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Research Paper

Photocatalytic Degradation of Textile Dyes Using Green-Synthesized ZnO Nanomaterials

Author:

Miss. Gangurde Vaishnavi Sunil, Miss. Kolate Shraddha Raju.
Assistant Professor, Department of Chemistry.
Jijamata College of Science and Arts, Bhende, Maharashtra, India.
Email: Vaishnavigangurde637@gmail.com, kolateshraddha 2002@gmail.com

Abstract-

Textile industries discharge large quantities of hazardous dyes that are non-biodegradable and toxic. Traditional wastewater treatments often fail to degrade these pollutants completely. This study investigates the green synthesis of zinc oxide (ZnO) nanoparticles using plant extracts and evaluates their photocatalytic degradation of methylene blue dye. Characterization using UV -Vis, XRD, and SEM confirmed the formation of wurtzite ZnO nanoparticles (30-50 nm). Photocatalytic tests showed 92% degradation within 120 minutes under UV irradiation. The results demonstrate that green-synthesized ZnO nanoparticles are efficient, sustainable, and environmentally friendly materials for wastewater treatment.
Keywords ZnO nanoparticles, green synthesis, photocatalysis, textile dye degradation, wastewater treatment.

I.INTRODUCTION.

Textile dyes are widely used in industries and are released into aquatic environments as wastewater. These dyes resist degradation, block sunlight penetration, and affect aquatic life. Methylene blue, a common dye, is carcinogenic and harmful even in small concentrations [1].

Advanced Oxidation Processes (AOPs), particularly photocatalysis, offer effective degradation of organic pollutants. Semiconductor materials like ZnO have been widely studied due to their suitable band gap (3.37 eV), high exciton binding energy, and non-toxicity [2]. However, chemical synthesis of nanoparticles often involves hazardous materials.

Green synthesis-using plant extracts rich in phenolics, flavonoids, and organic acids-provides an eco-friendly alternative. These phytochemicals act as both reducing and stabilizing agents [3].

This study synthesizes ZnO nanoparticles using plant leaf extract and examines their photocatalytic ability in degrading methylene blue.

II. MATERIALS AND METHODS.

A. Materials

Zinc nitrate hexahydrate, neem/tulsi leaf extract, distilled water, methylene blue dye, UV-visible spectrophotometer, UV irradiation source.

B. Preparation of Plant Extract

Freshly collected leaves were washed, boiled in distilled water for 20 minutes, cooled, and filtered. The extract was stored at 4°C for use [4].

C. Synthesis of ZnO Nanoparticles

Zinc nitrate solution (0.1 M) was heated while plant extract was added dropwise until a pale precipitate formed. This mixture was dried and calcined at 400°C for 2 hours, yielding ZnO nanoparticles [5].

D. Characterization.

- UV-Visible Spectrum: Confirmation of nanoparticle formation.
- IR Spectrum

E. Photocatalytic Activity Test

A 10 ppm solution of methylene blue was prepared. ZnO nanoparticles were added and irradiated with UV light. Absorbance at 664 nm was recorded.

F. Degradation Calculation

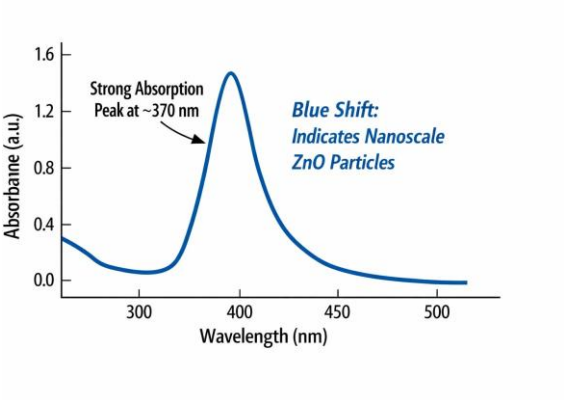
Degradation %=CO-CtC0×100Degradation\ \%= \frac{C_OC_t){C_0} \times 100Degradation %=COCO-Ct×100.

where.
Co initial concentration.
C_1 = concentration at time t.

III. RESULTS AND DISCUSSION

A. UV-Vis Spectroscopy.

A strong absorption peak at around 370 nm confirmed ZnO formation. A blue shift indicated particle sizes in the nanoscale range [6].



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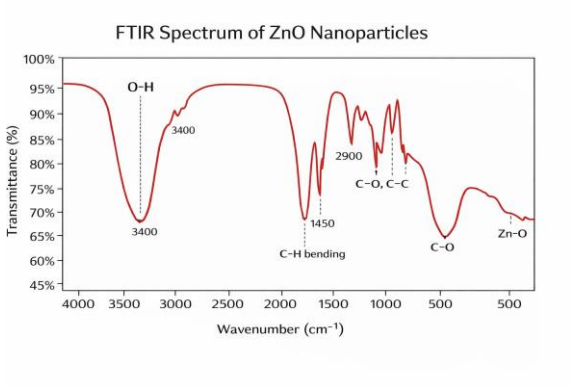
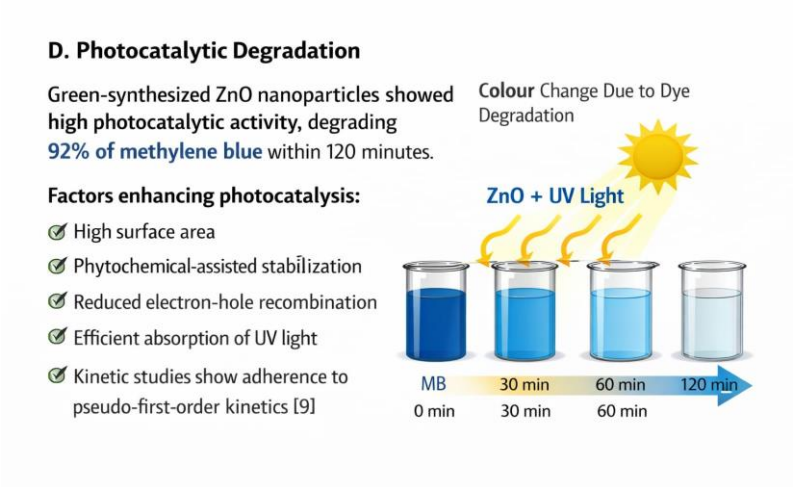
B. FTIR Spectrum



C. Photolytic Degradation

Green-synthesized ZnO nanoparticles showed high photocatalytic activity, degrading 92% of methylene blue within 120 minutes.



D. Proposed Mechanism

Under UV light:
ZnO+hv-e-+h+

Electrons and holes generate reactive oxygen species (ROS):

- Hydroxyl radicals OH\cdot OH OH
- Superoxide radicals 02-0_2^{\cdot-}02-

These ROS degrade dye molecules into harmless compounds such as CO2CO_2CO2 and H2OH_20H2O [10].

IV. ENVIRONMENTAL SIGNIFICANCE

The green synthesis eliminates toxic reagents and reduces cost. ZnO nanoparticles produced using renewable plant materials align with green chemistry principles. They offer a sustainable and eco-friendly method for treating dye-contaminated wastewater [11].

V. CONCLUSION

Green-synthesized ZnO nanoparticles are effective photocatalysts for methylene blue degradation. Characterization confirms crystalline ZnO with nanoscale dimensions. The nanoparticles exhibited 92% degradation within 120 minutes, demonstrating their potential in wastewater treatment applications.

Future work should explore:

· Sunlight-based photocatalysis.
· Catalyst recyclability.
· Industrial wastewater trials

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