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EMERGING TRENDS IN NANOTECHNOLOGY

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ABSTRACT

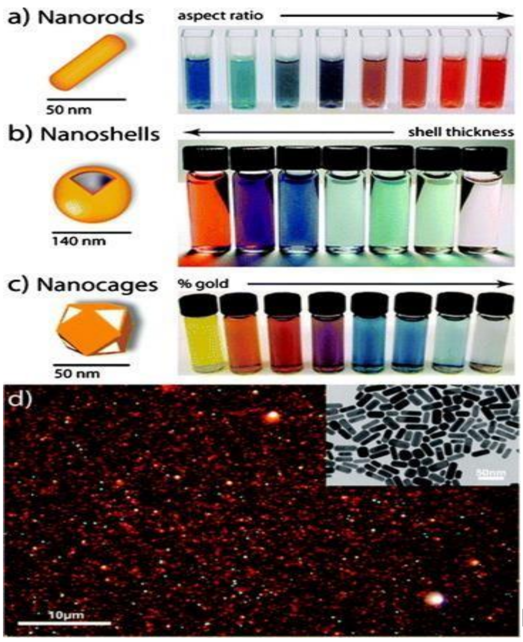
Nanotechnology is widely used in the realm of medicine as nanomedicine. There may be uses for some nanoparticles in cutting-edge diagnostic tools, imaging and methodology, pharmaceutical items, biomedical implants, and tissue engineering. Nanotechnology now allows for the safer administration of high-toxicity medicines like chemotherapy for cancer. The newest advancements in less hazardous and more effective nanomaterials, which have applications in the fields of diagnosis, imaging systems, disease therapy, drug administration, and tissue engineering, are summarized in the current review paper. Nano-fibers perform better in a variety of applications due to their high surface area to volume ratio. Nanofiber manufactured using an electrically spinning process (quick and efficient). Water filtration, tissue engineering scaffolds, wounds, fiber composites, drug release, and protective clothingare just a few uses for it. They each have a distinct set of qualities that contribute to their amazing uses. Since its debut, nanotechnology has had an ongoing impact on healthcare and has had a significant impact on its transformation, which has led to better results. Nanotechnology has advanced toward omnipresence during the past two decades, and the process has been sped up by intensive study across many healthcare industries. According to the report Vision for Nanotechnology in the Next Decade, nanotechnology is a broad-based, multidisciplinary discipline that is anticipated to become widely used by 2020 and offers a new perspective on governance, creativity, learning, and education. It is anticipated that this field will transform many facets of human life. Footnote 1 Nanotechnology has the potential to have a significant impact on how people live, how healthy they are, what they produce, how they connect and

communicate with others, how they create and use new types of energy, and how they care for the environment.[1][2][3][4][5]

KEYWORDS: Nanotechnology, nanoparticles, nanorods, nanoshells, nanocages, plasmonics, quantumdots, fullerences, Brownian motion, electrospray-differential analysis, polymersomes.

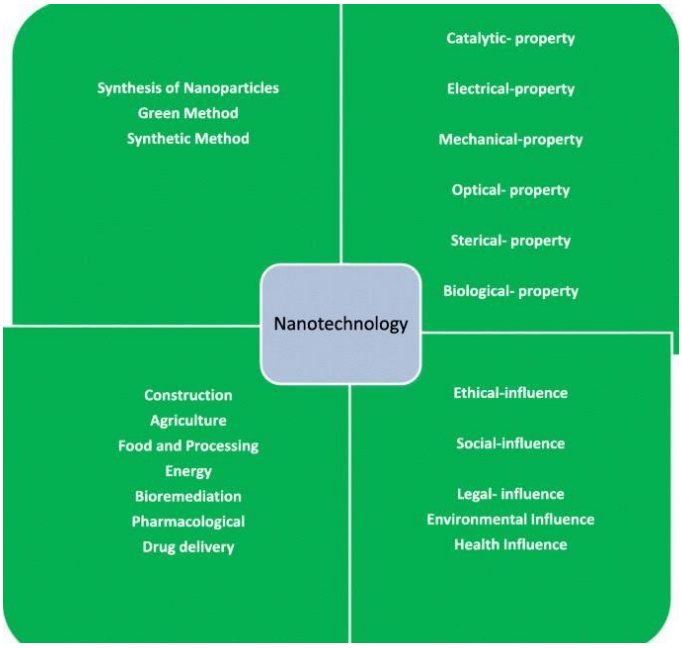
INTRODUCTION

- Although NPs are frequently thought of as a modern scientific discovery, they actually have a very long history. Pottery was once decorated with NPs made of silver, gold, and copper by artists; the first specimens were discovered in Mesopotamia in theninth century A.D.[1] A significant archeological discovery is a Roman cup from the fourth century A.D. named the Lycurgus cup, which is currently on display in the British Museum in London.[6]
- Nanotechnology has garnered a lot of acceptance recently. Nano is a prefix that refers to one billionth. A nanometer is one billionth of a meter in the metric system of linear measurements. The word "nanotechnology" is increasingly frequently used to describe the creation of novel materials with nanoscale dimensions between 1 and 100nm, primarily in the context of material science. 1 However, as it evolved, this definition's application grew as well. Different-sized nanoparticles are used for. Various biomedical applications. Nanotechnology is related to quantum mechanics and the behavior of electrons and photons in nanoscale structures in physics and electrical engineering.[7]



