Chapter 5
Comprehensive Insights Into the Biomedical Applications of Titanium Dioxide

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ABSTRACT

Metal oxide nanoparticles (NPs) particularly titanium dioxide have gained significant interest due to their exceptional properties and versatile applications in various sectors such as industrial, medicinal, and environmental areas. TiO2 (NPs) play a crucial role in improving the efficacy and stability of drug formulations. Their high surface area and reactive properties enable them to serve as effective carriers for drug delivery systems, ensuring efficient absorption of therapeutic agents by the body. In addition, TiO2 (NPs) are also pivotal in the development of advanced biosensors that exhibit heightened sensitivity and specificity, enabling precise detection of biological molecules. Furthermore, TiO2 (NPs) have shown remarkable potential in cancer therapy, with their application in photodynamic therapy (PDT) generating reactive oxygen species (ROS) that can selectively induce apoptosis in cancer cells.

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INTRODUCTION

In recent decades, nanotechnology has made significant progress, resulting improved performance of different field including electronics, medicine, energy, sensing, and materials science.(Kazemi Shariat Panahi et al. 2024; Sadegh, Dehcheshmeh, et Sadegh 2024; Lambin 2024) These advancements have created new opportunities and enhanced the effectiveness and functionality of many applications. Nanotechnology focuses on using materials at nanometer scale, specifically between 1 and 100 nanometers. Nanoparticles show characteristics in comparison to bulk materials due to their large surface area and volume ratio. (Nishu et Kumar 2023)Researchers had demonstrated significant interest in incorporating metal oxide nanoparticles into the medical field due to their antibacterial, drug delivery, anticancer properties, and ability to identify infections in clinical specimens.(Merugu, Sharma, et Rastogi 2023) Titanium dioxide nanoparticles have been employed in a variety of application and are typically considered environmentally friendly due to their exceptional chemical stability, photocatalytic performance, and low toxicity. These particles serve as a barrier against UV radiation and have been used in many applications such as food colorants, dyes, medicines, cosmetics, and toothpaste.(Shabib Akhtar et al. 2024; Mao et Hao 2024; Dubey et al. 2022; Moon et al. 2024; K, P, et U 2024; L. Zhang et Jin 2024)

In the context of environmental science, TiO_2 (NPs) have shown a lot of promise in the purification of air and water. There potent oxidative properties and high photostability make it ideal candidate for degradation pollutants in wastewater and atmospheric systems. This capability has driven extensive research into using TiO_2 (NPs) for removing organics contaminants from aquatic environments, highlighting their potential in mitigating pollution and protecting ecosystems. (Mehta et Bhushan 2024) In addition to environmental applications, TiO_2 (NPs) have many biological properties, such as antimicrobial, anticancer, and antioxydant effects.(Ali et al. 2024) These properties are particularly advantageous in biomedical applications, where TiO_2 (NPs) can be employed in medical imaging, drugs delivery systems, and as components in medical devises and implants. The versability of TiO_2 (NPs) in these fields emphasizes their importance and continues demand for research for improving their production and utilization.(Suresh et al. 2022; Hsu et al. 2024) This article focuses on emphasizing role of TiO_2 (NPs) in advancing biomedical technologies. Figure 1 shows the different biomedical applications of TiO_2.

BIOMEDICAL APPLICATIONS OF TIO_2 (NPS)

Antimicrobial Applications

Nano-scale materials, including various metallic nanoparticles (NPs) such as titanium dioxide TiO_2 (NPs), have appeared as promising antimicrobial agents due to their unique physicochemical properties and high surface area. TiO_2 (NPs) have demonstrated notable antibacterial and antifungal activities against a wide range of microorganisms, including bacteria, fungi, and viruses.(Kurutas 2016; Ziental et al. 2020) The efficacy of TiO_2 (NPs) in combating microbial infections stems from their photocatalytic action, which generates reactive oxygen species (ROS). These ROS disrupt microbial cell integrity by oxidizing phospholipids in the cell wall, leading to membrane damage and altering cellular functions. (Luksiene 2017) Additionally, TiO_2 (NPs) have been shown to inhibit microbial growth through various