International Journal of Advanced Academic Studies 2024; 6(SP-6): 120-126

E-ISSN: 2706-8927
P-ISSN: 2706-8919
www.allstudyjournal.com
IJAAS 2024; 6(SP-6): 120-126
Received: 05-04-2024
Accepted: 06-05-2024

Ginni Rani
DPG Degree College, Gurugram, Haryana, India

Himanshi Tanwar
DPG Degree College, Gurugram, Haryana, India

Chetna Rani
DPG Degree College, Gurugram, Haryana, India

Corresponding Author:
Ginni Rani
DPG Degree College, Gurugram, Haryana, India

Globalization and Sustainable Development: Interdisciplinary Perspectives (GSD IP-24) (Conference proceedings of DPG DEGREE College)

Advancement in nanomaterial in health science

Ginni Rani, Himanshi Tanwar and Chetna Rani

DOI: https://doi.org/10.33545/27068919.2024.v6.i6b.1221

Abstract

In the modern era, scientific communities have documented and confirmed the effect of leveraging nanoparticles worldwide. As nanotechnology grows very fast, natural and synthetic nanomaterials are created, processed, and released into the environment daily. Nanomaterials mainly explain how these are operated in different applications, including health sciences and biomedicine, i.e. in diagnosis and therapies of fetal diseases like Cancer, Nervous system disorder, human endocrine system and genetics. Nanomedicine, Nano sensors, and nanobots are also products particularly used in nanotech. In recent years, nanotechnology has emerged as a pioneering field with enormous potential to revolutionize various fields, specifically healthcare. Nanotechnology has inspired the globe in extraordinary ways, fostering various collaborations across all fields. Ongoing research efforts aim to develop technologies that maximize the benefits of nanomaterials while minimizing risks to both the environment and human health. In this review, we summarize the latest studies of important technologies and next-generation nanomaterials later on and discuss the applications in biomedical imaging and other fields of medicinal sciences. Among the plethora of nanoparticles, nanospheres, Nano shells, Nano stars, are frequently uses in biomedical imaging and cancer therapy due to their unique properties. Nanoparticles based biosensors can quickly detect biological producers, pathogens, disease specificity. Nanoparticle based agents increases the contrast of specificity of imaging technique such as MRI, CT Scan etc. This review article, provides a critical examination of various technologies of nanoparticles, highlights the advancements in healthcare and provides glimpses into future of nanotechnology.

Keywords: Nanotechnology, nanomaterials, biomedical application, diagnosis, treatment, health science

Introductions

Nanomaterials have emerged as a focal point of intensive investigation, propelled by their potential applications across industries and medicine since their inception [1]. Due to their unique physicochemical properties, nanomaterials modernize biomedical research, treatments diagnostics**,** in biomedicine, bio-labelling, agriculture, antimicrobial agents and many other fields [1, 2]. Nanomaterials, characterized by their dimensions typically falling within the range of 1 to 100 nanometers, manifest distinct properties compared to their bulk counterparts [3].

Nanomaterials exhibit remarkable versatility, available in diverse forms and sizes, including 1D, 2D, and 3D structures, spanning the realms of inorganic, organic, and dendrimer compositions [4]. Their dimensionally constrained electrical properties enable the fabrication of sheets, wires, rods, and other intricate shapes, offering a rich tapestry of possibilities. Numerous methodologies have been employed to tailor these engineered nanostructures' band structures and surface characteristics, poised to address a spectrum of medicinal needs. The integration of semiconductors, quantum dots (such TiO_2, ZnO, and CuO), and two-dimensional carbon allotropes like graphene or carbon nanotubes (CNTs) is particularly noteworthy since it improves safety profiles in addition to therapeutic efficacy [5]. Globally, researchers are engaged in a concerted effort to unlock solutions to a myriad of challenges confronting human welfare and health, leveraging the unique properties of nanomaterials [6]. The pivotal role of nanoscale technology in addressing health and medicine-related challenges is underscored across various domains, including gene therapy, medication delivery systems, diagnostics, and the burgeoning field of nanomedicine.

This review paper emphasizes nanomaterials' profound impact and potential in revolutionizing healthcare paradigms, promising novel solutions to age-old problems. Different types of nanomaterials have different applications on the basis of their size and use in biomedicine, surgeries diagnosis etc. Nanomaterials such as.

Metallic nanoparticles: Nanoparticles composed of metals like gold, silver, and iron have been thoroughly researched for a range of biomedical applications, such as drug delivery, imaging therapy, and cancer therapy.

Carbon nanotubes: Nanoparticles have special mechanical, electrical, and thermal properties that make them appropriate for applications like tissue engineering and bio sensing.

Fluorescent nanoparticles: Nanoparticles labelled with fluorescent dyes and quantum dots are used as contrast agents for fluorescence imaging and molecular imaging of biological structures and processes.

Nano medicines: Based drug delivery systems are utilized to enhance the pharmacokinetics, bioavailability, and therapeutic efficaciousness of drugs. They can target specific tissues and cells and overcome biochemical barriers such as blood brain barrier.