[8]

- When scientists discovered that a substance's size might affect its physiochemical qualities, such as its optical capabilities, they realized the significance of these materials. The typical colors of 20-nm gold (Au), platinum (Pt), silver (Ag), and palladium (Pd) NPs are, respectively, wine red, yellowish gray, black, and dark black. This is illustrated in Fig. 1 using synthetic Au NPs of various sizes as an example. According to Dreaden et al. (2012), these NPs displayed distinctive colors and characteristics along with variations in size and shape that can be usedin bioimaging applications.[9]
- The use of nanowires in applications such as thermoelectrics, catalysis, plasmonics, and photoelectrochemical water splitting for hydrogen generation necessitates excellent control over the geometry, crystallinity, and composition of individual nanostructures, as well as successful assembly into 2D and 3D architectures. Fabrication of 3D nanowire superstructures has been described using, for example, vapour-liquid-solid techniques; nevertheless, in most cases, the tunability of the relevant parameters is limited. Electrodeposition on etched ion-track membranes with interconnected nanochannels, on the other hand, provides a high degree of freedom in terms of parameter selection.[10]
- Nanomaterials have a wide range of physical, chemical, thermal, electrical, optical, and magnetic properties thanks to the quantum effect. At the nanoscale,materials gain strength and resistance, their color and light reflecting characteristics change, and reduction in size increases the surface area, which results in an alteration of the particle's physiochemical properties, leading to increased mobility, reactivity, and better aggregation and dissolution properties.[11]



NANOTECHNOLOGY BASED TECHNOLOGY[12]

1. **Solid-liquid based nanoparticles (SLN'S) technology:** High-pressure homogenisation, cold homogenisation, solvent emulsification evaporation, ultra- sonication, and multi-emulsion method can all be used to generate SLN. Surfactants such as lecithin, Tween 80, Pluronic F68, and mixtures thereof can be used to stabilize the resulting SLNs. Solid lipid(s), emulsifiers, and water are the most common materials used to make SLN. Triglycerides (e.g., tristearin), partial glycerides (e.g., Imwitor), fatty acids (e.g., stearic acid), steroids (e.g., cholesterol), and waxes (e.g., cetyl palmitate) are all examples of lipids. Emulsifiers aid in the stabilization of lipid nanoparticles, with a mixture of emulsifiers found to inhibit particle agglomeration.[13]

Table 1: Examples of sln's used in preparation of nanoparticles.

Triglycerides (lipids)	Free fatty acids & alcohols	Hard fat types	Surfactants
Tricapin Trilaurin Trimyristin Tripalmitin Tristearin Tristeain	Behenic acid Myristic acid Oleic acid Stearyl alcohol Cetyl alcohol Myristil alcohol Lauril alcohol	Glyceryl monostearate Glyceryl behenate Glyceryl palmitostearate Cetyl palmitate Stearic acid Palmitic acid Decanoic acid Witepsol grades	Soybean lecithin Egg lecithin Phosphatidylcholine PEG-35 castor oil PEG-40 hydrogenated castor oil Poloxamer 188 Poloxamer 182 Poloxamer 407 Polyoxyethylene (20)oleyl ether Polyoxyethylene (20)stearyl ether

2. **Implants:** By targeting cancers based on their cell surface receptors, nanoparticles can provide extremely selective chemotherapeutic treatment. Anisamide-targeted nanoparticles were employed in a study by Chen et al. To systemically transport c- Myc siRNA into the cytoplasm of B16F10 murine melanoma cells. This nanoparticle formulation targets melanoma cell sigma receptors. The nano treatment efficiently suppressed c-Myc expression, partially inhibited tumor growth, and sensitized melanoma cells to paclitaxel, culminating in total tumor growth inhibition. Inaddition, it significantly inhibited the growth of the MDA-MB-435 tumor, a metastatic human breast cancer model. Evans et al. recently developed and tested a therapeutic gene silencing strategy in a three-dimensional (3D) prostate cancer bone metastasis model using anisamide-targeted amphiphilic cyclodextrin nanoparticles by targeting the overexpressed sigma receptor on the surface of prostate cancer cells. Theresults demonstrated that as compared to the non-

targeted control nanoparticles, the targeted nanoparticles had much higher levels of Polo-Like Kinase 1 (PLK1) mRNA knockdown. PLK1 is a cell cycle essential regulator that has been linked to poor patient outcomes in prostate cancer cells.[14]

3. **Liquid nanoparticles(LNP's) based technology:** LNPs have shown tremendous promise as in vivo delivery vehicles for RNA therapies such as siRNAs, antisense oligonucleotides (ASOs), and mRNAs. Table 3 includes three LNP-formulated RNA therapies that have been FDA-approved for gene therapy.[82] However, with the exception of COVID-19 mRNA vaccines that have been approved for emergency use, the majority of mRNA treatments for protein replacement therapies and gene editing are in development.[15]

NANOPARTICLES APPLICATIONS IN MEDICINE

1. **Diagnostic:** Imaging has become a powerful tool in the diagnosis of sickness in the last decade. Magnetic resonance imaging and computer tomography have made remarkable advances. However, nanotechnology provides instruments for in vitro and in vivo diagnostics that are sensitive and extremely accurate, far exceeding the capabilities of current equipment. The ultimate goal, like with any advancement in diagnostics, is to allow clinicians to diagnose an ailment as soon as possible.

