Title

Nanotechnology based waste water Treatment System for Textile Industry

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Introduction

Nanomaterials such as carbon nanotubes, metal-organic frameworks (MOFs), and nanocomposites play a crucial role by offering high surface area, selectivity, and reactivity for pollutant adsorption and degradation. Additionally, nanocatalysts and photocatalytic nanoparticles, such as titanium dioxide (TiO_2) and zinc oxide (ZnO), facilitate the breakdown of complex organic molecules under light irradiation, ensuring the removal of persistent dyes and toxic substances. Hybrid systems combining membrane filtration with nanotechnology further enhance efficiency by reducing membrane fouling and improving permeability. Moreover, these systems can be tailored to target specific pollutants, making them highly adaptable for various effluent compositions. By reducing energy consumption and minimizing the use of harmful chemicals, nanotechnology-enabled treatment systems not only improve environmental sustainability but also help industries comply with stringent wastewater discharge regulations.The Indian textile industry is one of the largest and most vital contributors to the nation's economy, representing approximately 2.3% of the GDP and employing over 45 million people, making it the second-largest source of employment in India. Additionally, it plays a key role in textile and garment exports, with exports surpassing US$44 billion in 2022-23. With a rapidly expanding domestic market, growing demand for technical textiles, and supportive government policies, the industry is expected to grow at a CAGR of 10% in the coming years. Despite its economic importance, water pollution from textile manufacturing remains a major environmental issue.

Abstract

In the coming era, clean water will become increasingly vital due to its critical role in improving human health, fostering economic progress, preserving environmental stability, and elevating overall quality of life. Ensuring sustainable and accessible clean water sources will be paramount to tackling the mounting pressures from population growth, climate change, and environmental degradation. With rising water demand across agriculture, industry, and domestic sectors, the strain on freshwater resources is set to escalate. Therefore, breakthroughs in water treatment, conservation, and management will be key to addressing these challenges, safeguarding water security for future generations, and building resilience against global water scarcity.

To design an innovative solution and prototype for wastewater treatment in the textile industry, we will adopt advanced technologies like adsorption and photocatalysis, employing cutting-edge nanomaterials such as graphene oxide and titanium dioxide. Graphene oxide, known for its large surface area and superior adsorption properties, will efficiently capture various pollutants, while titanium dioxide, a highly effective photocatalyst, will degrade organic contaminants under light.

This combined approach aims to significantly improve the removal of dyes, chemicals, and heavy metals, delivering a sustainable, scalable, and cost-efficient wastewater treatment system tailored to meet the demands of large-scale textile production.

Methodology

The integration of adsorption and photocatalysis results in a hybrid technology that significantly improves wastewater treatment efficiency. This approach utilizes reusable active materials, offering a sustainable and economically viable solution to address water pollution. By merging the strong pollutant-capturing capabilities of adsorption with the contaminant-degradation power of photocatalysis, this hybrid system provides a highly effective method for minimizing wastewater impurities and promoting environmental sustainability.

Step 1:

Fabrication of Graphene Oxide Adsorbent-Filled Membrane: Muslin fabric is selected as the packing material for graphene oxide due to its lightweight and transparent properties. Made of fine, loose fibers, this fabric serves as a permeable membrane, allowing water containing dissolved methylene blue—a commonly used industrial dye—to pass through and enabling the adsorption of the dye.

Step 2:

Fabrication of Magnetic stir bar assisted Photocatalytic Material (TiO_2) coated floating wheel:

This wheel consists of a thin, transparent sheet encasing a magnetic bead. The surface of the transparent sheet is coated with nano titanium dioxide (TiO2) for visible light photocatalytic activity.

Step 3:

A well-designed housing is established to facilitate the adsorption and photocatalysis processes under visible light. The water to be treated is continuously circulated through the system using appropriate inlet and outlet mechanisms.

Materials Used:

- Graphene Oxide
- TiO_2
- Glass ware
- Magnetic pellet
- Transparent sheet

Scientific Principles/Concepts:

Adsorption:

The presence of oxygen-containing functional groups, such as hydroxyl, carboxyl, and epoxy groups, enhances its hydrophilicity and enables strong interactions with polar and nonpolar contaminants. Additionally, GO can be easily modified or functionalized to improve its selectivity and adsorption capacity for specific pollutants. Its exceptional mechanical strength and flexibility allow it to be incorporated into membranes and hybrid filtration systems, offering high flux and durability. Furthermore, GO-based composites, when combined with photocatalytic materials, can degrade organic pollutants under light, providing a dual-function approach for adsorption and degradation. These features make graphene oxide a promising material for advanced water treatment technologies, especially in industries with complex wastewater profiles.

