***Title: The ecotoxicology of nanoparticles and nanomaterials: current status, knowledge gaps, challenges, and future needs***

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**Abstract**:

In the journal Ecotoxicology, a special issue on the environmental chemistry and ecotoxicology of nanoparticles (NPs) and nanomaterials (NMs) is introduced in this paper. The scientific community is observing NP ecotoxicity to inform the larger debate regarding the risks and benefits of these materials. There are numerous types of NMs. Since the beginning of time on Earth, natural NPs have been present in the environment. Natural sources include volcanic dust, the majority of natural waters, soils, and sediments.Although there is evidence that some natural NPs can be toxic, organisms have also evolved in an environment containing natural NPs. Natural NPs are produced by a wide range of geological and biological processes .There are worries that pollution might have an effect on natural nano scale processes. Particle shape, size, surface area, and surface charge, in addition to the materialand#039;s adsorption properties, are likely to influence the complex colloid and aggregation chemistry of manufactured NPs. aggregation chemistry will be altered by abiotic factors like pH, ionic strength, water hardness, and the presence of organic matter ;and are anticipated to impact toxicity .Understanding the uptake and distribution of NPs within organisms, as well as the interactions of NPs with other pollutants, and the fate and behavior of NPs in the environment are all dependent on the physicochemistry .According to data on their biological effects, NPs can be harmful to mammals as well as bacteria, algae, invertebrates, and fish species .However, the majority of ecotoxicological data is restricted to freshwater organisms and species used in regulatory testing. Particularly lacking are data on bacteria, terrestrial, marine, and higher plant species. Although there are some data on fish, comprehensive studies of absorption, distribution, metabolism, and excretion (ADME) still need to be conducted on species from the major phyla. The tiered approach and regulatory framework that are currently in place could be utilized for the environmental risk assessment of NMs; however, there would need to be modifications made to the methodology, one of which would include chemically defining the materials that are being utilized. Knowledge transfer from mammalian toxicology, colloid chemistry, and the material and geological sciences will enable ecotoxicology studies to advance in this new multidisciplinary field, despite the many obstacles and controversies that lie ahead (such as reference substances for ecotoxicology).

**Keywords**

:Nanoparticles classification ,nanomaterial history ,nanotoxicity ,oxidative ,stress, reactive oxygen species ,regulations .

**REVIEW**

**INTRODUCTION:**

Nanoparticles(NPS) and nanostructured materials (NSMS) represent an active area of research and a techno – economic sector with full expansion in many application domains. NPS and NSMS have gained prominence in technological development due to their controllable physicochemical properties such as melting point, wettability, electrical and thermal conductivity, catalytic activity and light absorption .Introduction

Nanotechnology has evolved into a scientific achievement in the 21st century. The synthesis, control and use of sub-100 nm materials fall under the interdisciplinary umbrella of this field. Nanoparticles have important applications in various fields such as environment, agriculture, food, biotechnology, biomedicine, pharmaceuticals, etc.; for water purification (Zahra et al., 2020), environmental monitoring (Rassaei et al., 2011), as a functional food additive (Chen et al., 2023) and as an antimicrobial agent (Islam et al., 2022). The main characteristics of NPs as; nature, biocompatibility, anti-inflammatory and antibacterial activity, efficient drug delivery, bioactivity, bioavailability, tumor targeting and bioabsorption have led to an increase in biotechnological and applied microbiological applications of NPs.

A particle of matter between one and one hundred nanometers (nm) in diameter is usually called a nanoparticle or an ultrafine particle. Nanoparticles often exhibit characteristic size-dependent properties, mainly due to their small size and enormous surface area. The periodic boundary conditions of a crystalline particle are destroyed when the particle size approaches the nanoscale on a characteristic length scale close to or smaller than the de Broglie wavelength or the wavelength of light (Guo et al., 2013). Therefore, many of the physical properties of nanoparticles are significantly different from those of bulk materials, leading to many new uses (Hasan, 2020)

2. Birth of Nanotechnology Nanotechnology appeared in the 1980s due to experimental advances such as the scanning tunneling microscope. In 1981 and the discovery of fullerenes in 1985 (Bayda et al., 2019), with an explanation. The popularization of the conceptual framework of the goals of nanotechnology began with the publication of the book "Engines of Creation” in 1986 (Bayda et al., 2019).

2.1. An early phase of NPsCarbon nanotubes was found in ceramics from Keelad, India, dated around 600–300 BC. (Bayda et al., 2019; Kokarneswaran et al., 2020). Nanowires of cementite, a material dating back to about 900 AD, have been found in Damascus steel. However, its origin and method of creation are unclear (Kokarneswaran et al., 2020). However, it is not known how they formed or whether the material containing them was used intentionally.

