WebLog Journal of Nanomedicine and Nanotechnology

Review Article
Published: 24 Oct, 2026

Nanotechnology and Good Health and Well-being (SDG Goal 3)

Nida Tabassum Khan and Aemad Tabasum*

Department of Biotechnology, Faculty of Life Sciences & Informatics, Balochistan University of Information Technology, Engineering and Management Sciences, Takatu Campus, Airport Road, Quetta, Balochistan

WebLog Open Access Publications
Article ID : wjnn.2026.j2403
Author : Dr. Nida Tabassum Khan

Abstract

Nanotechnology has the potential to significantly revolutionize healthcare, opening up new and exciting opportunities in cancer therapy, controlled drug delivery, diagnosis, and the fight against infectious diseases. Scientists are developing instruments and treatments that can enhance diagnostics, increase the efficacy of medications, and provide more individualized treatment alternatives by working with materials at nearly the most basic level. In addition to improving patient care, this cutting-edge technology addresses some of the most pressing medical issues of the day, creating new opportunities for healthcare solutions. When compared to conventional methods, nanotechnology shows potential for further progress in the medical field, with promising prospects for cancer treatment, targeted medication delivery, diagnostics, and the management of infectious disorders.

Keywords: Nanotechnology; Good Health; Diagnostics; Therapeutics; Antimicrobial

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Correspondence:
Dr. Nida Tabassum Khan, Department of Biotechnology, Faculty of Life Sciences & Informatics, Balochistan University of Information Technology, Engineering and Management Sciences, Takatu Campus, Airport Road, Quetta, Balochistan, E-mail: nidatabassumkhan@yahoo.com

Received Date: *08 Oct 2026*
Accepted Date: *22 Oct 2026*
Published Date: *24 Oct 2026*

Citation:
Tabassum Khan N, Tabasum A. Nanotechnology and Good Health and Well-being (SDG Goal 3). WebLog J Nanomed Nanotechnol. wjnn.2026.j2403. https://doi.org/10.5281/zenodo.23879182

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Introduction

Researchers are creating novel instruments and treatments to improve the precision of disease detection, the efficiency of medication distribution, and the customization of operations to each patient by manipulating matter at the ultra-small level [1]. In this way, "smart materials" will raise the bar for patient care while addressing some of the main challenges in contemporary medicine, offering a fresh approach to cutting-edge medical solutions. Neural, dental, bone, and skin tissues may be repaired with the help of nanomaterials, which play a much bigger role in tissue engineering by encouraging cell contact and tissue regeneration [2]. In order to improve therapeutic outcomes and reduce side effects, some other nanomaterials are still being studied and developed to investigate their targeting capabilities for drug and gene delivery systems [3]. Nanomaterials may be taken into consideration for the development of novel cancer treatment approaches including biotherapy, photothermal therapy, and photodynamic therapy in addition to improving the effectiveness of current treatments like chemotherapy and surgery [4]. By using nanoparticles in antimicrobial and antiviral techniques, coatings and materials are being produced to prevent infection and therapeutically target resistant pathogens [5] (Figure 1).

Key Contributions of Nanoscale Technology to SDG 3

1. New enhanced diagnostics: With the advent of nanosensors, and other very sensitive diagnostic tools based on nanotechnology, diseases can now be identified far sooner than with traditional methods. Before a diagnosis can be made, they can be programed to identify biomarkers that belong to particular disease categories, such cancer, diabetes, and infections, in less time following the onset of symptoms [7]. In order to improve patient outcomes and lessen the burden of healthcare, early detection entails prompt access to treatment [8].

2. Target-Oriented Drug Delivery: Nanomaterials allow therapeutic medicines to target specific cells or regions. In essence, this approach enhances fine-tuning relativity in the delivery of treatment; yet, it limits optimal treatment utilization, especially in cancer-specific medicines [9]. These nanoparticles, for instance, can be engineered to find and attach to cancer cells, delivering their therapeutic payload in close proximity to the tumor. Therefore, this type of strategy to treatment administration improves overall quality of life and reduces collateral damage to healthy tissues [10].