Quantum Dot: Manufactured to several nanometres in diameter with a nearly unlimited range of sharply defined colours. These particles are excited using white light and can be linked to biomolecules to form long-lived sensitive probes when coupled with biomolecules, facilitating sensitive detection and imaging applications.
Advancements in nanotechnology stand poised to revolutionize the landscape of drug production, supply, and therapeutic diagnostics [7]. By harnessing the precision and versatility afforded by nanotechnology, the boundaries of medical science are being continually pushed, offering unprecedented opportunities for improving human health and well-being, as described in Fig 1.

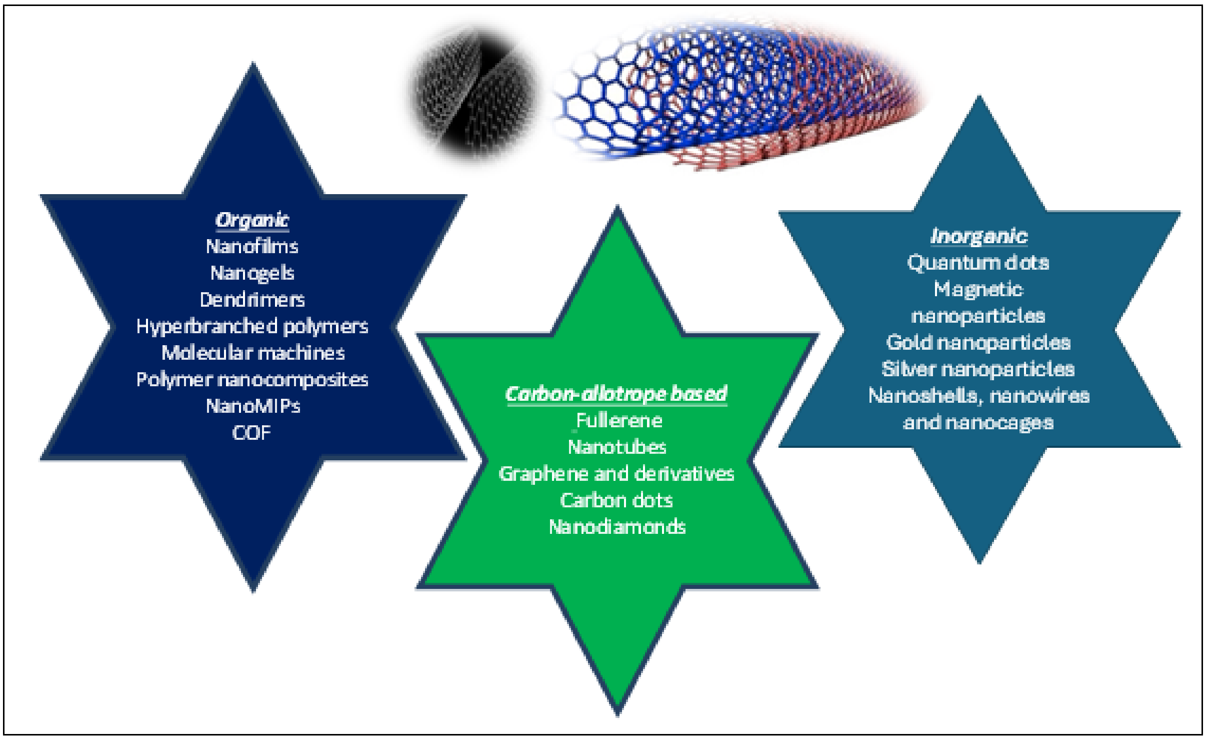

Fig 1: Nanom aterials for healthcare biosensing applications

Table 1: Types of nanoparticles with its applications and benefits

Types of Nanoparticles	Description	Size (NM)	Advantages	Disadvantages	applications
magnetic	Particles of super magnetic iron oxide that exhibit huge magnetic moments in a magnetic field	50-100	An external magnetic field demonstrates that distribution can be controlled by magnetism. It's chemically stable and also not harmful for nature.	Thrombosis and embolization are major Consequences after aggregation of magnetic nanoparticles	Cancer diagnosis and monitoring through magnetic cell, and also useful in separation of target drug delivery.
metallic	Gold or silver nanoparticles	<50	Large surface area particles can withstand high doses of drugs.	Biocompatibility is poor indecisive in vivo fate	helpful in regulating the distribution of proteins
Nano shells	A particular kind of spherical nanoparticle known as a Nano shell plasmon is made up of a metallic shell covering a dielectric core.	10-300	Imaging therapeutic potentials	Greater than size of quantum dots.	Utilized as an optical coherence contrast agent. Tomography
ceramic	Porus, titania, alumina	<100	Steady in terms of biology.		Efficiency to carry proteins

Literature review

Nanomaterials represent a class of substances meticulously crafted or altered at the minuscule scale of nanometers, typically spanning dimensions between 1 and 100 nanometers. Within this infinitesimal realm, materials showcase distinctive and frequently augmented characteristics in contrast to their macroscopic forms, owing to the intricate interplay of quantum phenomena and the heightened ratio of surface area to volume. Nanomaterials offer various advantages in cancer treatment, including targeted delivery to tumour sites, reduced systemic toxicity, enhanced imaging capabilities, and the potential for combination therapies. They represent a promising avenue for improving cancer treatment outcomes [8].

