IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

Human Journals
**Review Article**
December 2023 Vol.:29, Issue:1
© All rights are reserved by Swati S. Dusane et al.

# A Review on Nanoparticles

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

**Swati S. Dusane*, Pratiksha Wasankar, Shubhngi Katkade**

*NCRD's Sterling Institute of Pharmacy, Nerul Navi Mumbai. Maharashtra, India.*

**Submitted:** 20 November 2023
**Accepted:** 25 November 2023
**Published:** 30 December 2023

HUMAN JOURNALS
**ijppr.humanjournals.com**

**Keywords:** Nanomaterial classification, nanomaterial history, nanotoxicity, oxidative stress, reactive oxygen species, regulations

**ABSTRACT**

Nanomaterials (NMs) have gained prominence in technological advancements due to their tunable physical, chemical and biological properties with enhanced performance over their bulk counterparts. NMs are categorized depending on their size, composition, shape, and origin. The ability to predict the unique properties of NMs increases the value of each classification. Due to the increased growth of the production of NMs and their industrial applications, issues relating to toxicity are inevitable. The aim of this review is to compare synthetic (engineered) and naturally occurring nanoparticles (NPs) and nanostructured materials (NSMs) to identify their nanoscale properties and to define the specific knowledge gaps related to the risk assessment of NPs and NSMs in the environment. The review presents an overview of the history and classifications of NMs and gives an overview of the various sources of NPs and NSMs, from natural to synthetic, and their toxic effects towards mammalian cells and tissue. Additionally, the types of toxic reactions associated with NPs and NSMs and the regulations implemented by different countries to reduce the associated risks are also discussed.

## 1. INTRODUCTION

Nanotechnology evolved as the achievement of science in the 21st century. The synthesis, management, and application of those materials with a size smaller than 100 nm fall under the interdisciplinary umbrella of this field. Nanoparticles have significant applications in different areas such as the environment, agriculture, food, biotechnology, biomedical, medicines, etc. like; for the treatment of waste water, environment monitoring, as a functional food additive, and as antimicrobial agents. Cutting-edge properties of NPs such as; nature, biocompatibility, anti-inflammatory and antibacterial activity, effective drug delivery, bioactivity, bioavailability, tumor targeting, and bio-absorption have led to a growth in the biotechnological, and applied microbiological applications of NPs.

According to the Environmental Protection Agency (EPA), "NMs can exhibit unique properties dissimilar than the equivalent chemical compound in a larger dimension" [2]. The US Food and Drug Administration (USFDA) also refers to NMs as "materials that have at least one dimension in the range of approximately 1 to 100 nm and exhibit dimension-dependent phenomena" [3]. Similarly, The International Organization for Standardization (ISO) has described NMs as a "material with any external nanoscale dimension or having internal nanoscale surface structure" [4]. Nanofibers, nanoplates, nanowires, quantum dots and other related terms have been defined based on this ISO definition [5]. Likewise, the term *nanomaterial* is described as "a manufactured or natural material that possesses unbound, aggregated or agglomerated particles where external dimensions are between 1–100 nm size range", according to the EU Commission [6].

**Nanoparticles in biomedical and healthcare products:**

NMs are incorporated in cosmetics and sunscreens as antioxidants [1] and antireflectants [7]. Mostly, NPs used for commercial applications are engineered NPs that are produced using physical [8], chemical and biological methods. As engineered NPs are attached to a firm surface, the risk of detachment and causing health issues is lessened. Other than cosmetics, NPs have been extensively used in commercial products ranging from personal care products to paints [11]. Titanium oxide NPs larger than 100 nm are broadly utilized as a white pigment in cosmetic creams and sunscreens [12]. Similarly, Ag NPs have been used in diverse applications including air sanitizer sprays, wet wipes, food storage containers, shampoos, and toothpastes [13]. Several NPs are under research and evaluation of additives in personal care products. In spite of the emerging growth of products with different types of nanomaterials, their hazardous effects on humans are largely unknown. The extensive studies reported that Ag NPs demonstrated a size, morphology, and dosage-dependent higher cytotoxicity to humans and animals cells than asbestos [14-18].

**2. Classification of NPs**

NPs are broadly divided into various categories depending on their morphology, size and chemical properties. Based on physical and chemical characteristics, some of the well-known classes of NPs are given below.

**2.1. Carbon-based NPs**

Fullerenes and carbon nanotubes (CNTs) represent two major classes of carbon-based NPs. Fullerenes contain nanomaterial that are made of globular hollow cagess such as allotropic forms of carbon. They have created noteworthy commercial interest due to their electrical conductivity, high strength, structure, electron affinity, and versatility.