Visible-light photocatalysis

Visible-light photocatalysis using titanium dioxide (TiO_2) involves activating TiO_2 with visible light to generate reactive oxygen species (ROS) that can break down pollutants. TiO_2, a semiconductor with a 3.2 eV band gap, typically requires UV light (wavelengths shorter than 388 nm) for activation. However, as visible light constitutes approximately 43% of the solar spectrum, there is significant interest in designing TiO_2-based photocatalysts that respond to visible light. When TiO_2 is activated by visible light, it produces ROS such as hydroxyl radicals (OH•), superoxide radicals (O_2•−), and hydrogen peroxide (H_2O_2). These ROS are potent oxidizing agents, capable of degrading a variety of pollutants, including organic compounds, dyes, and bacteria.

Procedure/Description:

The visible light catalysis chamber employs photocatalysts, such as titanium dioxide or zinc oxide nanoparticles, often doped with metals or graphene derivatives, to improve their light absorption and catalytic activity under visible light. This process not only breaks down complex organic molecules into less harmful by-products but also aids in the degradation of color-causing compounds, resulting in clear and purified water. The graphene oxide bath, due to its high surface area and functionalized surface, captures heavy metals and residual dyes, preventing secondary pollution. To further enhance efficiency, automated control systems can be incorporated to monitor pH, turbidity, and pollutant concentrations in real-time, ensuring optimal operating conditions. The modular design allows for easy scaling, enabling industrial plants to adopt this technology incrementally, reducing initial investment risks. By facilitating resource recovery and pollutant reduction, this system aligns with global goals for sustainable industrial development and water resource management.

Result and Conclusion:

The integration of such systems not only enhances the quality of discharged water but also enables the potential for wastewater reuse in industrial processes, thereby reducing the overall water footprint of textile manufacturing. Advanced nanomaterials used in these systems, such as graphene oxide, metal nanoparticles, and nanocomposites, ensure higher pollutant removal efficiency compared to conventional methods. Moreover, these systems can be coupled with renewable energy sources, such as solar-powered photocatalysis, to further lower operational costs and energy consumption. The modular nature of the technology allows for easy upgrades and maintenance, ensuring consistent performance over time. In the long run, widespread adoption of these systems can contribute to a circular economy model within the textile industry, minimizing waste and preserving vital water resources.

Advantages:

Enhanced Pollutant Removal Efficiency
Nanomaterials, such as graphene oxide, carbon nanotubes, and metal nanoparticles, offer superior adsorption capacity and catalytic properties, ensuring effective removal of dyes, heavy metals, and organic contaminants that are difficult to treat using conventional methods.

Targeted and Selective Treatment
The functionalization of nanomaterials allows for selective adsorption of specific pollutants, enabling customized treatment solutions based on the type of contaminants present in textile wastewater.

References:

- Nishu, Sudesh Kuma, "Smart and innovative nanotechnology applications for water purification", Hybrid Advances Volume 3, August 2023, 100044
- N. Saravanan [a], K.S.K. Sasikumar , "Waste water treatment process using Nano TiO_2", Volume 33, Part 7, 2020, Pages 2570-2572
- Ilka Gehrke , Andreas Geiser , Annette Somborn-Schulz , "**Innovations in nanotechnology for water treatment" Nanotechnol Sci Appl . 2015 Jan 6;8:1–17**
- Sandeep Kumar, Wandit Ahlawat, Gaurav Bhanjana, Solmaz Heydarifard, Nanotechnology-Based Water Treatment Strategies, February 2014
- Journal of Nanoscience and Nanotechnology 14(2):1838-58
  N. Saravanan [a], K.S.K. Sasikumar, Waste water treatment process using Nano TiO_2. Materials Today: Proceedings, Volume 33, Part 7, 2020, Pages A1.
- **P. Raja Lakshmi A critical analysis of the nanotechnology-based approach in**
- **textile wastewater treatment,** March 2023. Nanotechnology for Environmental Engineering 8(2):1-14