1. Biomedical applications in health sciences

The biomedical applications of nanomaterials hold great promise for revolutionizing healthcare by enabling personalized and precise treatments, early disease detection, and regenerative therapies, ultimately improving patient outcomes and quality of life. Nanomaterials also play a crucial role in imaging, drug delivery, and diagnostics. Nanoparticle-based contrast agents enable more sensitive and specific imaging modalities, allowing for early detection and accurate characterization of diseases such as cancer. Nanomaterials are being explored for their potential in targeted therapies, such as photothermal therapy and gene therapy. Nanoparticles can be functionalized to selectively target diseased cells or tissues, allowing for precise delivery of therapeutic agents while sparing healthy cells. Moreover, nanocarriers can facilitate the delivery of nucleic acids, enabling the modulation of gene expression for therapeutic purposes.

1.1 Cancer treatment

Cancer is a multifaceted ailment that can impact any cell or tissue within the body. As normal cells undergo uncontrolled proliferation, they transform into abnormal cells, giving rise to tumours or lesions, which can be either benign or malignant. Key risk factors for skin cancer include inadequate diet, familial predisposition, genetic mutations, exposure to ultraviolet (UV) radiation, certain medications, occupational hazards, and habits like smoking and alcohol consumption [9]. There exists a variety of cancer types such as breast cancer, lung cancer, brain cancer, and nasopharyngeal cancer, which can be detected through screening, visual inspection, and laboratory examinations. By utilizing enhanced permeability and retention (EPR) and active targeting mechanisms, modified nanocarriers like nanoparticles (NPs), dendrimers, or carbon nanomaterials (CNMs) can reach cancer cells and release biological agents or biomaterials [10] as mentioned in Fig.2. Their application addresses the limitations of chemotherapy by reducing cytotoxicity to normal tissues, enhancing drug transport capacity, prolonging drug half-life, and enabling targeted drug release. Nucleic acid delivery and nanotechnology-based drug delivery systems (nano-DDS) utilizing exosomes, polymer nanoparticles (PNPs), liposomes, and dendrimers have demonstrated successful applications in cancer therapy [11].