Nanotechnology is expected to enable cellular diagnostics and maybe sub-cellulardiagnostics.

2. **Therapy development:** The greatest impact of nanomedicine on medication deliveryand treatment is expected to be in therapy. Nanoparticulars enable doctors to target medications to the source of the ailment, increasing efficiency and reducing side effects. They also open up new avenues for controlling therapeutic release. With many forms of nano medicines, drug transport, and diagnostic applications, nanomedicine has acquired great benefits in instrumentation and pharmaceutical synthesis.

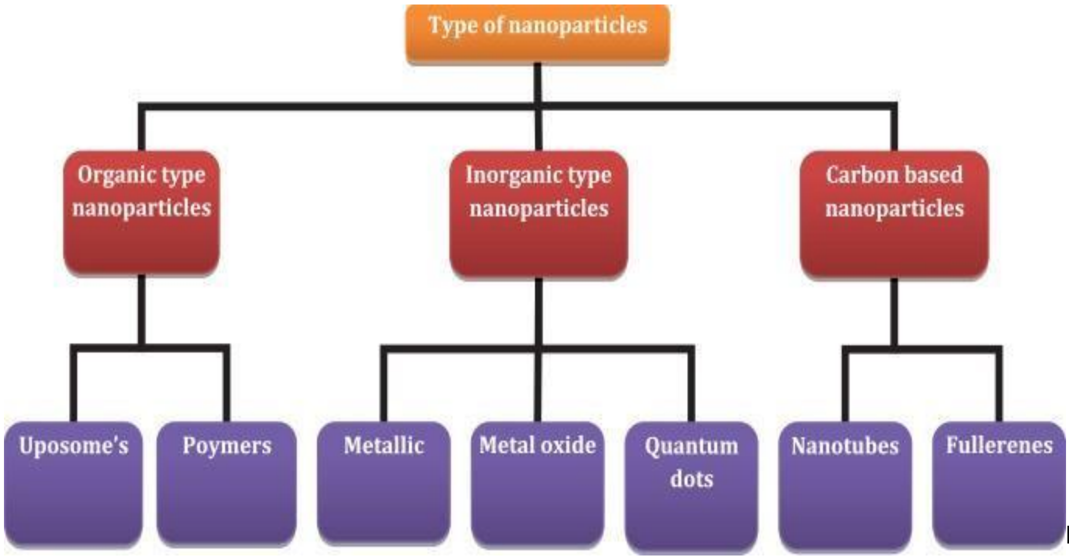
Nanoparticles and nanotechnology-based treatments are being developed as a researchfield.

3. **Drug-delivery:** Nanotechnology-based drug delivery systems begin with nanoparticles containing one or more therapeutic medicines that can bind or scatter, aswell as adsorbed polymer matrices. There has been substantial progress in nano-drug synthesis using im-agery, therapies, and diagnostics in recent years. Nano-drug systems are largely concerned with increasing the bioavailability of targeted tissue delivery, extending the half-life of injectable medicines, and administering medicinal items orally. Nano medicines are supplied at lower levels, resulting in significant advances in their pharmacological effects as well as a reduced risk to health and unwanted

consequences.[16]

4. **Wound treatment:** Cells from a human can be used to generate tissues and organsfrom a holy grail for reconstructive and transplant surgery for people who have lost them due to illness or disease. This research, aided by knowledge of the topography of nanoscale tissues, attempts to construct tissues with functions and structures similar tothose found in natural organisms. Nanogenerators, polymer nanoparticles, and precise solutions could help people's wounds heal faster and more effectively. Only images and target ligands can attach nanoparticles to cells or tissue. This enables surgeons and radiographers to more efficiently discern sick tissue from healthy tissue, improve sickness treatment, and limit the risk of injuring healthy tissue. The speed and specificity of biomarker analyses in physiological fluids have been greatly influencedby nanotechnology.
5. **Nanomedicine diagnostic techniques:** Nanotechnology applications for diagnostics,such as the use of carbon nanotubes, gold nanorobs, and quick and inexpensive detections, have made disease identification possible at an earlier stage. This technology use submicrometer-sized devices to better diagnose, prevent, and cure illnesses, as well as to improve patients' overall quality of life. Nanotechnology has significantly advanced the discovery of regenerative medications. In patients with organ failure or significant injuries, new technologies allow for the use of prosthetic skin, bone, cartilage, or other tissues. Nanotechnology alters cellular activity more effectively in order to mimic the effects of natural tissues and organs.
6. **Minimise damage of healthy cells:** Medical nanotechnology inventors are developing methods for more efficiently delivering medicines, such as specifically targeting cancer cells through therapy. Patient outcomes improve, and minimal damage to healthy cells is noted, which may cause injury during chemotherapy with nanoparticles that locate and destroy cancer cells. Physicians can also deliver more precise heat treatment by combining nanotechnology and chemotherapy. In such therapy, nanotubes attached to tumor-attracted antibodies absorb laser light, causing the tumor to incinerate.67-68 Nanomedicine makes considerable use of bio- biological, nonbiological, biomimetic, or hybrid materials.