2.2. Discovery of C, Ag, Zn, Cu, and Au nanoparticles In 1991,carbon NPs were discovered, and Iijima and Ichihashi reported the synthesis of a single-walled carbon nanotube with a diameter of 1 nanometer in 1993 (Chen et al., 2021). Carbon nanotubes (CNTs), also known as Bucky tubes, are a type of nanomaterial consisting of a two-dimensional hexagonal lattice of carbon atoms. They are bent in one direction and connected to form a hollow cylindrical cylinder. Carbon nanotubes are allotropes of carbon that lie between fullerene (0-dimensional) and graphene (2-dimensional) (Chen et al., 2021).

In addition, M. C. Lea reported the synthesis of citrate-stabilized colloidal silver almost 120 years ago (Nowack et al., 2011). During this process, particles with an average diameter of 7-9 nm are obtained. The nanoscale size and citrate stabilization are analogous to recent findings on nano-silver production using silver nitrate and silver citrate (Majeed Khan et al., 2011). The use of proteins to stabilize nanosilver was also documented as early as 1902 (Nowack et al., 2011; Beyene et al., 2017).

Since 1897, nano-silver, known as Collargol, has been produced commercially and used for medicinal purposes (Nowack et al., 2011). Collargol, a type of silver nanoparticle, has a particle size of about 10 nanometers (nm). It was already determined in 1907 and the Collargol diameter was found to be in the nanoscale range. In 1953, Moudry developed another type of silver nanoparticles, called gelatin-stabilized silver nanoparticles, with a diameter of 2-20 nm. These nanoparticles were produced using a different method than Collargol. The creators of nanosilver formulations realized the need for nanoscale silver decades ago, as evidenced by the following patent note: “for optimal efficiency, silver must be used as colloid-sized particles with a crystallite size of less than 25 nm” (Nowack et al., 2011).

Gold NPs (AuNPs) have a long history in chemistry dating back to Roman times when they were used to decorate glassware by painting. With the work of Michael Faraday, who may have been the first to realize that colloidal gold solutions have different properties than bulk gold, the modern era of AuNP synthesis began more than 170 years ago. Michael Faraday studied the preparation and properties of “Ruby” gold colloidal suspensions in 1857. They belong to the class of magnetic nanoparticles due to their characteristic optical and electrical properties. Faraday showed how gold nanoparticles can create solutions of different colors under certain lighting conditions (Bayda et al., 2019; Giljohann et al., 2020).

3. Classification of NPsNanoparticles (NPs) are classified into the following categories based on their shape, size and chemical properties.

3.1. Carbon-based NPsFullerenes and carbon nanotubes (CNTs) are two important subclasses of carbon-based NPs. Spherical hollow cage NPs, as allotropic forms of carbon, are found in fullerenes. Due to their electrical conductivity, high strength, structure, electron affinity and adaptability, they have attracted considerable economic interest. These materials have an arrangement of pentagonal and hexagonal carbon units, each of which is sp2-hybridized. CNTs are elongated and form tubular structures with a diameter of 1-2 nm. They basically look like sheets of graphite rolling over each other. Therefore, they are called single-walled (SWNT), double-walled (DWNT), or multi-walled carbon nanotubes (MWNT), depending on the number of walls in the rolled sheets (Elliott et al., 2013; Astefanei). Et al., 2015).

3.2. Metal NPsMetals NPs are made only of metals. These NPs exhibit distinct electrical properties due to the well-known properties of localized surface plasmon resonances (LSPRs). Cu, Ag and Au nanoparticles have a broad absorption band in the visible region of the solar electromagnetic spectrum. Metal NPs are used in several scientific fields due to their advanced properties such as milling, size and shape-controlled synthesis of metal NPs (Khan et al., 2019).

3.3. Ceramic NPsCeramic NPs are small particles composed of inorganic non-metallic materials that are heat treated and cooled..RecommendationsFor future work, we recommend using different reaction parameters such as temperature, pressure, time and pH. Can play an important role in controlling the shape and morphology of NP materials, so it should be optimized to achieve a certain characteristic product. In addition, special characterization techniques should be used to investigate good effects and properties. More importantly, environmental concerns must be considered before using these materials, especially when dealing with heavy metals that are harmful to the environment and can also affect life.

3.4. Lipid-based NPsThese NPs are useful in several biological applications because they contain lipid moieties. LipidNPs are typically 10–1000 nm in diameter and spherical in shape. Lipid NPs, i.e. polymeric NPs, have a solid lipid core and a matrix composed of soluble lipophilic molecules (Khan et al., 2019).c aluminum nanoparticles. The strong reactivity of aluminum nanoparticles makes them promising for use in high-energy compounds, hydrogen production in water processes, and the synthesis of 2D and 3D structures of alumina (Lerner et al., 2016