**2.2. Metal NPs**

Metal NPs are purely made of the metals precursors. Due to well-known localized surface plasmon resonance (LSPR) characteristics, these NPs possess unique optoelectrical properties. NPs of the alkali and noble metals i.e. Cu, Ag and Au have a broad absorption band in the visible zone of the electromagnetic solar spectrum.

**2.3. Ceramics NPs**

Ceramics NPs are inorganic nonmetallic solids, synthesized via heat and successive cooling. They can be found in amorphous, polycrystalline, dense, porous or hollow forms (19). Therefore, these NPs are getting great attention of researchers due to their use in applications such as catalysis, photocatalysis, photodegradation of dyes, and imaging applications. (20).

**2.4. Semiconductor NPs**

Semiconductor materials possess properties between metals and nonmetals and therefore they found various applications in the literature due to this property (21). Semiconductor NPs possess wide bandgaps and therefore showed significant alteration in their properties with bandgap tuning. Therefore, they are very important materials in photocatalysis, photo optics and electronic devices .As an example, variety of semiconductor NPs are found exceptionally efficient in water splitting applications, due to their suitable bandgap and bandage positions (22).

### 2.5. Polymeric NPs

These are normally organic based NPs and in the literature a special term polymer nanoparticle (PNP) collective used for it. They are mostly nanospheres or nanocapsular shaped. The former are matrix particles whose overall mass is generally solid and the other molecules are adsorbed at the outer boundary of the spherical surface. In the latter case the solid mass is encapsulated within the particle completely. The PNPs are readily functionalize and thus find bundles of applications in the literature (23).

### 2.6. Lipid-based NPs

These NPs contain lipid moieties and effectively using in many biomedical applications. Generally, a lipid NP is characteristically spherical with diameter ranging from 10 to 1000 nm. Like polymeric NPs, lipid NPs possess a solid core made of lipid and a matrix contains soluble lipophilic molecules. Surfactants or emulsifiers stabilized the external core of these NPs. Lipid nanotechnology is a special field, which focus the designing and synthesis of lipid NPs for various applications such as drug carriers and delivery and RNA release in cancer therapy (24).

## 3. Applications of Nanoparticles

Nanoparticles exhibit unique physical and chemical properties such as: electronic & optical properties, mechanical properties, magnetic properties & thermal properties. This uniqueness has led to its application in different areas. Some of the significant applications of NPs are discussed below:

### *3.1 Medicine*

Nanoparticles have made major contributions to clinical medicine in the areas of medical imaging and drug/gene delivery. Iron oxide particles such as magnetite (Fe3O4) or its oxidized form hametite (Fe2O3) are most commonly employed for biomedical applications. Ag NPs are being used increasingly in wound dressings, catheters and various households' products due to their antimicrobial activity. Gold nanoparticles are emerging as promising agents for cancer therapy, as drug carriers, photothermal agents, contrast agents and radio sensitizers (25,26). Over past few decades there has been considerable interest in developing biodegradable NPs as effective drug delivery devices. Various polymers have been used in drug delivery research as they can effectively deliver the drugs to the target site thus increases the therapeutic benefit, while minimizing side effects.

### *3.2 Environmental Remediation*

Nanoparticles are commonly used for environmental remediation, since they are highly flexible towards both in situ and ex situ applications in aqueous systems. Silver nanoparticles (AgNPs) due to their antibacterial, antifungal, and antiviral activity has been extensively used as water disinfectants (27). TiO2 NPs have been increasingly studied for waste treatment, air purification (28), self- cleaning of surfaces and as a photocatalyst in water treatment application due to their characterized low-cost, non-toxicity, semiconducting, photocatalytic, electronic, gas sensing, and energy converting properties.

### *3.3 Mechanical Industries*

Owing to excellent young modulus, stress and strain properties, NPs finds applications in mechanical industries especially in coating, lubricants (29), adhesives (30) and manufacturing of mechanically stronger nanodevices reported two-step dip-coating method using silver nanoparticles (AgNPs) and fluorine-free silane monomer,3-(Trimethoxysilyl) propyl methacrylate (TMSPM) for thefabrication of hydrophobic coating on cotton fabric.

### *3.4 Food*

Nanoparticles have been increasingly incorporated into food packaging to control the ambient atmosphere around food, keeping it fresh and safe from microbial contamination (31). Now-a-days, inorganic & metal NPs are extensively used as alternatives to petroleum plastics in the food packaging industry as they can directly introduce the anti-microbial substances on the coated film surface.