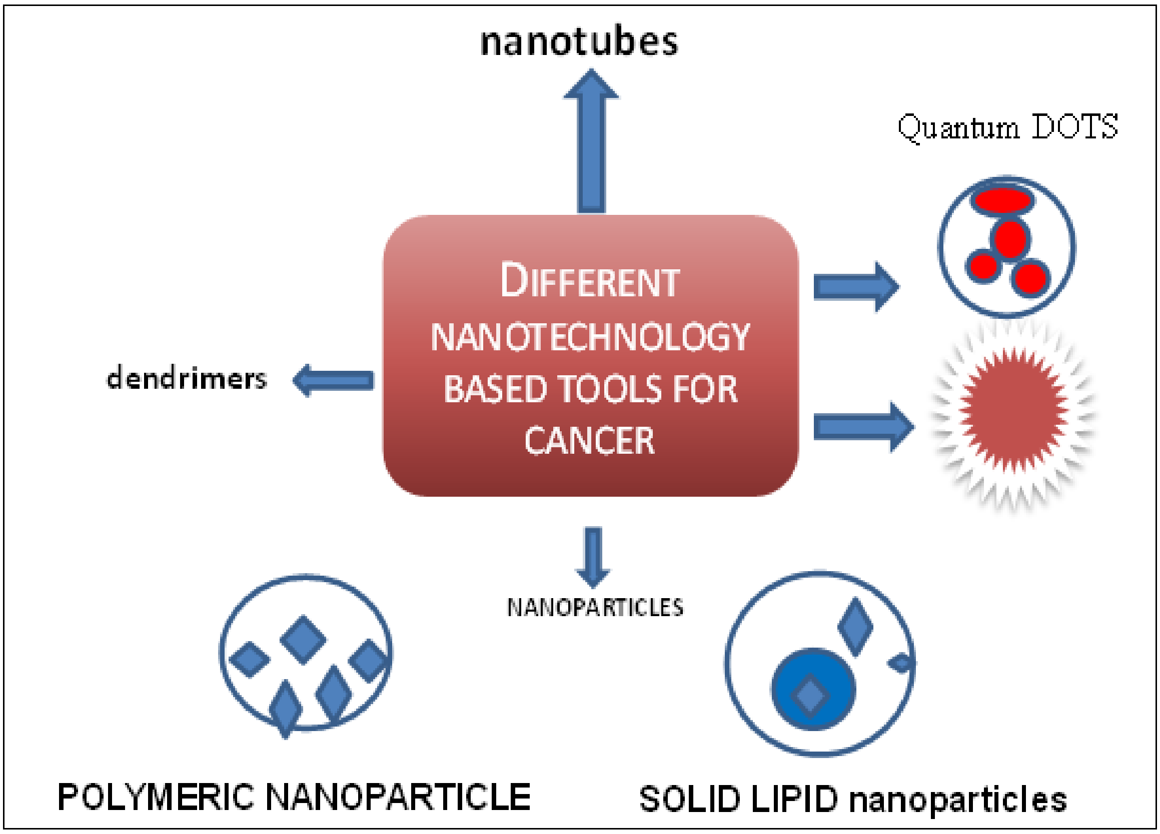

Fig 2: Examples of some nanomaterials on the basis of their origin, dimension and composition. (some of them are used in cancer treatment)

1. Based on origin: Nanodics, Nanocrystals
2. Based on Dimension: Nanotube, Graphene, Dendrimers, and Dendrimers, nanorods, films and coats
3. Based on Composition: Inorganic, Organic, Polymeric, LIPD NPS

Table 2: Nanomaterials used in cancer treatment with its working and benefits

Nanomaterial	Size	Description	Working	Benefits
Liposomes	50-100 nm	Lipid bilayer-based sphere-shaped vesicles. They can target particular cells or tissues and encapsulate medications.	By delivering medications straight to cancer cells, they can reduce systemic toxicity.	Enhanced drug solubility, targeted delivery, reduced side effects.
Gold Nanoparticles	1-100 nm	Tiny gold-containing particles. They can be made functional by using medications or targeted ligands.	Through photothermal therapy, they are able to absorb near-infrared light and transform it into heat, effectively killing cancer cells.	Targeted delivery, photothermal therapy, imaging capabilities.
Iron Oxide Nanoparticles	5-100 nm	Nanoparticles composed of iron and oxygen. They can be coated with biocompatible materials.	They can act as contrast agents for magnetic resonance imaging (MRI) and can also deliver drugs.	Imaging capabilities, drug delivery, potential for hyperthermia therapy.
Carbon Nanotubes	1-100 nm	Carbon atom-based cylindrical structures. They can be made functional by adding medicines or targeted moieties.	They can absorb near-infrared light and generate heat (photothermal therapy) or be used for drug delivery.	Imaging capabilities, photothermal, drug delivery
Polymeric Nanoparticles	10-200 nm	Polymer-based biodegradable nanoparticles. They have the ability to encapsulate medications and release them gradually.	They can target specific cells and tissues and release drugs at right time .increasing effectiveness and reduce side effects.	Controlled drug release, biocompatibility.

1.2 Diagnostics

Nanomaterials play a pivotal role in the field of diagnostics due to their unique biological, chemical and physical properties. Various types of nanoparticles such as metallic, magnetic, and fluorescent ones have proven to be effective in diagnosing infectious diseases. Fluorescent nanoparticles, known for their sensitivity and stability, can be utilized to label a wide range of biological targets. Gold and silver nanoparticles are among the most commonly used metallic nanoparticles in diagnostics [12]. These nanoparticles exhibit significant absorption when stimulated by electromagnetic radiation, allowing for the conjugation or grafting of various probes, such as nucleic acids and antibodies, to modify their surface chemistries. Optical imaging, photoacoustic imaging, computed tomography and fluorescence imaging are the diagnostic methods used to diagnose brain tumours and cancer [13]. In diagnostic applications, nanomaterials offer several benefits:

Enhanced Sensitivity and Specificity

Nanomaterials' specialized surface characteristics and high surface area-to-volume ratio contribute to improved diagnostic sensitivity and specificity. Functionalization with targeting ligands enables selective identification of biomarkers, thereby enhancing detection limits and precision [14].

Differentiated Detection

Nanomaterial-based platforms facilitate multiplexed detection of numerous analytes in a single experiment, enabling simultaneous measurement of multiple biomarkers. This capability is particularly advantageous when multiple biomarkers are implicated in complex disorders [15].

Drug Delivery

Nanomaterials serve as carriers for targeted drug delivery in both therapy and diagnosis as shown in Fig 3. Which describes particular properties of nanomaterials responsible for medical applications. By encapsulating drugs or imaging agents in functionalized nanoparticles, they enable precise delivery to diseased tissues while minimizing systemic toxicity and off-target effects [16]. Overall, nanomaterials have tremendous potential to advance the field of diagnosis by offering unprecedented capabilities for sensitive, precise and rapid biomarker identification. Early disease diagnosis, personalized therapy and improved patient outcomes are among the potential benefits of nanomaterial-based diagnostics. Ongoing research and development efforts are aimed at addressing major challenges and integrating with emerging technologies.