TYPES OF NANOPARTICLES



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MANUFACTURING OF NANOPARTICLES: INTRODUCTION

Nanoparticle production in an industrial flame aerosol

More than 8 Mt/year carbon blacks are produced for tires (70%) and rubber (20%); titania (2 Mt/year) is primarily used for pigments, zinc oxide (0.6 Mt/year) as an activator of rubber vulcanization (50%) and pigment or pharmaceutical additive, fumed silica (0.2 Mt/year) as a powder flowing aid, in cosmetics, and in the fabrication of optical fibers for telecommunications.

Heterogeneous catalysis

Because the fundamentals of aerosol production are well established, the time has come to apply them to the synthesis of more complex and functional products than pure silica or titania. Most industrial chemical processes today rely significantly on catalysis. Rawmaterials are processed at a rate of several hundred million tons per year, and catalytic processes are used to produce high-value goods such as polymers and pharmaceuticals.[19]

METHODS

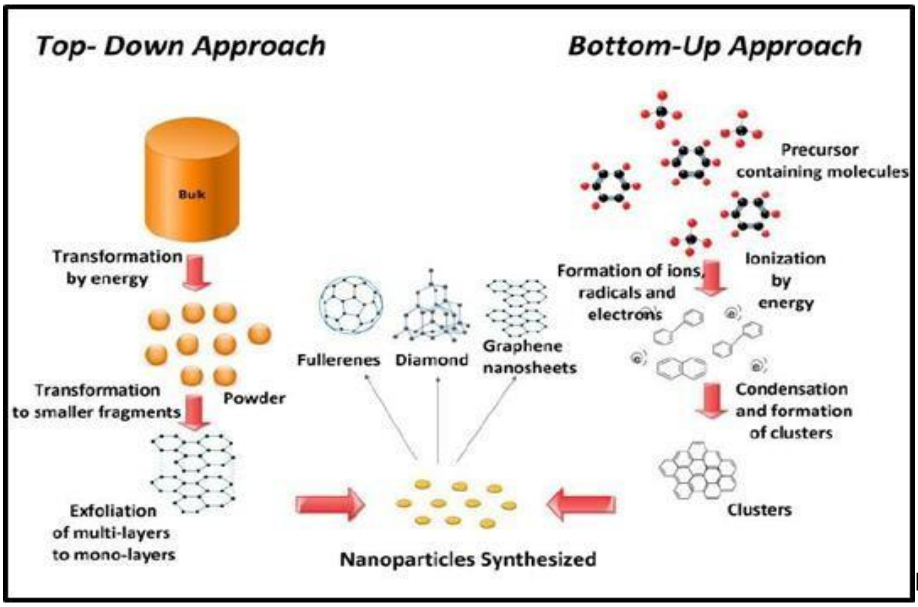
1. Bottom-up approaches

Aerosol-based methods are a common way for industrial synthesis of nanoparticles. An aerosol is a system of solid or liquid particles suspended in air or another gaseous medium. Particles can range in size from molecules to 100 m. Aerosols were used for many years before the core science and engineering behind them were understood. Pigments such as carbon black particles and titania, for example, were utilized as tire reinforcements and in the creation of paints and plastics, respectively. Another example is fumed silica and titania, which are generated by flame pyrolysis from respective tetra chlorides. Optical fibers are also made in a similar manner. Spraying is used to dry wet materials or to apply coatings. Precursor pyrolysis happens when the precursor chemicals are sprayed onto a heated surface or into a hot environment, and particles are formed. Oxford University devised an electro-spraying technique at room temperature for the manufacture of semiconductors and metal nanoparticles.[8] In order to achieve CNT growth, the spray gun deposition approach was also used to deposit catalystprecursors such as iron chlorides (III). Catalyst deposition as a film on diverse substrates is a straightforward, cost-effective process that may be applied to huge surfaces.

2. Liquid phase technique

The sol-gel method has long been used in industry to create colloidal nanoparticles from liquid phase. It has recently been improved for the creation of sophisticated nanomaterials and coatings. The sol-gel method is a chemical procedure based on hydrolysis or condensation processes. Nanosized particles precipitate when the correct amount of reactants are used. Sol-gel processes have numerous advantages, including low processing temperatures, adaptability, and ease of sculpting and embedding. Alkoxides are commonly employed as precursors for the manufacture of oxides due to their availability and the high liability of the M-OR bond, which allows for easy tailoring in situ during processing. This approach reduces the risk ofnanoparticle leakage once the solution has dried.[20]

