Original Article
Bulletin of Pure and Applied Sciences.
Chemistry , Vol.44 C, No.2
July-December 2025: P.101-104

http://www.bpasjournals.com/chemistry
Print version ISSN 0970 4620
Online version ISSN 2320 320X

Hydrothermal synthesis of BiOCl photocatalyst for photocatalytic degradation of Rhodamine B dye

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ABSTRACT

Bismuth oxychloride photocatalysts were successfully synthesized through a simple hydrothermal process carried out at 160 °C and subsequently characterized using powder XRD, FESEM, and UV–Vis DRS techniques. Their photocatalytic efficiency was evaluated for the degradation of RhB under natural sunlight. The BiOCl nanoparticles achieved approximately 90% removal of RhB within 100 minutes of irradiation.

Keywords: BiOCl, Photocatalyst, Rhodamine B

Received on 25.08.2025, Revised on 15.10.2025, Accepted on 30.11.2025

How to cite this article: Kumar G. Hydrothermal synthesis of BiOCl photocatalyst for photocatalytic degradation of Rhodamine B dye. *Bulletin of Pure and Applied Sciences-Chemistry,* 2025;44C(2):101-104.

INTRODUCTION

The rapid growth of industrial activities worldwide has intensified numerous environmental issues, particularly water pollution and energy scarcity. Among the various sources of aquatic contamination, untreated textile effluents have drawn significant concern due to their adverse effects on ecosystems and human health [1–3]. Cationic dyes especially Rhodamine B are extensively utilized in textile and allied sectors for their vivid coloration and high stability [4,5]. Yet, their strong solubility in water and resistance to natural degradation render them persistent environmental pollutants with notable ecological and toxicological impacts [6–8]. To address these challenges, researchers have explored various wastewater treatment approaches, among which semiconductor-based heterogeneous photocatalysis has gained prominence for its capability to mineralize organic contaminants. Nevertheless, traditional photocatalysts often suffer from limited redox capability, intrinsic structural defects, and rapid recombination of photogenerated charge carriers, all of which hinder their overall efficiency [9–11]. This has driven the search for durable, efficient, and solar-active materials capable of degrading dyes under natural sunlight. Recently, bismuth-containing photocatalysts have emerged as attractive candidates due to their distinctive layered architectures and strong visible-light absorption [12–14]. Compounds such as Bi_2WO_6, $BiVO_4$, Bi_2MoO_6, and Bi2S3 have been widely examined, benefiting from the advantageous electronic structure of Bi^{3+} ($6s^2$). Among these, bismuth oxychloride (BiOCl) has gained particular interest owing to its unique tetragonal layered structure, environmental compatibility, non-toxicity, and remarkable chemical stability [15–17].

METHODOLOGY

Synthesis of BiOCl nanoparticles

First, 2 mmol of KCl and 2 mmol of bismuth nitrate pentahydrate were dissolved in 50 mL of deionized water and stirred for 30 minutes. The pH of the mixture was then adjusted to 6 using 10 M NaOH. The prepared solution was transferred to a 100 mL Teflon-lined autoclave and subjected to hydrothermal treatment at 100 °C for 12 hours. After the reaction, the resulting BiOCl photocatalyst was collected, washed, and dried overnight at 60 °C.

RESULTS AND DISCUSSIONS

Crystal Study

The crystalline structure of the synthesized BiOCl was examined using X-ray diffraction (XRD), and the corresponding patterns are shown in Figure 1. The obtained BiOCl sample displays diffraction peaks characteristic of the monoclinic scheelite phase, in agreement with the standard JCPDS card No. 14-0688.

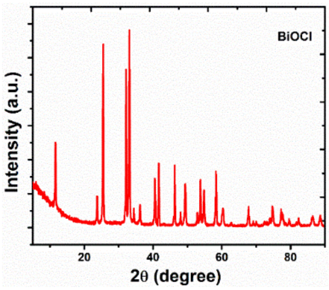

Figure 1: XRD of as-synthesized BiOCl

Surface Morphology of BiOCl

The surface morphology of the BiOCl nanoparticles was examined using FE-SEM, and the obtained micrographs reveal that the particles tend to form agglomerated clusters (Figure 2). The observed aggregation of BiOCl nanoparticles suggests an increased number of active sites, which can enhance the adsorption of dye molecules and thereby improve their removal from wastewater.