3. New Treatment Approaches: In terms of treatment, next-generation uses include opening up new therapeutic modalities including photothermal and photodynamic therapies [11]. With the least amount of harm to healthy surrounding tissues, nanomaterials will be able to selectively destroy

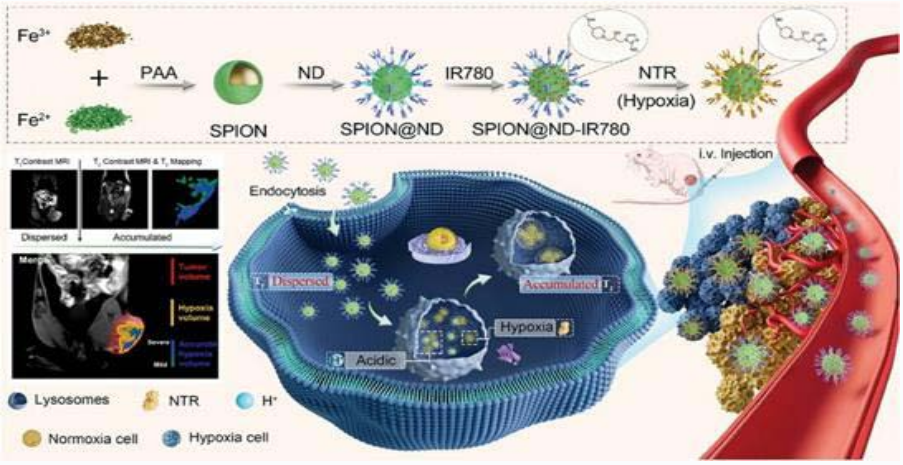


Figure 1: Schematic representation of SPION@ND-IR780. Schematic representation of SPION@ND-IR780, a tri-modal hypoxia imaging nanoprobe designed for precise tumour hypoxia imaging and the streamlined construction of hypoxia-guided Biological Target Volumes (BTVs). The nanoprobe exhibits dual-stimuli responsive characteristics: hypoxia sensitivity, which facilitates nanoprobe accumulation, and acidic *pH* sensitivity, which induces nanoprobe aggregation [6].

cancer cells by producing reactive oxygen species and converting light into heat. These developments in cancer treatment not only improve patient recovery but also provide alternative therapeutic techniques [12].

4. New Paradigms in Vaccine Development: The stability, effectiveness, and administration of vaccinations are altered by nanotechnology. Nanoparticle-based implant adjuvants that would boost immunity and prevent vaccinations from expiring would be discovered [13]. From the standpoint of global health, this kind of advancement in vaccine composition becomes even more important since successful vaccination is essential to preventing the spread of epidemics and containing infectious diseases [14].

5. Antimicrobial Applications: Coatings and materials with antibacterial qualities are being developed using nanomaterials in several healthcare domains. In an urgent need to prevent antibiotic resistance, such materials will be able to stop the growth of bacteria and viruses [15]. Silver nanoparticles, for example, have demonstrated potent antibacterial action and are being used into medical devices and wound dressings to control infections [16].

6. Regenerative Medicine: In tissue engineering, nanomaterials play a major role in fostering the interaction between cells and tissue regeneration. These nanoparticles are also used for particular applications such as bone and skin restoration, as well as neurological repair [17]. These suitable scaffolds for cell growth enable or encourage the healing of damaged organs or tissues, including those that are most likely to enhance patient outcomes and restore function to damaged or degenerative tissues [18].

Need for Nanotechnology in the Medical Domain

A significant milestone in nanomedicine is being reached by the widespread discovery of advances in nanotechnology and nano medicines. In order to advance medicine formulation and maximize healthcare advantages, this discipline has experienced a miraculous metamorphosis. The unexplored ideas of nanotechnology in healthcare must be discussed. Research on the optimal medical methods for cancer, cardiovascular conditions, and nephrology has persisted. Over time, this has resulted in some changes. New promise was offered by recent advancements in nanotechnology, nanoparticles, and their medicinal value [19]. Numerous research has been conducted to evaluate the effectiveness of viral vectors as drug delivery systems, and gene therapy is one area where medicine applications using nanodrugs have gained traction [20]. Nanobots are being developed to locate specific cancer cells, while smart tablets give the researchers information about whether the patient has taken the right dosage [21]. Nanotechnology may also enable more affordable and user-friendly in vitro diagnostics. Nanoparticles can provide information about the functional traits of tumor cells and genetic alterations associated with cancer as molecular imaging techniques [22]. Additionally, depending on the intended use, nanotechnology-based functional coatings frequently contain a variety of nanomaterials, such as silicon dioxide, titanium dioxide, carbon black, iron oxide, zinc oxide, and silver. This means that the aforementioned materials help with the physicochemical evaluation of nanomaterials and nano surfaces utilized in medical device engineering, offering both safety and efficacy [23]. Scientists can make significant contributions to the advancement of medicine by developing innovative products that use new materials, sensors, and energy storage systems [24].