1. Bottom-Up Approch



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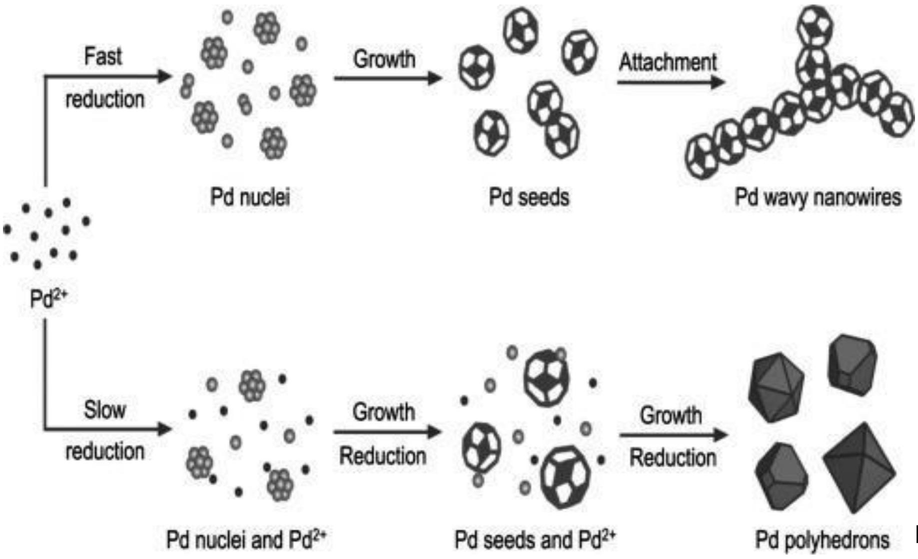
2. **Liquid Phase Technique**



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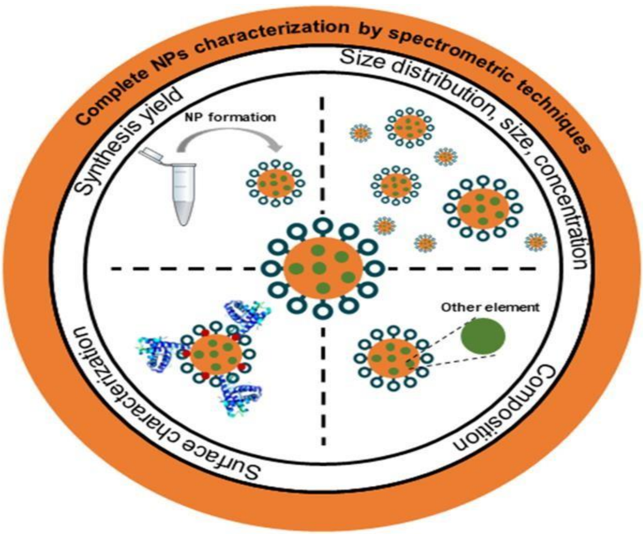
CHARACTERIZATION AND ISOLATION OF NANOPARTICLES

1. **Scanning electron microscopy:** The methods for sample preparation, image capture, and characterization of nanoparticle size and shape using the scanning electron microscope (SEM) in reflecting and transmitted working modes are detailed in this. These aid in attaining consistent, repeatable results. The optimal options differ depending on the raw (powdered or suspension) nanoparticle material, the necessary measurement uncertainty, and the SEM performance.[23]
2. **Particle tracking analysis:** Particle tracking analysis, PTA (also known as nanoparticle tracking analysis, NTA), is a technology that analyzes the Brownian motion of particles to determine size and size distribution and counts the number ofparticles present within a volume to determine particle concentration (in particles/millilitre). It also analyzes the benefits and drawbacks of PTA anddescribes specific applications where the technology has shown to be mostbeneficial.[24]
3. **Electrospray-differential mobility analysis:** Among the available methods for characterization of nanostructured materials, electrospray-differential mobility analysis (ES-DMA), also known as electrospray scanning mobility particle sizer (ES-SMPS) or electrospray ionization-gas-phase electrophoretic mobility molecular analysis (ESI-GEMMA), has been identified as a powerful technique for measuring nanoparticle (NP) size distributions and has recently yielded promising results whenmeasuring the absolute ES-DMA is typically made up of three units: (1) a charge- reduced electrospray generator (ES), i.e. an electrospray generator that is directly linked to a neutralization source. (2) a

differential mobility analyzer (DMA) that chooses particles based on their electrical mobility equivalent diameter; and (3) a condensation nucleus counter (CNC) (also known as condensation particle counter, CPC) that counts selected particles. Electrical mobility equivalent diameter, or simply mobility diameter, is the diameter of a spherical particle having the same mobility (defined as the particle velocity produced by a unit external force) as the particle in question. This chapter provides an overview of the ES-DMA apparatus and various configurations, as well as applications to the measurement of number size distributions and particle number concentrations of nanostructured materials incolloidal suspensions.[25]

4. **Small angle x-rays scattering:** This chapter introduces small angle x-ray scattering for nanoparticle characterisation. Before discussing the determination of the most relevant parameters, the basic principles and instruments are given. These characteristics are the size of nanoparticles in liquid suspensions, particularly the mean particle diameter for spherical particles, the width of the size distribution, and the number concentration. The topic of standardization in the field is discussed, and instances of achievable uncertainties are offered. Finally, specific studies of core- shell nanoparticles are described.[26]



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NANOPARTICLES IN ENVIRONMENT