Table 3: Describes types of diagnostics and its treatment through nanomaterials

Types of Diagnosis	Description	Treatment With Nanomaterials
Neurological Disorder Diagnosis	Diagnosis of neurological conditions such as Alzheimer's disease, Parkinson's disease, or multiple sclerosis	Nanomaterial-based biosensors for detecting specific biomarkers in cerebrospinal fluid or blood samples, aiding in early diagnosis and monitoring of neurological diseases.
Cardiovascular Disease Diagnosis	Detection and assessment of cardiovascular conditions such as coronary artery disease, hypertension, or heart failure.	Use of nanomaterials for enhancing the sensitivity and specificity of imaging techniques such as MRI or CT angiography for visualization of cardiovascular structures and abnormalities
Cancer Diagnosis	Detection and characterization of cancerous cells or tumors	Targeted drug delivery using functionalized nanoparticles to deliver anti-cancer drugs specifically to tumor cells.

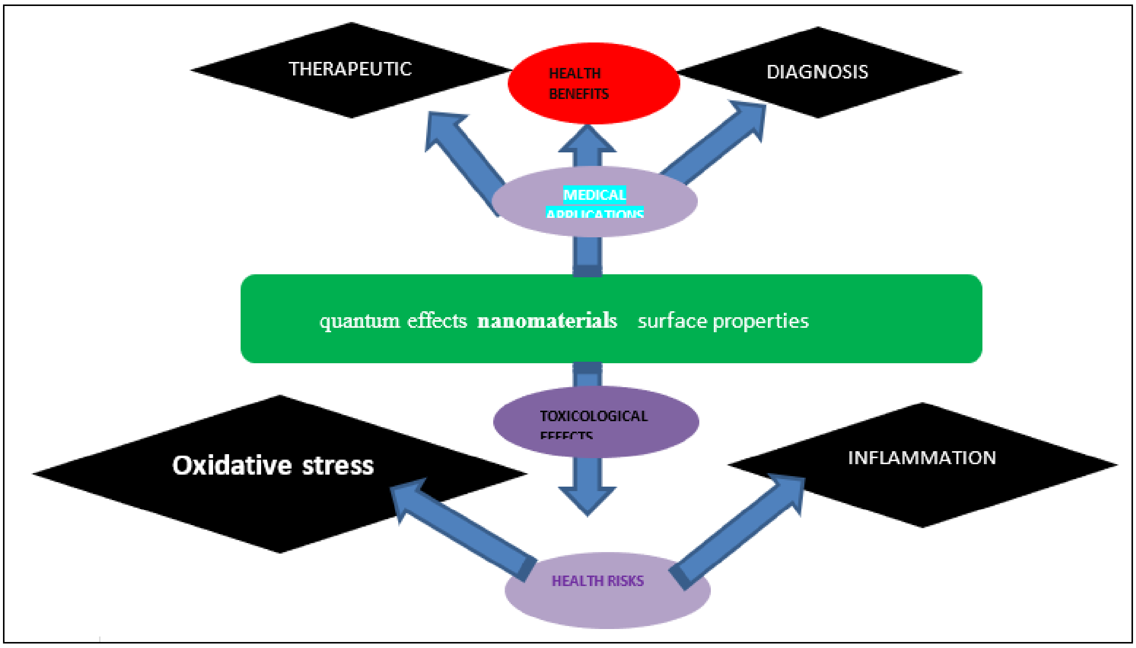

Fig 3: Schemetic diadram showing that the particular properties of nanomaterials are responsible for both medical applications and potential toxicological effects

1.3: Drug Delivery

Recent advancements in nanotechnology have enabled the development of targeted, safe and efficacious drug formulations incorporating nanoparticles. These systems have shown promising results in enhancing the solubility of hydrophobic drugs, optimizing pharmacokinetics and biodistribution, and facilitating selective accumulation at the desired site. Nanotechnology-based drug delivery systems hold significant potential for improving drug delivery efficacy and safety, offering solutions to challenges such as poor solubility and non-specific distribution of drugs in the body. Drug delivery formulations have utilized various nanocarriers, such as liposomes, polymer micelles, dendrimers, polymer-drug conjugates, inorganic nanoparticles, and carbon-based nanomaterials. Among these, liposomes have been extensively researched and widely used. However, polymer nanoparticles have emerged as a leading-edge approach in drug delivery. These nanoparticles can be fabricated from synthetic or natural polymers that are biocompatible.

Different drug delivery strategies influence a drug compoun d's absorption, distribution, metabolism, and elimination (A DME) in order to maximize therapeutic effects at the intend ed site of action and minimize potential side effects. Shown in Fig 4.

