Chapter 22

Nanomaterials for Environmental Applications:
Water Treatment, Air Purification, and Remediation

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ABSTRACT

In this chapter, the authors discuss nanomaterials for environmental application as promising technology of water treatment, air purification, and remediation. Water contamination remains a critical issue in many developing nations, including African countries. Traditionally, chlorine has been employed for water treatment; however, its association with cancer risks has raised significant health concerns. In response to these challenges, nanomaterials have emerged as innovative solutions for environmental remediation due to their unique physicochemical properties. This chapter explores the recent advancements in the application of nanomaterials for addressing environmental pollution. In this chapter, the author discussion attempts to provides a comprehensive overview of the nanomaterial use in water treatment and air purification, highlighting their effectiveness in overcoming traditional treatment limitations and offering sustainable alternatives for improving environmental pollution.

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INTRODUCTION

Nanomaterials are molecules that typically range in size from 1 to 100 nm and are characterized by their unique biological and physiochemical properties (Quazi *et al*., 2023). These materials, such as quantum dots and nanowires, exhibit high surface area-to-volume ratios and special properties such as surface plasmon resonance and quantum confinement effects (Gavali, 2023). Nanomaterials can be engineered with exceptional magnetic, electrical, mechanical, optical, and catalytic capabilities by controlling their size, shape, and synthesis conditions (Mekuye & Abera, 2023). The transition from bulk materials to nanomaterials leads to significant changes in properties, making materials magnetic at the nanoscale and altering their characteristics based on size and shape. Nanomaterials have diverse applications in various fields, such as medicine, agriculture, and engineering, due to their unique physical and chemical properties (Napagoda *et al*., 2023; Senthil Kumar *et al*., 2023).

Nanomaterials play a fundamental role in various environmental applications, offering innovative solutions for remediation and monitoring. They are utilized in methods such as nanoadsorbents, nanofiltration, and photocatalysis for pollutant removal and detection in air, water, and wastewater. Nanomaterials such as nanosilver, carbon nanotubes, fullerenes, and zero-valent iron are employed for disinfection and remediation of contaminated environments (Aghababai Beni & Jabbari, 2022). Strategies to immobilize nanomaterials have been developed to enhance their effectiveness in renewable energy production and pollutant removal from industrial streams (Pelaez *et al*., 2012). Additionally, nanoscale polymeric coatings are used to improve the mobility and reusability of nanoparticles, facilitating faster site clean-ups and reducing remediation costs (Cervantes & Ramírez-Montoya, 2022).

Nanomaterials play a crucial role in environmental applications such as water treatment, air purification, and remediation (Abd-Elhamid *et al*., 2023; Pham & Ong, 2023). These materials, with dimensions less than 100 nm, exhibit superior physicochemical properties, high reactivity, and large specific surface areas, making them highly effective at interacting with pollutants (Cherian & Jamal, 2023). Modified nanomaterials (MNMs) have shown enhanced efficiency in remediation strategies by reducing aggregation, increasing the bioavailability of metals, and accelerating pollutant breakdown. Compared with pristine nanomaterials (PNMs), MNMs offer improved mobility, reactivity, and controlled release of active ingredients for in situ remediation, making them more efficient and cost-effective. MNMs also demonstrate potential in addressing global issues such as climate change by reducing contaminants and converting CO_2 into valuable products.

The increasing levels of environmental contaminants resulting from human activities are causing detrimental effects and posing a risk to numerous living organisms on the planet. Due to their harmful persistence in the environment, heavy metals and certain organic pollutants are recognized as significant pollutants globally. Although pollutants have existed in the environment for a considerable period, conventional methods face challenges in eliminating them due to various constraints. As a result, there has been a shift in research towards developing efficient and cost-effective technologies for pollutant removal (Bansal, 2023).

Nanotechnology to Prevent Pollution

Environmental pollution refers to the accumulation of harmful substances in the environment that impact human health, animals, and ecosystems. These include air pollution from industrial emissions and vehicle exhaust, water pollution from industrial effluents, agricultural runoff, and soil pollution

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