Introduction: Nanotechnology is highly effective at removing and detecting pollutants. Nanoadsorbents, nanofiltration, nanophotocatalysts, magnetic nanoparticles, and nanosensors for a healthy environment. Green technology is a powerful tool for achieving long-term growth. The use of nanotechnology in the production of nanocomposites has resulted in the development of highly durable and lightweight raw materials capable of replacing heavy metal parts and significantly reducing the weight of equipment and auto parts, thereby significantly reducing energy consumption and, ultimately, air pollution. Additionally, eliminating the emission of 2 million tons of carbon compounds and saving billions of dollars in energy are positive outcomes of applying semiconductor manufacturing technology in the sector of lighting, which will minimize air pollution.[28]

1. **Absorption in the context of the environment:** On mammalian cells, toxicity tests on nanoparticles have been mostly conducted. These research involved exposing the nanoparticles to protein- and biologically- rich cell culture medium. Since prokaryotes, including bacteria, lack a method to transport colloidal particles through the cell wall, their cellular surfaces operate as a protective barrier that prevents many types of nanoparticles from being absorbed. Eukaryotes, such as early, unicellular creatures and multicellular organisms, have some processes for the entry of nanoparticles and microparticles, namely endocytosis and phagocytosis, which make the situation in these species distinct. It has been noted that certain nanoparticles can be taken by cells; for instance, carbon nanotubes can be absorbed by protozoa and accumulate in the mitochondria of the cells. The body and eggs of the little Japanese fish Oryziaslatipes absorb latex nanoparticles, which then build up in the gills, intestines, brain, sexual organs, liver, and blood. Inorganic nanoparticles, such as zinc oxide, can infiltrate bacteria and are also taken up by the cells. The cell wall of the E. coli bacteria is capable of absorbing CeO2 nanoparticles.[17] Nanoparticles are hazardous to aquatic unicellular creatures and animals, including fish and Daphnia, according to toxicological investigations.[16] Carbon nanotubes have harmful effects on rainbow trout's respiratory systems and are a growth inhibitor for protists. However, carbon nanotubes stimulated the growth of several unicellular protists in a solution containing yeast.

2. **Nanoparticles in outdoor spaces:** Nanoparticles are released in both indoor and outdoor environments by a variety of natural and artificial processes. Construction workers, those who maintain gas and oil transmission pipelines, police officers, farmers, and people with many other occupations frequently work outside. However, the scant information that is now available implies that these persons are vulnerable to an elevated risk of unfavorable health effects brought on by their exposure to nanoparticles. Few studies have been undertaken on the impact of the exposure of such workers to nanoparticles. It is possible in some circumstances for nanoparticles from interior locations to enter the outdoor

environment.[29]

HEALTH EFFECTS OF NANOPARTICLES

Introduction: Following the publication of the paper by Oberdörster et al. and the establishment of the journal Nanotoxicology in 2007, the multidisciplinary research field known as nanotoxicology—a term coined by Donaldson in 2004—consolidated in 2005. According to Guadagnini et al. (2015), Shvedova introduced the definition of nanotoxicology in 2010 as a field that investigates the interactions between manufactured nanoparticles and cellular and extracellular macromolecules. The goal of nanotoxicology is to evaluate the risks posed by nanotechnology. It does not appear to follow the same laws as traditional toxicology (Oberdorster, 2010). A fully developed scientific field is nanotechnology. Nanomaterials are used in a wide range of technological fields (Prosie F. & Deschamps, 2008). The creation and application of nanoparticles are expanding significantly. Because of this, concerns have been raised about their possible short- and long-term impacts on health (Andujar et al., 2009), making them a source of worry. According to the scientific community, nanoparticles constitute an increasing toxicological issue (Masse, 2013). In this scoping review, nanoparticles (NPs) employed in the food industry, their main uses, and their long-term health implications were of special interest.

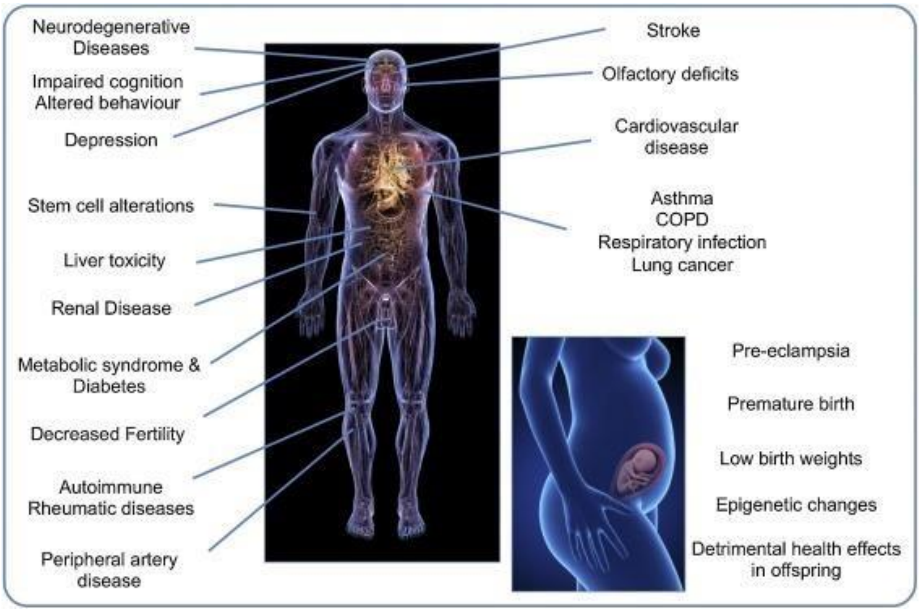
1. **Cytotoxicity:** Nanotechnology is a fully developed scientific discipline. Numerous technological fields utilise nanomaterials (Prosie F. & Deschamps, 2008). The production and use of nanoparticles are rapidly growing. Because of this, worries about their potential short- and long-term effects on health have been raised (Andujar et al., 2009), making them a worry. Nanoparticles are a growing toxicological concern, according to the scientific community (Masse, 2013). The usage of nanoparticles (NPs) in the food business, as well as their primary applications and potential long-term health effects, were of particular interest in thisscoping review.