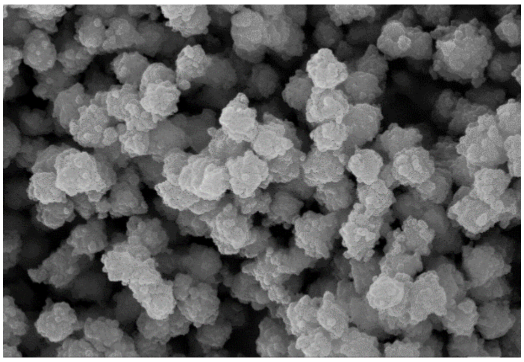

Figure 2: FE-SEM images of BiOCl

Band Gap analysis

The UV–vis DRS spectrum of pristine BiOCl nanoparticles (Figure 3a) indicates their ability to absorb light in the visible region. The diffuse reflectance data were converted to absorption spectra using the Kubelka–Munk (K–M) function, and the band gap energy was calculated from the corresponding Tauc plot (Figure 3b). Based on this analysis, the optical band gap of the BiOCl photocatalyst was found to be approximately 2.81 eV.

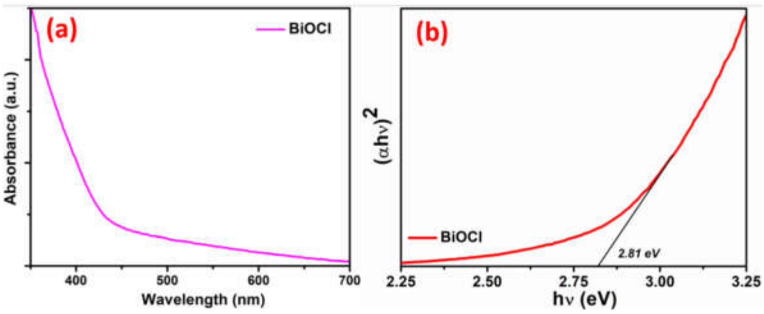

Figure 3: a) Absorbance Spectra of pure BiOCl, b) Tauc's plot

Photocatalytic Test

The photocatalytic degradation of RhB dye (5 mg/L) using BiOCl nanoparticles is illustrated in Figure 4. Under sunlight irradiation for 100 minutes, the BiOCl photocatalyst achieved approximately 90% removal of RhB, demonstrating its effective photocatalytic activity. The UV–vis absorption spectra presented in Figure 4 depict the progressive decline in RhB concentration during the degradation process. A noticeable reduction in the characteristic absorption peak of RhB was observed throughout the 100-minute irradiation period, confirming the dye's photodegradation.

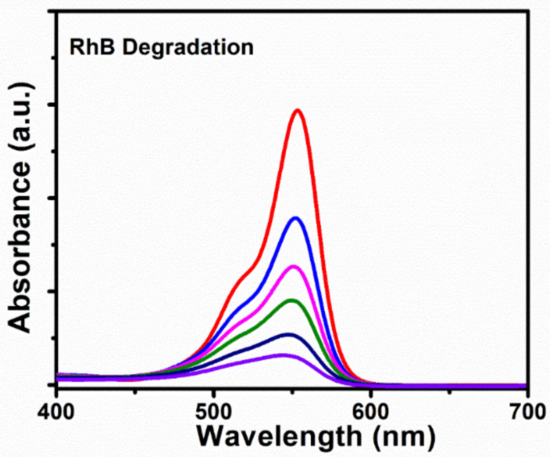

Figure 4: UV-vis absorbance spectra of RhB dye solution.

CONCLUSIONS

BiOCl was successfully prepared through a straightforward hydrothermal method. The resulting photocatalyst demonstrated excellent activity, achieving nearly 90% degradation of RhB under natural sunlight. Owing to its strong photoactivity, BiOCl nanoparticles represent a promising sunlight-responsive photocatalyst for the efficient removal of a wide range of organic dyes from aqueous solutions.

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