and domestic wastewater along with sludge accumulated. The substitute of conventional chemicals by nanoparticles is feasible because of their higher efficiency, confined work space and low capital investment requirement for remediation **[42]**.

Research conducted at the PNL (Pacific North Laboratory) synthesized low cost chemically synthesized nanoporous ceramics which were deployed in treatment of waste water streams faster than conventional techniques such as activated carbon filters and ion-exchange resins. Ceramic nanomaterials can be efficiently utilized for environmental applications, wastewater treatment, site remediation, waste stabilization and drinking-water purification **[43–45]**. Industry standards have certified the use of Granular activated carbons (GACs) for removing unwanted chemical compounds from effluent. As its output these nanomaterials have become integral part throughout industry, wastewater treatment facilities and households for drinking water purification **[46–48]**. Modern nanomaterials have advanced in efficient removal of organic pollutants, heavy metals, bacteria and inorganic anions without intoxicating our environment **[49–52]**.

Other applications

Engineered nanomaterials exhausted high stability even into the atmospheric environment where exposure to sunlight and UV wavelengths is very high as compared to standard parameters **[53]**. Advanced nanomaterials are also been used in aircraft manufacture as a substitute of conventional composites which help in reducing aircraft weight hence making them fuel efficient **[54]**. Nanotechnology has also shown tremendous application in the field of food technology andagro food industry, where it is majorly used for primary production, food processing and packaging and food supplements **[55]**. Different properties such as optical, electrical and structural parameters of one dimensional metals and semiconductor nanoparticles makes them ideal source for buildingunit for a next generation of photonic materials, sensors and electronic devices **[56–57]**.

With such rapid depletion of resources NPs have provided efficient prospective for energy harvesting supplications because of catalytic nature, optical behaviour and large area of contact **[58]**. NPs are widely used in photocatalytic applications especially to generate energy from electrochemical water splittingand photoelectron chemical (PEC) **[59]**. Apart from water splitting other techniques such as solar cells, fuels precursors by electrochemically reducing CO2 and piezoelectric generators provideefficient option to harvesting energy **[60–61]**. Not only for energy harvesting, nanoparticles with electromagnetic properties can be used as storage applications of electricity at nanoscale in different forms **[62–63]**.

Nanotechnology has made construction processes much quicker, inexpensive andsafer from time consuming and tedious task. For example, addition of nanosilica (SiO_2) with the regular concretethey can make improvements in durability and also improve its mechanical properties **[64]**. Strength of concrete can be significantly improved by adding haematite (Fe_2O_3) nanoparticles to concrete. In the construction industrysteel is the most abundantlyused material.Nanotechnology can be used to alter strength and other mechanical properties like stronger steel cables made up of of nano size steel can be used in bridge construction **[65]**.

Nanotechnology has advanced in synthesizing carbon nanotubes which can be used for the development of molecular detection, such as small molecular sensors, gas sensors, chromatographic applications and electrochemical detectors. Further modification of macroelectrode with nanoparticles and use of other nanomaterials improves the degree of sensitivity and selectivity of measurements hence a higher degree of accurate data can be estimated **[66-67]**. **[26]** Researchers have carried out experiments providing results for more possible development of sensors usingvarious nanoparticles for the electrochemical detection of common additives and contaminants, like ascorbic acid (AA), caffeine, caffeic acid (CA), hydrazine (N_2H_4),malachite green (MG), nitrite (NO2−), sulfite ($SO_3$2−) and bisphenol A (BPA) readily adulterated in food and supplements.

CONCLUSION

Nanotechnology has become a partof day to-day life by increasing the limits and efficiency of dailyused products. It provides a scope for sustainable future by cleaning environment, and source of renewable energy. Within a short period of time nanotechnology has flourished at a large scale due to investments made all over the globe in various development programmes carried out by industries, organisations and institutions.

Nanotechnology has led to advanced study of science and research projects conducted to make this technology easily accessible and cost efficient. Technology is advancing every day to increase the efficiency and performance of existing objects and formulating applications in unexplored filed of study. The nanotechnology can be adapted as future due to numerous application found in various field of advance science.

Environmental study has been our major concern over a decade but with important aspect of nanomaterials research. The use of nanoparticles for environmental and health protection with relatively low cost and wide availability could increase the use of nanoparticles. Catalytic properties of nanoparticles have appeared as suitable replacements for extraction of organic compounds and trace metals. Nanoparticles were used for developing sensors for estimation drug residues, mycotoxins, pesticides, allergens, bacteria, probable carcinogenic compounds, antioxidants and amino acids.

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