PENGEMBANGAN KOMPOSIT NANOSELULOSA DARI ALGA COKELAT (*Sargassum Duplicatum*) TERFUNGSIONALISASI TiO_2 UNTUK FOTODEGRADASI LIMBAH ANTIBIOTIK

SKRIPSI

diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar sarjana kimia

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Sebuah skripsi yang diajukan untuk memenuhi salah satu syarat memperoleh gelar Sarjana Sains pada Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam Universitas Pendidikan Indonesia

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Dengan ini saya menyatakan bahwa karya tulis ini merupakan hasil kerja saya sendiri. Saya menjamin bahwa keseluruhan isi karya ini, baik sebagian maupun keseluruhan, bukan merupakan plagiarisme dari karya orang lain, kecuali pada bagian yang dinyatakan dan disebutkan sumbernya dengan jelas.

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Bandung, 22 Agustus 2025

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ABSTRAK

Limbah medis, khususnya kontaminan farmasetik seperti antibiotik, menjadi ancaman lingkungan yang serius karena sifatnya yang persisten di perairan dan potensi mengganggu keseimbangan ekosistem. Metode pengolahan air limbah konvensional seperti koagulasi dan sedimentasi sering kali tidak mampu menghilangkan polutan farmasetik secara efektif, sehingga diperlukan metode lanjutan. Pencemaran antibiotik di lingkungan perairan dapat menyebabkan akumulasi biologis dan resistensi genetik. Fotokatalisis sebagai bagian dari Advanced Oxidation Processes (AOPs) merupakan metode yang efektif dan ramah lingkungan untuk mendegradasi senyawa tersebut. Penelitian ini bertujuan untuk mengisolasi nanoselulosa dari biomassa alga cokelat *Sargassum duplicatum*, mengembangkan komposit nanoselulosa–TiO_2 dalam bentuk film, serta menguji aktivitas fotokatalitiknya terhadap antibiotik. Selulosa berhasil diisolasi dengan rendemen tertinggi 56,55% pada perlakuan $NaClO_2$ 5% (3 jam), kemudian dihidrolisis menjadi nanoselulosa (CNC) dengan morfologi batang (rod-like), diameter rata-rata 11,19 ± 3,52 nm, panjang 816,36 ± 184,05 nm, rasio aspek 72,93, dan kristalinitas meningkat dari 45,39% menjadi 59,64%. Analisis FTIR menunjukkan adanya gugus sulfat ester (1050 cm^{-1}), sedangkan TEM menegaskan bentuk rod-like CNC. Komposit optimum diperoleh pada rasio 3:1 (NC:TiO_2). Karakterisasi SEM-EDS menunjukkan TiO_2 terdispersi homogen tanpa aglomerasi besar, dengan kandungan unsur utama O (49,44%), C (37,00%), dan Ti (13,56%). Pola XRD menegaskan keberadaan fase anatase TiO_2 (25,3° 2θ) serta selulosa Iβ (16° dan 22,6° 2θ), sementara UV-Vis DRS memperlihatkan penurunan band gap dari 2,99 eV (TiO_2 murni) menjadi 2,63 eV pada komposit. Uji fotokatalitik menunjukkan kinerja komposit lebih baik dibanding TiO_2 murni maupun nanoselulosa tunggal. Efisiensi degradasi mencapai 94,83% untuk rifampisin dan 90,83% untuk amoksisilin, lebih tinggi dibandingkan TiO_2 murni (80,26% dan 79,26%). Optimasi dosis katalis menunjukkan hasil terbaik pada 5 g/L, sedangkan uji reusabilitas hingga siklus ketiga masih mempertahankan efisiensi cukup baik, yaitu 88,35% (RIF) dan 72,10% (AMX). Analisis kinetika menegaskan bahwa reaksi degradasi mengikuti model orde pertama. Hasil ini menunjukkan bahwa komposit nanoselulosa–TiO_2 berpotensi sebagai fotokatalis berkelanjutan untuk pengolahan limbah antibiotik di lingkungan perairan.

Kata Kunci: Nanoselulosa, TiO_2, Fotokatalisis, Antibiotik, *Sargassum duplicatum*

ABSTRACT

Medical waste, particularly pharmaceutical contaminants such as antibiotics, poses a serious environmental threat due to their persistence in aquatic systems and potential disruption of ecosystem balance. Conventional wastewater treatment methods such as coagulation and sedimentation are often ineffective in removing pharmaceutical pollutants, thus requiring advanced treatment strategies. Antibiotic pollution in aquatic environments can lead to bioaccumulation and genetic resistance. Photocatalysis, as part of Advanced Oxidation Processes (AOPs), is an effective and environmentally friendly method for degrading such compounds. This study aimed to isolate nanocellulose from the brown algae *Sargassum duplicatum*, develop nanocellulose–TiO_2 composites in film form, and evaluate their photocatalytic activity against antibiotics. Cellulose was successfully isolated with the highest yield of 56.55% under $NaClO_2$ 5% treatment (3 h), then hydrolyzed into nanocellulose (CNC) with rod-like morphology, an average diameter of 11.19 ± 3.52 nm, length of 816.36 ± 184.05 nm, aspect ratio of 72.93, and crystallinity increased from 45.39% to 59.64%. FTIR analysis revealed sulfate ester groups (1050 cm^{-1}), while TEM confirmed the rod-like shape of CNC. The optimum composite was obtained at a 3:1 ratio (NC:TiO_2). SEM-EDS analysis showed well-dispersed TiO_2 without large agglomeration, with the main elements O (49.44%), C (37.00%), and Ti (13.56%). XRD patterns confirmed the presence of anatase TiO_2 (25.3° 2θ) and cellulose Iβ (16° and 22.6° 2θ), while UV-Vis DRS demonstrated a reduction in band gap from 2.99 eV (pure TiO_2) to 2.63 eV in the composite. Photocatalytic tests revealed that the composite outperformed pure TiO_2 and nanocellulose alone. Degradation efficiencies reached 94.83% for rifampicin and 90.83% for amoxicillin, higher than pure TiO_2 (80.26% and 79.26%). Catalyst dose optimization indicated the best performance at 5 g/L, while recyclability tests up to three cycles retained good efficiency, with 88.35% (RIF) and 72.10% (AMX) in the third cycle. Kinetic analysis confirmed that the degradation reaction followed a first-order model. These findings indicate that nanocellulose–TiO_2 composites have strong potential as sustainable photocatalysts for antibiotic wastewater treatment in aquatic environments.

Keywords: Nanocellulose, TiO_2, Photocatalysis, Antibiotics, *Sargassum duplicatum*

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DAFTAR GAMBAR

DAFTAR TABEL

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