2. **Genotoxicity and carcinogenesis:** Indirect oxidative damage to DNA or indirect genotoxicity can be caused by NPs' production of ROS in the cells and the inflammation it causes (Trouiller et al., 2009). NPs are directly genotoxic as well. (Barillet et al., 2010, Magdolenova Z et al., 2013) They can enter the nucleus and interact with DNA arranged in chromatin or chromosomes. and attach to topoisomerase II alpha to interact with proteins involved in DNA replication, transcription, or repair (Baweja et al., 2011). The interaction of NPs with centrioles, the mitotic spindle apparatus, or the proteins linked to

these structures may also have an aneugenic effect (Huang et al., 2009). For instance, a study using five rats that received intraperitoneal injections of silver NPs at doses of 1, 2, and 4 mg/kg body weight every day for 28 days (El Mahdy et al., 2015) showed that silver NPs cause variable and dose-dependent chromosomal aberrations. Nanoparticles are genotoxic substances that have the potential to cause cancer in people. In fact, the International Agency for Research on Cancer (IARC) has classified TiO2 NPs, SiO2, and multi-walled CNTs as carcinogenic based on the findings of published experimental research.(table 2)

NPs	New classification	Classification year	Old classification
TiO2	2B	2010	3 in 1989
SiO2	1	2012	-
Multi-wall NTC	2B	2017	2B in 1996
Single-wall NTC	3	2017	

3. **Nephrotoxicity:** As NPs are eliminated through renal excretion, this means that they can harm the kidneys and induce nephrotoxicity by causing oxidative stress (Makhdoumi et al., 2020). Several experimental studies have looked into how NPs affect the kidneys. In an experimental investigation conducted by Liu (2020), male Wistar rats were given an intraperitoneal injection of a solution containing silver nanoparticles (3 mg/kg of body weight) for one, two, or three weeks. Increased and time-dependent ROS production resulted in significant structural damage to proteins and DNA, changed the expression of ion channel proteins, and brought on kidney inflammation (Liu et al., 2020). Albahim (2020) also gave male rats an 80mg/kg dose of silver nanoparticles.[30]