### *3.5 Electronics*

Unique structural, optical and electrical properties of one- dimensional semiconductor and metals make them the key structural block for a new generation of electronic, sensors and photonic materials.

### *3.6 Energy Harvesting*

Due to scarcity of fossil fuels scientist have been shifting their research interests in the development of different strategies which can help in generating renewable energies from easily available resources at cheap cost. NPs are the suitable candidate for this purpose due to their large surface area, optical behavior and catalytic nature. NPs are widely used to generate energy from photoelectrochemical (PEC) and electrochemical water splitting (32)Other advanced options such as electrochemical $CO_2$ reduction to fuels precursors, solar cells and piezoelectric generators also utilized to generate energy reported use of graphene as a source of energy as well as next generation smart energy storage devices.

## CONCLUSION

In this review article we have given a brief overview of nanoparticles, their structure, classification, method of synthesis, and applications in various fields. Owing to tunable physicochemical as well as biological properties, nanoparticles have gained prominence in medicine, environmental remediation, energy harvesting and many other areas.

## REFERENCES:

1. Xiao L, Takada H, Maeda K, Haramoto M, Miwa N. *Biomed Pharmacotherapy.* 2005;**59**:351-358. doi: 10.1016/j.biopha.2005.02.004
2. United Nations [Aug 21;2014 ];*Questions About Nanotechnology.* 2012 Available from: https://www.epa.gov/chemical-research/research-nanomaterials.
3. *Considering Whether an FDA-Regulated Product Involves the Application of Nanotechnology.* USA: Federal Drug Administration; 2011. [Jan 25; 2016 ]. Available from: https://www.fda.gov/RegulatoryInformation/Guidances/ucm257698.htm.
4. *ISO/TS 80004-1:2010, Nanotechnology – Vocabulary – Part 1: Core Terms.* Geneva, Switzerland: International Organization for Standardization; 2010. [Jul 17; 2017]. Available from: https://www.iso.org/standard/51240.html.
5. Bleeker E A J, Cassee F R, Geertsma R E, et al. *Interpretation and implications of the European Commission's definition on nanomaterials; Letter report 601358001.* Bilthoven, Netherlands: RIVM; 2012. https://www.rivm.nl/bibliotheek/rapporten/601358001.html.
6. Potocnik J. *Off J Eur Communities: Legis.* 2011;**L 275**:38–40. doi: 10.3000/19770677.L_2011.275.eng.
7 . Monteiro-Riviere N A, Wiench K, Landsiedel R, Schulte S, Inman A O, Riviere J E. *Toxicol Sci.* 2011;**123** :264–280. doi: 10.1093/toxsci/kfr148.
8. Cao G. *Synthesis, properties and applications.* Singapore: World Scientific; 2004.
9. Hyeon T. *Chem Commun.* 2003:927–934. doi: 10.1039/b207789b.
10. Mohanpuria P, Rana N K, Yadav S K. *J Nanopart Res.* 2008;**10**:507–517. doi: 10.1007/s11051-007-9275-x.
11. *Nano-particles in baby formula: Tiny new ingredients are a big concern.* 2016 Available from: http://webivadownton.s3.amazonaws.com/877/eb/2/8482/FOE_NanoBabyFormulaRep ort_13.pdf.
12. Donaldson K, Stone V, Tran C L, Kreyling W, Borm P J A. *Occup Environ Med.* 2004;**61**:727–728. doi: 10.1136/oem.2004.013243.

13. *Inventory Finds Increase in Consumer Products Containing Nanoscale Materials.* 2013 Available from: http://www.nanotechproject.org/news/archive/9242/

14. de Lima R, Seabra A B, Durán N. *J Appl Toxicol.* 2012;**32**:867 879doi: 10.1002/jat.2780.

15. Durán N, Seabra A B, de Lima R. Cytotoxicity and genotoxicity of biogenically synthesized silver nanoparticles. In: Durán N, Guterres S, Alves O L, editors. *Nanotoxicology.* Berlin, Germany: Springer; 2014. pp. 245–263.

16. Skalska J, Strużyńska L. *Folia Neuropathol.* 2015; **53**:281–300. doi: 10.5114/fn.2015.56543.

17. Heydarnejad M S, Samani R J. *J Nanomed Nanotechnol.* 2016;**7**:1000382.doi: 10.4172/2157-7439.1000382.

18. Ema M, Okuda H, Gamo M, Honda K. *Reprod Toxicol.* 2017; **67**:149–164. doi: 10.1016/j.reprotox.2017.01.005.

19. Sigmund, W., Yuh, J., Park, H., Maneeratana, V., Pyrgiotakis, G.,Daga, A., Taylor, J., Nino, J.C., 2006. Processing and structure relationships in electrospinning of ceramic fiber systems. J. Am.Ceram. Soc. 89, 395–407. http://dx.doi.org/10.1111/j.1551-2916.2005.00807.x.