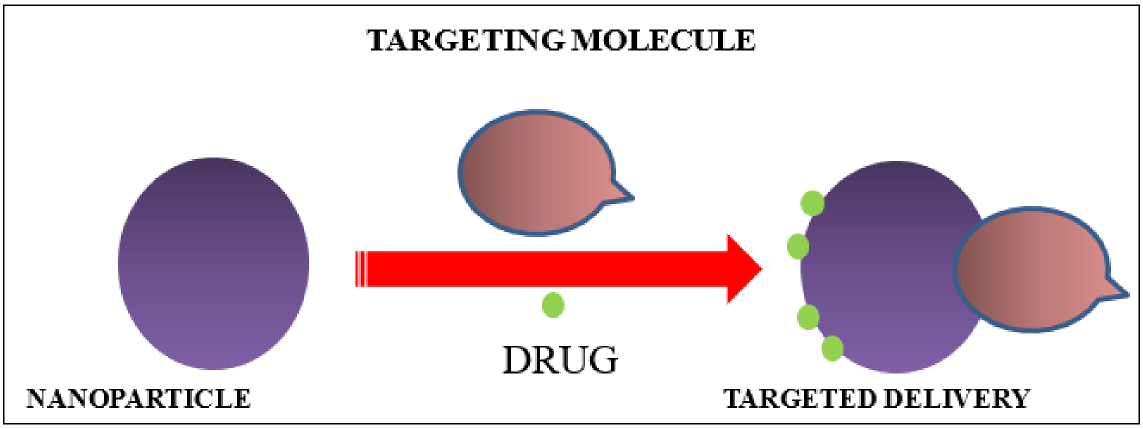

Fig 4: New approach helps achieve effective nanoparticle- Based Drug Delivery

In the realm of technology nanoaprticles serves as vehicles for delivering drugs to specific sites within the body. This targeted approach significantly mitigates side effects by ensurthat the active medication is deposited only at the diseased area, thereby reducing the necessary drug dosage. Such precise delivery not only diminishes costs but also alleviates suffering for patients. Various types of nanoparticles, including dendrimers and nanoporous materials, are utilized for this purpose which is also mentioned in Fig 2. Among these, block co-polymer-derived micellar systems stand out for encapsulating drugs and ferrying minuscule medication molecules to their designated destinations [17].

The health sciences have witnessed a revolution in medication delivery due to nanotechnology, which has made therapeutic agents more effective and allows for precise targeting and controlled release. Nanoparticles have various benefits in medication delivery applications because of their small size and special qualities.

Targeted Delivery: Nanoparticles can be engineered to target specific tissues, organs, or cells, minimizing off-target effects and reducing systemic toxicity. For example, surface modification of nanoparticles with ligands or antibodies allows for recognition and binding to specific receptors or biomarkers on target cells [18].

Controlled Release: Drugs can be made to release from nanoparticles in a controlled way, giving them long-lasting therapeutic benefits. This is especially helpful for medications that have a limited therapeutic window or that need to be taken often. Different stimuli-responsive nanoparticles release the medication at the intended location in response to environmental cues like pH, temperature, or enzymatic activity [19].

Improved Bioavailability: Nanoparticles can encapsulate poorly soluble drugs, enhancing their solubility and bioavailability. This is crucial for drugs with low aqueous solubility, as it improves absorption and distribution within the body, leading to enhanced therapeutic outcomes.

Combination therapy: By enabling the co-delivery of multiple medicines or drugs, nanoparticles can enhance treatment outcomes and produce synergistic benefits. Furthermore, imaging agents or diagnostic probes can be included into nanoparticles, enabling theranostic applications for customized treatment [20].

Enhanced Penetration: Compared to traditional medication formulations, nanoparticles are more effective at piercing biological barriers such the blood-brain barrier (BBB) and tumor microenvironment, allowing for tailored delivery to previously unreachable regions.
Some nanotechnology-based drugs that are commercially available or in human clinical trials include.

1. Rapamune, approved by the FDA in 2000, prevents organ rejection after transplantation. It's made of nanocrystals that enhance drug solubility and dissolution rate, leading to better absorption.
2. Onivyde, approved by the FDA in October 2015, treats metastatic pancreatic cancer. It's a liposome-encapsulated form of irinotecan.
3. Abraxane is approved by the FDA for treating breast cancer, non-small cell lung cancer (NSCLC), and pancreatic cancer. It contains nanoparticle-bound paclitaxel [21].

1.4 Neuroscience
One of the most significant applications of nanotechnology lies in treating neurodegenerative disorders. Various nanocarriers, such as dendrimers, Nano gels, Nano emulsions, liposomes, polymeric nanoparticles, solid lipid nanoparticles, and nanosuspensions have been investigated for delivering drugs to the central nervous system (CNS). In the future, novel targeting moieties will be used to increase the drug trafficking performance and specificity of CNS nanomedicines for brain tissue. These nanomedicines have successfully traversed in vitro and in vivo blood-brain barrier (BBB) models through mechanisms like endocytosis or transcytosis, offering the potential for early preclinical success in managing various CNS conditions including:

- Alzheimer's disease
- Brain tumours
- HIV encephalopathy
- Acute ischemic stroke, and others.

Enhancing the permeation of these nanomedicines across the BBB holds promise for further advancing their efficacy in treating neurodegenerative disorder.

