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**PENGARUH PENAMBAHAN NANOKOMPOSIT g-C3N4/Co/ZrTiO4 TERHADAP FOTODEGRADASI ZAT WARNA MALACHITE GREEN DI BAWAH IRADIASI SINAR TAMPAK**
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# PENGARUH PENAMBAHAN g-$C_3N_4$ PADA NANOKOMPOSIT g-$C_3N_4$/Co/$ZrTiO_4$ TERHADAP FOTODEGRADASI ZAT WARNA *MALACHITE GREEN* DI BAWAH IRADIASI SINAR TAMPAK

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## INTISARI

*Malachite green* (MG) merupakan zat warna kationik golongan triphenylmethane yang bersifat toksik, karsinogenik, dan sulit didegradasi secara konvensional. Oleh karena itu, penelitian ini bertujuan mengkaji pengaruh variasi komposisi g-$C_3N_4$ terhadap sifat struktural, sifat optik, dan aktivitas fotokatalitik nanokomposit g-$C_3N_4$/Co/$ZrTiO_4$ dalam mendegradasi MG di bawah iradiasi sinar tampak, serta menentukan kondisi reaksi optimum dan memahami stabilitas fotokatalis melalui uji penggunaan berulang. Nanokomposit disintesis menggunakan metode sol-gel dengan prekursor titanium tetraisopropoksida (TTIP) dan tetrabutil zirkonat (TBZ), konsentrasi dopan Co tetap sebesar 5% (b/b), serta variasi komposisi g-$C_3N_4$ sebesar 10, 20, dan 30% (b/b), kemudian dikalsinasi pada suhu 700 °C. Material hasil sintesis dikarakterisasi menggunakan XRD, FTIR, UV–Vis DRS, SEM–EDX, dan TEM–SAED. Aktivitas fotokatalitik dievaluasi melalui variasi pH, massa fotokatalis, konsentrasi awal MG, dan waktu iradiasi, kemudian dilanjutkan dengan studi kinetika, uji pengaruh sumber radiasi, dan uji penggunaan berulang selama tiga siklus.

Hasil karakterisasi menunjukkan bahwa nanokomposit g-$C_3N_4$/Co/$ZrTiO_4$ dengan komposisi 20% berhasil terbentuk dengan fase $ZrTiO_4$ ortorombik dan memiliki nilai band gap terendah sebesar 2,43 eV. Kondisi optimum fotodegradasi zat warna MG diperoleh pada pH 5, massa fotokatalis 75 mg, konsentrasi awal zat warna MG 3 mg/L, dan waktu iradiasi 120 menit dengan efisiensi fotodegradasi sebesar 95,25%. Reaksi fotodegradasi mengikuti model pseudo-orde satu Langmuir-Hinshelwood dengan konstanta laju sebesar 0,0256 menit$^{-1}$ ($R^2$ = 0,9969). Efektivitas fotokatalitik pada daerah sinar tampak ditunjukkan melalui pengujian pengaruh sumber radiasi, sedangkan uji penggunaan ulang menunjukkan bahwa nanokomposit memiliki stabilitas fotokatalitik yang baik selama tiga siklus penggunaan. Berdasarkan hasil tersebut, nanokomposit g-$C_3N_4$/Co/$ZrTiO_4$ berpotensi digunakan sebagai fotokatalis sinar tampak yang efektif dan stabil untuk degradasi zat warna *malachite green*.

Kata kunci: fotokatalisis, *malachite green*, g-$C_3N_4$/Co/$ZrTiO_4$, sinar tampak, *heterojunction*

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# EFFECT OF NANOCOMPOSITE g-$C_3N_4$/Co/$ZrTiO_4$ ON THE PHOTODEGRADATION OF MALACHITE GREEN DYE UNDER VISIBLE LIGHT IRRADIATION

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## ABSTRACT

Malachite green (MG) is a cationic triphenylmethane dye that is toxic, carcinogenic, and resistant to degradation by conventional treatment methods. Therefore, this study aimed to investigate the effect of g-$C_3N_4$ composition on the structural, optical, and photocatalytic properties of the g-$C_3N_4$/Co/$ZrTiO_4$ nanocomposite for MG degradation under visible-light irradiation, as well as to determine the optimum reaction conditions and understand the photocatalyst stability through a reusability test. The nanocomposite was synthesized using the sol–gel method with titanium tetraisopropoxide (TTIP) and tetrabutyl zirconate (TBZ) as precursors, a fixed Co dopant concentration of 5% (w/w), and g-$C_3N_4$ compositions of 10, 20, and 30% (w/w), followed by calcination at 700 °C. The synthesized materials were characterized using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), UV–Vis diffuse reflectance spectroscopy (UV–Vis DRS), scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM–EDX), and transmission electron microscopy coupled with selected area electron diffraction (TEM–SAED). The photocatalytic activity was evaluated by varying the solution pH, photocatalyst dosage, initial MG concentration, and irradiation time, followed by kinetic analysis, irradiation source evaluation, and a three-cycle reusability test.

The characterization results indicated that the 20% g-$C_3N_4$/Co/$ZrTiO_4$ nanocomposite was successfully synthesized with an orthorhombic $ZrTiO_4$ phase and exhibited the lowest band gap energy of 2.43 eV. The optimum photocatalytic degradation of MG was achieved at pH 5, a photocatalyst dosage of 75 mg, an initial MG concentration of 3 mg $L^{-1}$, and an irradiation time of 120 min, resulting in a degradation efficiency of 95.25%. The photocatalytic degradation followed the pseudo-first-order Langmuir–Hinshelwood kinetic model, with a rate constant of 0.0256 $min^{-1}$ ($R^2$ = 0.9969). The superior photocatalytic performance under visible-light irradiation was confirmed through irradiation source evaluation, while the reusability test demonstrated that the nanocomposite maintained good photocatalytic stability over three consecutive cycles. These findings suggest that the g-$C_3N_4$/Co/$ZrTiO_4$ nanocomposite is a promising visible-light-responsive photocatalyst for the efficient and stable degradation of malachite green.

Keywords: photocatalysis, malachite green, g-$C_3N_4$/Co/$ZrTiO_4$, visible light, heterojunction