20.Thomas, S., Harshita, B.S.P., Mishra, P., Talegaonkar, S., 2015.Ceramic nanoparticles: fabrication methods and applications in drug delivery. Curr. Pharm. Des. 21, 6165–6188.

21. Ali, S., Khan, I., Khan, S.A., Sohail, M., Ahmed, R., Rehman, A.,Ur Ansari, M.S.,Morsy, M.A., 2017. Electrocatalytic performance of Ni@Pt core–shell nanoparticles supported on carbon nanotubes for methanol oxidation reaction. J. Electroanal. Chem. 795, 17–25.

22. Hisatomi, T., Kubota, J., Domen, K., 2014. Recent advances in semiconductors for photocatalytic and photoelectrochemical water splitting. Chem. Soc. Rev. 43, 7520–7535

23. Abd Ellah, N.H., Abouelmagd, S.A., 2016. Surface functionalization of polymeric nanoparticles for tumor drug delivery: approaches and challenges. Expert Opin. Drug Deliv. 1–14

24. Gujrati, M., Malamas, A., Shin, T., Jin, E., Sun, Y., Lu, Z.-R., 2014.Multifunctional cationic lipid-based nanoparticles facilitate endosomal escape and reduction-triggered cytosolic siRNA release.Mol. Pharm. 11, 2734–2744.

25. Cai, W., Gao, T., Hong, H., & Sun, J. (2008). Applications of gold nanoparticles in cancer nanotechnology. *Nanotechnology,Science and Applications*, 1, 17.

26. Jain, S., Hirst, D. G., & O'Sullivan, J. (2012). Gold nanoparticles as novel agents for cancer therapy. *The British Journal ofRadiology*, 85(1010), 101-113.

27. Zhang, C., Hu, Z., Li, P., & Gajaraj, S. (2016). Governing factors affecting the impacts of silver nanoparticles on wastewater treatment. *Science of the Total Environment*, 572, 852-873.

28.Haider, A., Al-Anbari, R., Kadhim, G., & Jameel, Z. (2018). Synthesis and photo catalytic activity for $TiO_2$ nanoparticles as air purification. *In MATEC Web of Conferences* (Vol. 162, p. 05006). EDP Sciences.

29. Ghaednia, H., Hossain, M. S., & Jackson, R. L. (2016). Tribological performance of silver nanoparticle–enhanced polyethylene glycol lubricants. *Tribology Transactions*, 59(4), 585-592

30. Cao, Z., & Dobrynin, A. V. (2016). Nanoparticles as adhesives for soft polymeric materials. *Macromolecules*, 49(9), 3586- 3592.

31. Bhardwaj M. & Saxena D.C., (2017). Preparation of Organic and Inorganic Nanoparticles and their Subsequent Application in Nanocomposites for Food Packaging Systems: A Review, *Indian Journal of Science and Technology*, 10 (31),

32. Avasare, V., Zhang, Z., Avasare, D., Khan, I., & Qurashi, A. (2015). Room temperature synthesis of $TiO_2$ nanospheres and their solar driven photoelectrochemical hydrogen production. *International Journal of Energy Research*, 39(12),1714-1719.

| | |
|---|---|
|  | ***Author Name***- Ms. Swati S. Dusane<br>*Author Affiliation*-N.C.R.D's Sterling Institute of Pharmacy<br>*Author Address/Institute Address*- Plot No. 93/ 93A, Sector 19, Near Sea-Woods Railway Station,Nerul (E),Navi Mumbai - 400706. |
|  | ***Author Name*** –Ms. Pratiksha Wasankar<br>*Author Affiliation*-N.C.R.D's Sterling Institute of Pharmacy<br>*Author Address/Institute Address*- Plot No. 93/ 93A, Sector 19, Near Sea-Woods Railway Station,Nerul (E),Navi Mumbai - 400706. |
|  | ***Author Name*** –Ms. Shubhangi Katkade<br>*Author Affiliation*-N.C.R.D's Sterling Institute of Pharmacy<br>*Author Address/Institute Address*- Plot No. 93/ 93A, Sector 19, Near Sea-Woods Railway Station,Nerul (E),Navi Mumbai - 400706. |