Parkinson's disease: This advancement has the potential to enhance the current treatment of Parkinson's disease (PD). PD, the second most prevalent neurodegenerative disorder after Alzheimer's disease, impacts approximately one out of every 100 individuals aged above 65. PD affects the central nervous system, triggering neuroinflammatory responses that result in significant motor impairments. Current therapies aim to optimize the patient's functional abilities for as long as feasible but are unable to halt the progression of the neurodegenerative process [22]. The goals of applied nanotechnology include the regeneration and neuroprotection of the central nervous system (CNS), areas that will greatly benefit from basic nanotechnology research conducted in conjunction with advances in neurophysiology, neuropathology, and cell biology. Efforts are made to develop novel technologies that can offer neuroprotection, an environment that is conducive to guided axon growth, or active signaling signals. In an effort to lessen the peripheral side effects of conventional Parkinson's disease medication, research is focused on the design, biometric simulation and optimization of an intracranial nano-enabled scaffold device (NESD) for the site-specific administration of dopamine to the brain. Recently, peptides and peptidic nanoparticles have been used to treat a range of CNS illnesses [23].

Alzheimer's disease
The most common form of dementia, Alzheimer's disease (AD), affects approximately 35 million people worldwide. The field of neurology greatly benefits from the application of nanotechnology. These approaches are based on the concept that the development and manipulation of various nanoparticle entities with high specificity for brain capillary endothelial cells enable the early detection and treatment of AD. Nanoparticles (NPs) exhibit a strong affinity for circulating forms of amyloid-β (Aβ), potentially creating a "sink effect" to alleviate the symptoms of AD as described in Fig.5. Advancements in in vitro diagnostics for AD have been achieved through the development of highly sensitive NP-based bio-barcodes, immunological sensors, and scanning tunnelling microscopy techniques capable of identifying Aβ1-40 and Aβ1-42. Recent studies have focused on utilizing nanoparticles to treat Alzheimer's disease [24].

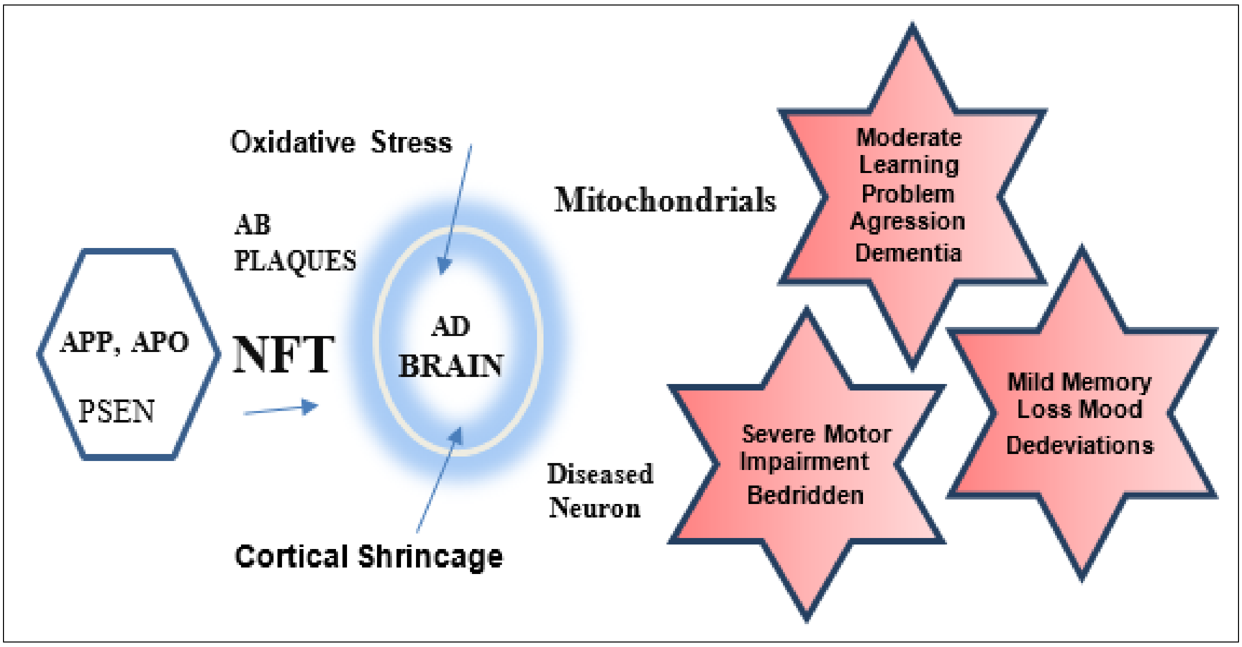

Fig 5: Nanomaterials in Alzheimer's disease treatment: diagrammatic representation which describes impact on human brain

Conclusion

The advancement of nanomaterials in health sciences with biomedical applications represents a significant leap forward in modern medicine. Nanotechnology has revolutionized various aspects of healthcare, including diagnostics, therapy, drug delivery, and tissue engineering. The unique properties of nanomaterials such as their small size, large surface area-to-volume ratio, and tunable surface chemistry offer unprecedented opportunities for targeted and precise interventions. Nanomaterials play a crucial role in biomedical applications, particularly in diagnostics and drug delivery. However, ongoing research both in vivo and in vitro has underscored the biological impacts of nanomaterials, including inflammation and structural or functional alterations at the cellular or systemic levels. Despite the growing body of research, there is still limited data available, highlighting the need for deeper understanding.