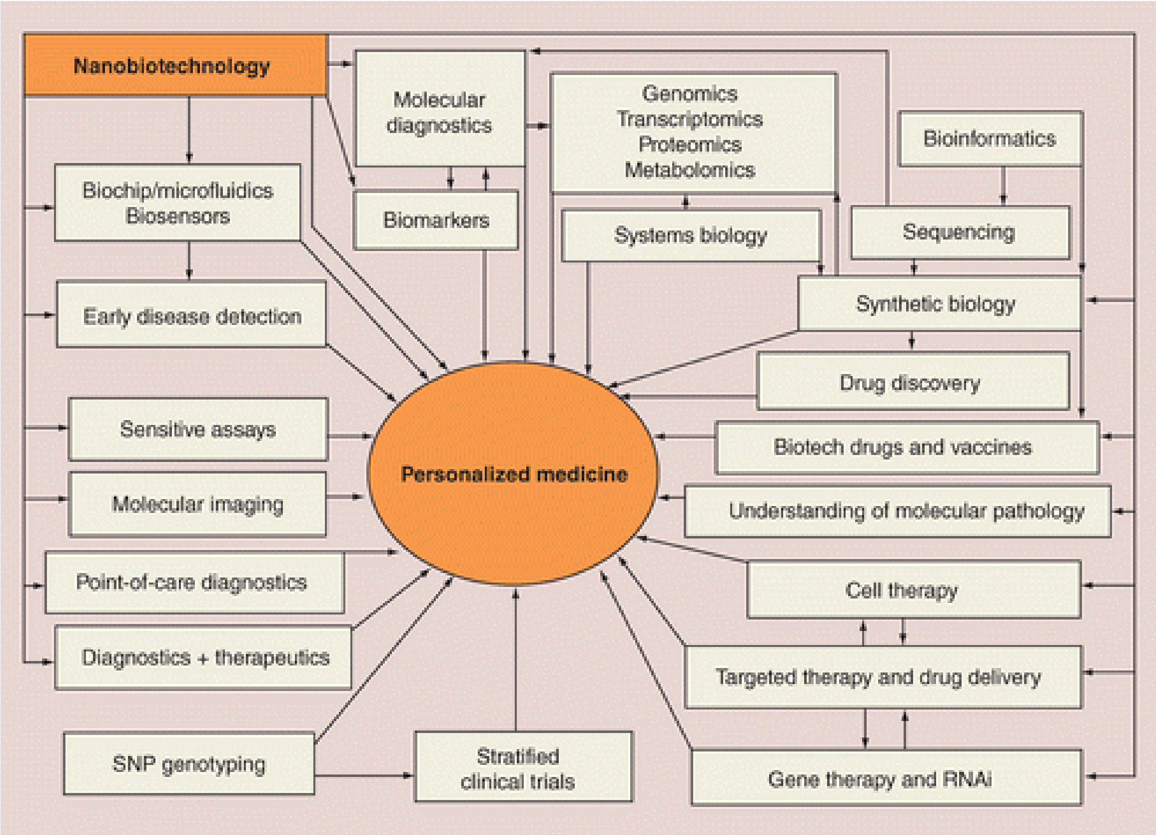


NANOTECHNOLOGY SUMMARY[31]

- In the world of pharmaceuticals and medicine, nanotechnology is regarded as a recentand quickly developing sector. As drug delivery vehicles, nanoparticles provide a number of benefits in terms of increased efficacy and less negative medication reactions.
- Many other kinds of nanosystems, such as carbon nanotubes, paramagnetic nanoparticles, dendrimers, nanoemulsions, etc., have been created. Shape and properties of the generated nanoparticles are significantly influenced by the physicochemical qualities of the starting materials and the method of synthesis chosen. The most widely used methods for creating nanocarriers are dispersion of premade polymers, coacervation, polymerization, nano-spray drying, and supercriticalfluid technologies.[32]
- Nanospheres are matrix systems in which the drug is physically and evenly spread, whereas nanocapsules are vesicular systems in which a drug is confined to a cavity and surrounded by a polymer membrane. Nanoparticles range in size from 10 nm to 1000 nm and are solid, colloidal particles made up of macromolecular components (Kreuter, 1994a). Nanomedicine frequently refers to objects with a width of less than 200 nm, or the width of a microcapillary. However, particles larger than 200 nm are not actively explored. A nano-matrix is typically used to dissolve, entrap, adsorb, attach, and/or encapsulate the desired medication. For the greatest therapeutic agent delivery or encapsulation, different features and release characteristics can be builtinto nanoparticles, nanospheres, or nanocapsules depending on the fabrication process.
- When creating a nanoparticulate delivery system, it's crucial to take medication release and polymer biodegradation into account. Drug solubility, surface-bound oradsorbed drug desorption, drug diffusion through the nanoparticle matrix, nanoparticle matrix erosion or degradation, and a combination of erosion and diffusion processes are all factors that affect the drug release rate in general. Therefore, the release mechanism is controlled by the particle matrix's solubility, diffusion, and biodegradation.
- The most promising currently available anticancer medications have a poor water solubility problem that has been successfully addressed by nanomaterials, which will boost the effectiveness of these drugs. In order for the weakly soluble anticancer medications to be readily absorbed into cancer cells, solvents must be added. Unfortunately, these solvents not only lessen the drug's efficacy but also make them hazardous. Researchers from the University of California Los Angeles California Nanosystem Institute have created a novel strategy to deliver the anticancer medication

CPT and other water insoluble medicines to cancer cells using silica-based nanoparticles.[33]

- The use of nanomedicine represents a significant improvement in the aforementioned domains and promises to be encouraging in the coming ten years. The vast range of NP design and functionalization will lead to more effective and secure treatments. As the list of potential uses grows, the nanocarrier can be tailored to best fit a particular active component, a particular environment, and then supply the right drug placement at the site of action, in a regulated manner. It is important to note that NP-based treatments have limitations and difficulties to be overcome. First, despite the fact that R&D has evolved over the past ten years, the number of polymeric materials currently accessible for their use as DDS is still quite small. In the near future, it would be fascinating to conduct research in this area using stimuli-responsive polymers that have triggered release features. Nanospheres and nanocapsules are simple to produce using the already available techniques, while novel structures like polymersomes must still undergo improved synthesis in order to join the family of nanoparticulate DDS. The necessity to create multifunctional NPs, also known as NPs with many functions (targeting, image contrast enhancement), entails additional synthetic stages, more regulatory requirements, and greater costs. Although achieving these goals may seem exceedingly challenging, there is still hope for a better outcome. A interdisciplinary and collaborative strategy has been developed in the field of nanomedicine over the past few years, and it has shown promising outcomes. Collaborations between theoretical and experimental scientists, the pharmaceutical industry, doctors, and regulatory agencies will be crucial in the future and will enable us to translate laboratory findings into clinical practice and thereby launch the next generation of clinical therapies in an effort to lessen the devastation caused by terrible diseases like pandemic COVID-19.In order to achieve the intended results, several challenges or restrictions still need to be overcome through intense interdisciplinary scientific collaboration.[34]



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