Different Types of Nanoparticles Are Being Used in Medical Field

Because of their nanoscale size, nanoparticles have a large surface-area-to-volume ratio, which enables them to swiftly travel through the bloodstream and absorb large amounts of drugs [25]. They can be employed in more medicinal applications thanks to their larger surface area, which also improves their mechanical, magnetic, optical, and catalytic properties [26]. Based on their chemical makeup, nanoparticles are divided into three categories: carbon-based, inorganic, and organic. Some of the main categories of the nanoparticles [27] are depicted in figure 2 below. Organic nanoparticles having a particular size, such as a radius of less than 100 nm, are created from proteins, carbohydrates, lipids, and other organic compounds [28].

Significant Areas for Nanotechnology Applications in Medical Field

Some of the applications of nanotechnology in medical fields is

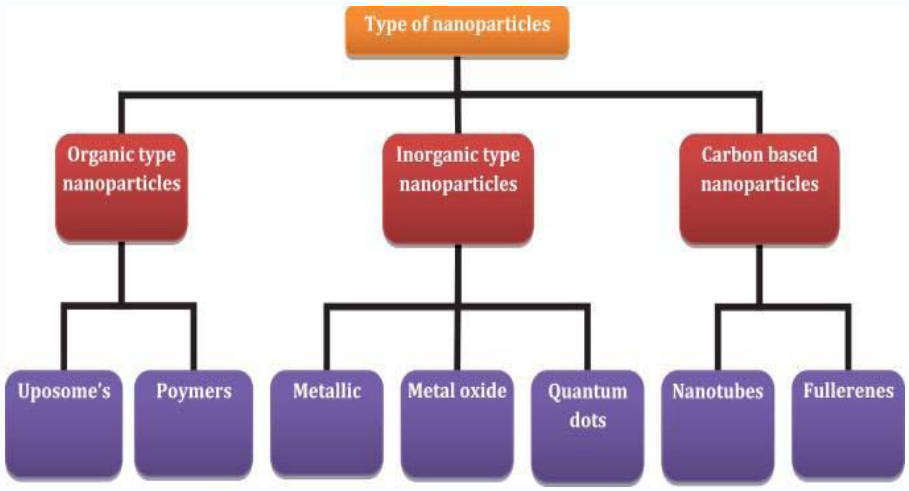


Figure 2: Categories of the nanoparticles.

as follows:

- Diagnostics
- Tissue engineering and cell treatment
- Therapy development
- Drug delivery
- Disease detection
- Detection of body oxygen
- Economical healthcare
- Improve the efficiency of medicine
- Management of illness
- Fight against cancer
- Helpful for cardiovascular disease
- Nanobots
- Better preventive procedure
- Radiation therapy [29, 30]

Limitations

Though developments in nanotechnology hold promise, many hindrances exist to impede its wider application in the medical field. Some of the big challenges are as follows:

1. Reproducibility Control and Quality Control: Finding high-quality, repeatable criteria for the creation of nanomaterials is one of the biggest obstacles to scientific and technological advancement. Because production variability directly contributes to variations in performance and safety features, this variability has been shown to be a barrier to regulatory approval [31].

2. Scaling Up and Production Rate: Another major challenge is setting up scalable manufacturing processes to meet the growing demand for output. It is possible that existing techniques are not effective enough to produce these nanoparticles at a scale appropriate for broad clinical application [32].

3. Unwanted By-products: The manufacture of nanomaterials may result in the creation of undesirable pollutants, exacerbating the environmental and health issues that are already present. For nanotechnology to be used safely and effectively, these by-products must be managed [33].

4. High Costs: Nanoparticles' accessibility and uptake in clinical practice are hampered by their continued high development and production costs. Pharmaceutical businesses and other stakeholders are deterred from investing by such obstacles [34].

5. Health and Environmental Issues: Since there is still a lot of uncertainty regarding the long-term health consequences and environmental implications, a thorough understanding of the potential risks of using nanoparticles should be investigated and resolved before widespread deployment [35].

Conclusion

Thus, Nanotechnology has the potential to drastically transform healthcare, creating new and exciting options in diagnosis, controlled medication delivery, cancer therapy, and the battle against infectious diseases. By working with materials at almost the most fundamental level, scientists are creating tools and therapies that can improve diagnostics, boost the effectiveness of drugs, and offer more customized treatment options.

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