It is essential to monitor the processes governing the potential toxicity of nanomaterials, especially considering their current and potential future use in biomedicine, as well as their widespread industrial production and distribution. The unique properties that make nanomaterials desirable for various applications also pose risks to human health. Therefore, meticulous attention must be paid to ensure the safe utilization of these materials.

Overall, the advancements in nanomaterials have opened up new frontiers in health sciences, offering promising solutions to address unmet medical needs and improve patient outcomes. With careful consideration of safety and ethical implications, nanotechnology holds the potential to revolutionize healthcare and shape the future of medicine.

References

1. Modi S, Prajapati R, Inwati GK, Deepa N, Tirth V. Recent trends in fascinating applications of nanotechnology in allied health sciences.
2. Keçili R, Büyüktiryaki S, Hussain CM. Advancement in bioanalytical science through nanotechnology: Past, present and future.
3. Shinde MU, Patwekar M, Patwekar F. Nanomaterials: A potential hope for life sciences from bench to bedside. Journal of Nanomedicine & Nanotechnology; c2022.
4. Nikalje AP. Nanotechnology and its applications in medicine. Department of Pharmaceutical Chemistry, YB Chavan College of Pharmacy, Dr. Rafiq Zakaria Campus.
5. Shrivastava S, Dash D. Applying nanotechnology to human health: revolution in biomedical sciences. Journal of Nanotechnology; c2009.
6. Husen A, Siddiqi KS. Advances in smart nanomaterials and their applications. Google Books; c2023.
7. Cheng Z, Li M, Dey R, Chen Y. Nanomaterials for cancer therapy: current progress and perspectives. Journal of Hematology & Oncology; c2021.
8. Tan YY, Yap PK, Lim GLX, Mehta M, Chan Y, *et al.* Perspectives and advancements in the design of nanomaterials for targeted cancer theranostics. Chemico-Biological Interactions; c2020.
9. Ndlovu NL, Mdlalose WB, Ntsendwana B, Moyo T. Evaluation of advanced nanomaterials for cancer diagnosis and treatment. Pharmaceutics; c2024.
10. Jon S, *et al.* Biomedical applications of nanoparticles. Annual Review of Biomedical Engineering.
11. Das S, *et al.* Recent advances in biomedical applications of chitosan and its nanocomposites in nanomedicine. Progress in Polymer Science.
12. Thwala LN, Ndlovu SC, Mpofu KT, Lugongolo MY. Nanotechnology-based diagnostics for diseases prevalent in developing countries: current advances in point-of-care tests.
13. Cheng H, *et al.* Nanomaterials for cancer therapy: current progress and perspectives. Journal of Hematology & Oncology; c2021.
14. Okerst JV, Gabrielson NP, Kircher MF. Integrated nanoparticle biosensors for diagnostic cellular and molecular imaging. Biomedical Optics Express; c2017.
15. Soleymani L, Li F. Mechanisms and applications of nanomaterial-based universal biosensing platforms. Nanotechnology. 2017;28(25):25200.

16. Yetisen AK, Akram MS, Lowe CR. Paper-based microfluidic point-of-care diagnostic devices. Lab on a Chip. 2013;13(12):2210-2251.
17. Peer D, Karp JM, Hong S, *et al*. Nanocarriers as an emerging platform for cancer therapy. Nature Nanotechnology; c2007.
18. Shi J, Kantoff PW. Nanomaterials: a potential hope for life sciences from bench to bedside. Nanomedicine in Urology. Nature Reviews Urology. 2017;14(3):175-191.
19. Peer D, Karp JM, Hong S, Farokhzad OC, Margalit R, Langer R. Nanocarriers as an emerging platform for cancer therapy. Nature Nanotechnology. 2007;2(12):751-760.
20. Hua S, de Matos MBC. Polymer-based nanoparticles for drug delivery. In Comprehensive Biotechnology (Second Edition); c2021. p. 304-317.
21. Davide B, Benjamin LD, Nicolas J, Hossein S, Lin-Ping W, *et al*. Nanotechnologies for Alzheimer's disease: diagnosis, therapy and safety issues. Nanomedicine: Nanotechnology, Biology and Medicine. 2011;7:521-540.
22. Nikalje AP. Nanotechnology and its applications in medicine. Department of Pharmaceutical Chemistry, YB Chavan College of Pharmacy, Dr. Rafiq Zakaria Campus, Rauza Bagh, Aurangabad, Maharashtra, India.
23. Sivaramakrishnan SM, Neelakantan P. Nanotechnology in dentistry - What does the future hold in store? Dentistry. 2014;4(2).
24. Davide B, Benjamin LD, Nicolas J, Hossein S, Lin-Ping W, *et al*. Nanotechnologies for Alzheimer's disease: diagnosis, therapy and safety issues.