.4.. Iron nanoparticles (FeNPs)Iron nanoparticles (FeNPs) are particles made of iron with a size of 1–100 nanometers (Khan et al., 2019). FeNPs have several potential applications, including their use as catalysts, drug delivery systems, sensors, and energy storage and conversion. They have also been studied for use in solar cells and solar cells, as well as in water purification and environmental restoration. FeNPs can also be used as contrast agents in magnetic resonance imaging (MR) to improve the visibility of tissues and organs. They can also be used in magnetic media such as hard drives (Zhuang and Gentry, 2011; Jamkhande et al., 2019).As with all NPs, there are potential health and safety concerns associated with the use of FeNPs, e.g., FeNPs are used to deliver drugs to specific sites in the body, such as cancer cells, and are used in magnetic resonance imaging and to remove. contaminants of water (Farrell et al., 2003; Zhuang Zhuang and Gentry, 2011). Tables 1, 2 show the properties of metal-based nanoparticles and the methods of studying these properties, respectively

5. Approaches for the synthesis of metal NPsThere are mainly three types of approaches for the synthesis of NPs: physical, chemical and biological approaches. The physical approach is also called the bottom-up approach, while the chemical and biological approaches are collectively called the bottom-up approach. The biological approach is also named green systems of NPs. All these approaches are further sub-categorized into various types based upon their method adopted. Figure 1 illustrates each approach’s reported methods for synthesizing

5.1. Top down/physical approachBulk materials are fragmented in top-down methods to create nano-structured materials (Figure 2). They are additionally known as physical approaches (Baig et al., 2021). The following techniques can achieve a top-down approach

5.1.1. Mechanical millingThe mechanical milling process uses balls inside containers and may be carried out in various mills, typically planetary and shaker mills, which is an impact process with high energy (Gorrasi and Sorrentino, 2015). Mechanical milling is a practical approach for creating materials at the nanoscale from bulk materials. Aluminum alloys that have been strengthened by oxide and carbide, spray coatings that are resistant to wear, nanoalloys based on aluminum, nickel, magnesium, and copper, and a variety of other nanocomposite materials may all be created mechanically. A unique class of nanoparticles known as ball-milled carbon nanomaterials has the potential to meet the needs for energy storage, energy conversion, and environmental remediation (Yadav et al., 2012; Lyu et al., 2017

).5.1.2. ElectrospinningTypically, it is used to create nanofibers from various materials, most often polymers (Ostermann et al., 2011). A technique for creating fibers called electrospinning draws charged threads from polymer melts or solutions up to fiber sizes of a few hundred nanometers (Chronakis, 2010). Coaxial electrospinning was a significant advancement in the field of electrospinning. The spinneret in coaxial electrospinning is made up of two coaxial capillaries. Core-shell nanoarchitectures may be created in these capillaries using two viscous liquids, a viscous liquid as the shell and a non-viscous liquid as the core (Du et al., 2012). Core-shell and hollow polymer, inorganic, organic, and hybrid materials have all been developed using this technique (Kumar R. et al., 2013).

5.1.3. Laser ablationA microfeature can be made by employing a laser beam to vaporize a single material (Tran and Wen, 2014). Laser ablation synthesis produces nanoparticles by hitting the target material with a powerful laser beam. Due to the high intensity of the laser radiation used in the laser ablation process, the source material or precursor evaporates, causing the formation of nanoparticles (Amendola and Meneghetti, 2009). Laser ablation is an environmentally friendly method for the production of precious metal nanoparticles (Baig et al., 2021). Various nanomaterials can be created using this method, including metal nanoparticles, carbon nanoparticles, oxide compounds, and ceramics (Su and Chang, 2018; Baig et al., 2021)

.5.1.4. SputteringMicroparticles of a solid are released from its surface in a phenomenon known as sputtering, which occurs when a solid is attacked by powerful plasma or gas particles (Behrisch, 1981). According to the energy of the incoming gas ion, the energetic gas ions used in the sputter coating process physically repel small clusters of atoms from the target surface (Muñoz-García et al., 2009). The sputtering method is interesting because it is cheaper than electron beam lithography and the composition of the sputtered nanomaterials is similar to the target material with fewer impurities (Baig et al., 2021).

5.1.5. Electron explosionIn this technique, a thin metal wire is exposed to a high current pulse, causing an explosion, vaporization and ionization. The metal vaporizes and ionizes, expands, and cools as it reacts with the nearby gas or liquid medium. The condensed vapor eventually forms nanoparticles (Joh et al., 2013). Electron implosion method because it produces plasma by electrical implosion of a metal wire, which can produce nanoparticles from a Pt solution without a reducing agent (Joh et al., 2013).

5.1.6. UltrasonicationUltrasonication is a crucial step in the creation of nanofluids. After mixing the mixture in a magnetic stirrer, sonication is performed in an ultrasonic path, an ultrasonic vibrator and a mechanical homogenizer. Sonicators have become the industry standard for probe sonication and are significantly more efficient than ultrasonic cleaning baths used in nanoparticle applications. Probe sonication is very effective in processing nanomaterials (carbon nanotubes, graphene, inks, metal oxides, etc.) (Zheng et al., 2010).

5.1.7. Pulsed Wire Discharge MethodThis is the most widely used method to create metal nanoparticles. The pulsating current causes the metal wire to vaporize, creating a vapor that is then cooled by the surrounding gas to form nanoparticles. This plan will be fast.

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